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BRAUN-BLANQUETIA

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8

MOUNTAIN VEGETATION
(Proceedings of the International Symposium, Beijing September 1986)

Camerino
1992

PUBLICATION DU DEPARTEMENT DE BOTANIQUE ET ÉCOLOGIE DE L'UNIVERSITÉ DE CAMERINO ET DE LA STATION INTERNATIONALE DE PHYTOSOCIOLOGIE DE BAILLEUL SOUS L'ÉGIDE DE L'ASSOCIATION AMICALE DE PHYTOSOCIOLOGIE ET DE L'ASSOCIATION INTERNATIONALE POUR L'ÉTUDE DE LA VÉGÉTATION

BRAUN-BLANQUETIA

Un héritage est enrichissant et ouvre de nouvelles possibilités créatrices. Mais il en découle en contre partie l'obligation de ne pas gaspiller le patrimoine reçu. Ceux qui, aujourd'hui étudient la végétation grâce à la phytosociologie peuvent utiliser des méthodologies bien au point et tirer profit d'un ensemble cohérent de connaisances.
C'est le résultat du travail méthodique de nombreux chercheurs de qualité pendant plusieurs décennies. Aujourd'hui, nous nous trouvons face à des problèmes qui ne sont sans doute pas tout à fait nouveaux mais qui paraissent infiniment plus graves que dans le passé: primauté de la technique, spécialisation, pénurie de matières premières, d'énergie et d'espace, crise de l'environnement...
Il se développe ainsi des problèmes spécifiques divers pour lesquels il est nécessaire de trouver des réponses nouvelles. Les chercheurs sont placés devant un véritable défi et il dépend de leur savoir et de leur imagination de montrer si la Science de la végétation est capable d'apporter une contribution appréciable à la solution de ces problèmes.
La tradition phytosociologique dans ce contexte constitue une base essentielle. La conception typologique de la végétation et la clarté du système qui en découle, l'habitude des chercheurs de vivre en contact étroit avec la végétation, les recherches basées sur l'observation condition antithétique de l'expérimentation, sont les traits caractéristiques de la phytosociologie.
Les lignes directrices qui nous ont été transmises par les maîtres de la Science de la végétation, Josias Braun-Blanquet et Reinhold Tüxen avant tout, constituent actuellement une part importante de notre patrimoine d'idées. Notre but est de valoriser cet héritage et d'honorer la mémoire du premier de ces maîtres et fondateur de la phytosociologie moderne par une nouvelle série de publications.
Pourront y trouver place des monographies étudiant concrètement la végétation selon les enseignements de J. Braun-Blanquet et R. Tüxen qui, à travers la créativité des auteurs, produiront de nouveaux fruits.
Disciples nous-mêmes de J. Braun-Blanquet et ayant collaboré à son activité, nous pensons qu'à travers cette série de publications son héritage restera vivant dans l'esprit originel et avec de nouvelles idées.

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J. BRAUN-BLANQUET, 1954
Drawn form a photograph by Françoise M. Dansereau

国际山地植被科学讨论会

论　文　集

北京　　　　　中国

一九八六年九月

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FOREWORD

The International Symposium on Mountain Vegetation held in Beijing, China on September 1-5, 1986 sponsored by the Committee on Plant Ecology and Geobotany of Chinese Botanical Society and Chinese Association for Science and Technology (CAST).

The mountain ecosystem is currently paid more attention in the world. As the major component of the ecosystem-mountain vegetation provides a great number of renewable natural resources for human being. It is the base for development of forestry, animal husbandry, and sideline production and plays an important role in maintaining ecological stability.

As the world population increases in number and the demands on natural resources rise, mountain vegetation are coming under increasing pressure, especially in China. Population stress is often associated with over-exploitation of certain natural resources. Forests are being destroyed in tropical, subtropical and temperate regions. Steppe and desert are under the severe human disturbance. The vegetation types become simplified. The production and biomass of vegetation decrease. Water and soil loss are aggravated. In order to continuing destruction of mountain vegetation, especially reclamation on mountains cause serious environmental deterioration. World Conservation Strategy aims to resolve conflicts between conservation and development. The strategy sets out there objectives for living resource conservation: To maintain essential ecological processes and life-support systems; To preserve genetic diversity; To ensure the sustainable utilization of species and ecosystems, vegetation conservation and utilization of species and ecosystems, vegetation conservation and restoration are important measures to improve degraded environment, to explore the effective approach to sustainable utilization of ecosystem, especially in mountain areas.

In the capacity of the chairman of Committee on Plant Ecology and Geobotany, Chinese Society of Botany. I greatly appreciated co-chairman of the International Symposium on Mountain Vegetation Professor Hou Hsioh-yu and Makoto Numata for their remarkable contribution to the Symposium. Many thanks to institutions and all the persons who have given generous support to this Symposium and publishing the proceedings.

Professor Chen Ling-zhi

Chairman of Committee on
Plant Ecology & Geobotany
Chinese Society of Botany

March, 1987

EDITORIAL NOTES

The International Symposium on Mountain Vegetation was held in Beijing during September 1986 and for many scientists from the western countries it was the occasion for a first contact with the chinese scientific community and with the vegetation of East Asia. In this occasion it was decided to publish the reports as a special volume of Braun Blanquetia.

The assemblage of manuscripts from a large number of contributors was a difficult task and required a lot of time. In many cases a revision of the manuscripts was necessary and this work required additional time and energies. The revision was carried out by L.C. Bliss (Seattle, USA), E.D. Box (Athens, USA), F. Klötzli (Zurich, Switzerland), L. Pignatti (Milano, Italy); an additional revision, mainly for chinese texts was given by C.Y. Sun (Trieste).

For the contacts with Authors and editing of some articles A. Ubrrizsy Savoia was responsible. The complete composition of the manuscript was carried out by L. Carimini, in interaction with R. Venanzoni, the secretary of Braun-Blanquetia, both in Camerino.

Financial support for the volume was provided by the Italian Research Council (CNR).

Sandro Pignatti
Franco Pedrotti

THE PRINCIPAL TYPES OF MONTANE VEGETATIONAL BELTS IN CHINA AND ECO-GEOGRAPHICAL CHARACTERISTICS

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Key words: Vegetational Belt, Eco-geographical Characteristics

1. INTRODUCTION

The uplift of mountains has altered even the smooth spherical surface of the earth. This has destorted, inclined, disrupted, or disguised the earth's ideal latitudinal zonation, which is determined by solar radiation and complicated the hydro-thermal effect of longitudinal zonation caused by maritime-terrestrial interactions. Different types of montane belts have thus been formed which deeply influence and greatly enrich human life and their economic activities.

However, the ideal and perfectly horizontal terrestrial landscape is nonexistant. Mountains are inevitable products of crustal movements. The vertical zonation of mountains is inevitably accompanied by horizontal zonation. The latter fundamentally affects the vertical differentiation of the montane vegetation on it. The characters of horizontal zones are strongly reflected in the various kinds of montane belts. Montane belts have the appearance of being secondary geographic zones based on horizontal zonation. A certain horizontal zone has its own particular type of successions. The cold-temperate, temperate, warm-temperate, subtropical, and tropical zones are aligned in parallel fashion from north to south in eastern Asia and the forests, steppe, and desert regions succeed each other as one moves in land from the Pacific Ocean. More than 2/3 of China's area is mountain and plateau, such as the Tibetan Plateau which is known as the "Roof of the world", with several of the highest peaks and greatest mountain ranges in the world, as well as many mountains rising high on coast plain or island in the country. Except for the polar and equatorial regions, China's mountains or plateaux are located in almost all the climatic zones. This makes for varied zonational patterns, the most prominent feature of China's vegetation and landscape. Their complicated types, extensive ranges, and striking constrasts are unparalleled.

Some authors have discussed the characteristics and patterns of China's montane vegetational belts from the view-point of geographical zonation or three-dimensional zonality (TROLL 1968; HOU 1963, 1982; HOU & CHANG 1980; LI & CHANG 1966). Based on this research, the present paper tries to generalize and analyze this long-standing but eternal topic from the view-point of comparative geographic ecology and vegetational typology.

2. STRUCTURE AND DIVISION OF MONTANE VEGETATIONAL BELTS IN CHINA.

The division and classification of montane vegetational belts is confused unanimously agreed upon. Attemps to standardize or unify classification for the belts have been suggested by several authors (see LOVE 1970). We propose the following system as a basis for description, comparison, and analysis (Table 1).

The division into strata and belts on the vertical zonation is based on the ecological character of vegetation and landscape, and not simply on the absolute elevation.

There are three important geographic or vegetational limits: snowline, upper limit of continuous vegetation, and upper forest limit. Snowline is the natural divide for nival stratum. Howeever glacial tongues and separate snow patches can appear in the alpine stratum below the snowline. The upper limit of continuous vegetation is the dividing line between the subnival and the continuous alpine vegetation belt. The upper forest limit can be used as a marker for delimiting montane stratum and alpine stratum. The subalpine belt on mountains of the temperate zone consists of scrubland, meadow, and krummholz. It represents a transitional section from the montane forest belt to the alpine belt. But, on subtropical and tropical mountains, the subalpine belt also includes the upper montane coniferous forest. It is difficult to distinguish alpine and montane strata on treeless arid mountains. The appearance of a certain number of alpine elements in plant communities should be taken to indicate the alpine stratum.

The vegetational belt may be further subdivided according to the differentiation of dominant species of communities within the belt. For instance the subalpine coniferous forest belt can be subdivided into an *Abies* subbelt and a *Picea* subbelt.

3. GRADIENTS OF MONTANE VEGETATIONAL BELTS IN CHINA

The principal montane vegetational types and their zonal geographic gradients in China can be summarized using the following latitudinal and longitudinal gradients (Fig. 1):

1. Latitudinal gradients: a. Eastern forest regions (Fig. 2); b. Western desert and plateau region (Fig. 3)
2. Longitudinal gradients: c. Temperate zone (Fig. 4); d. Warm-temperate/subtropical zone (Fig. 5); e. Subtropical/transition tropical zone (Fig. 6).

4. PRINCIPAL TYPES OF MONTANE VEGETATIONAL BELTS IN CHINA

1. Taiga type: is the typical vegetational belt for the mountains of the Siberian taiga zone. In China, it is present on the Great Xing'an Mts. in the cold-temperate coniferous forest zone and on the Changbaishan Mts. in the temperate coniferous and broadleaf mixed forest zone. It also appears on the northwestern Altai Mts. in northernmost Xinjiang. Its typical climatic/topographical parameters are long and severely cold winters, intermediate or low snowfall, with relatively abundant summer rainfall, flat relief with water accumulation on the ground surface and excessive moisture, as well as permafrost in the soils. The vegetation consists an alpine tundra belt with scrubs and mosses of largely boreal and artic-alpine affinities.

2. Broadleaf deciduous forest type: found on the Wutaishan Mts., Taihang Mts., Luliang Mts., northern slope of the Qinling Mts., etc. in the temperate and warm-temperate broadleaf deciduous forest zone of northern China. At the base is the lower montane broadleaf deciduous forest belt dominated by deciduous *Quercus* ssp. This species composition indicates that the climate of the broadleaf deciduous forest zone in Eastern Asia tends to be drier and transitional to steppe. The winter and spring are dry and cold and as such unsuitable for mesic broadleaf deciduous tree species. This is in sharp contrast to the broadleaf deciduous forest in Japan, eastern North America, and western Europe with stronger maritime influence and dominant species composition of *Fagus* and other mesic trees, mixed with *Tsuga*, *Taxus*, etc.

3. Eastern Asiatic subtropical broadleaf evergreen forest type: there are great number of subtropical high mountains in southwestern China. They form a series of continuous "mountain bridges" between tropical mountains in the south and temperate mountains in

Table 1 — Division of mountain vertical belt system in China.

	Vertical strata and belt	Mountain vertical vegetation types: Forest (moist) region	Steppe, desert (arid) region	
	Nival stratum (belt)	Icefield, glacier, bare rock, talus, etc.		
		Snow line		
Alpine Stratum	Subnival belt	Lichens, mosses, sparse alpine plants, or separate plant patches		
		Continuous vegetational upper limit		
	Typical or true alpine belt	Alpine tundra, meadow, Kobresia meadow cushion plants	Kobresia meadow & cushion plants	
		Tree/Forest limit		
	Subalpine belt	Scrubland, meadow, Krummholtz, subalpine coniferous forest	Alpine steppe	Alpine desert
		Forest limit	High cold limit	
Montane Stratum	Upper montane belt	Coniferous forest	Coniferous forest	Steppe or desert
	Montane belt	Coniferous-broadleaf deciduous mixed forest or broadleaf deciduous forest	Broadleaf deciduous forest	
	Lower montane belt	Broadleaf evergreen forest	Steppe or desert	
		Rainforestor seasonal rainforest		
	Plains	Zonal forest	Zonal steppe or desert	

the north. This greatly influences and accelerates the migration, exchange, mixing, adaptation, and evolution of montane floras and plant communities within these zones. These subtropical high mountains display complete and highly complicated vegetational belts. They did not suffer from continental glaciation during the Quaternary and avoided serious influences from the Mongoli-Siberian continental anticyclone and Artic cold current; rather they received precipitation from the wet Southwest Monsoon. As a result, extremely abundant and varied vegetation types have developed here. Besides the especially wide spread differentiated broadleaf evergreen forests in the basal belt, there is a mixed coniferous-broadleaf forest zone with *Tsuga chinensis* or *T. dumosa*, a multi-stratified subalpine coniferous forest belt, containing quite a few species of endemic *Abies*, *Picea*, and *Larix* as dominant species. The shrub layer of this coniferous forest consists of a particular shrub bamboo, *Sinarundinaria fegiana* and *Rhododendron* spp. This represents an important difference with the northern taiga forest and cold-temperate coniferous forest in northern mountains. However, there are also some boreal elements in its shrub and herb layers, that demonstrate its relationship with the boreal coniferous forest.

The subalpine scrub belt of this type is also characterized by abundant species of *Rhododendron*. The *Kobresia* meadow in the alpine belt is dominated by *Kobresia pygmaea*. It is the representative par excellence for alpine meadows in continental Eastern Asiatic high mountains and makes a striking contrast with the luxuriant alpine meadows in the European Alps.

4. Transitional tropical rainforest and seasonal rainforest type: There is a lack of typical tropical high mountains in China. Even to the south of the Tropical of Cancer, there is a cold winter season on the southern margin of the eastern Asiatic continent because of the powerful influence from the cold current and continental anticyclone which blows directly southwards without topographic intervention in eastern China. The mountains on tropical Hainan Island are too low to form the upper vertical vegetational belts in southwestern China, because of the protection from the Himalayas and Tibetan Plateau, the northern limit of the Tropics extendes northwards to 29° N. latitude in the Eastern Himalayas. However the typical montane vegetation is not developed here. The mountain vegetation has a strong transitional character. There is no sign of paramo or Puna vegetation types which are characterized by giant rosette plants (TROLL 1968). Instead of typical tropical alpine vegetations, there are alpine vegetations that are very similar to those on the eastern Asiatic subtropical high mountains *Rhododendron* scrub., *Kobresia* meadow, etc., with this difference that its basal belt consists of tropical montane rainforest and seasonal rainforest.

5. Temperate and warm-temperate steppe type: The mountains in the steppe zone, such as Daqingshan Mt., western slope of the Luliangshan Mts., Liupanshan Mts., and Xinglongshan Mts., are characterized by a basal belt of steppe. There is usually a montane coniferous forest belt with *Picea*, and finally, a subalpine scrubland and meadow belt at the top. The elevation of the mountains is usually not high enough for the appearance of an alpine belt.

6. Temperate and warm-temperate desert and extremely arid desert type: The Tianshan Mts. Qilian Mts., and Kunlun Mts. are high mountains in the desert zone. The Altai Mts. are situated in the transitional zone from desert to steppe. The northen slope of the Tianshan Mts. and eastern Qilian Mts. in the temperate desert zone, facing the moist current, developed a montane coniferous forest belt, consisting of *Picea* or *Larix*, in the upper part of the montane stratum, but usually without a broadleaf

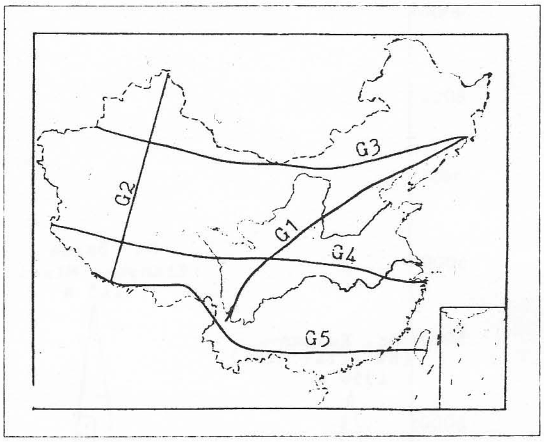

Fig. 1 — Geographic location of the gradients for mountain vertical vegetational belt system
G1 — latitudinal gradient for eastern forest regions
G2 — latitudinal gradient for western desert and plateau regions
G3 — longitudinal gradient for temperate zone
G4 — longitudinal gradient for warm-temperate/subtropical zone
G5 — longitudinal gradient for subtropical/transition tropical zone.

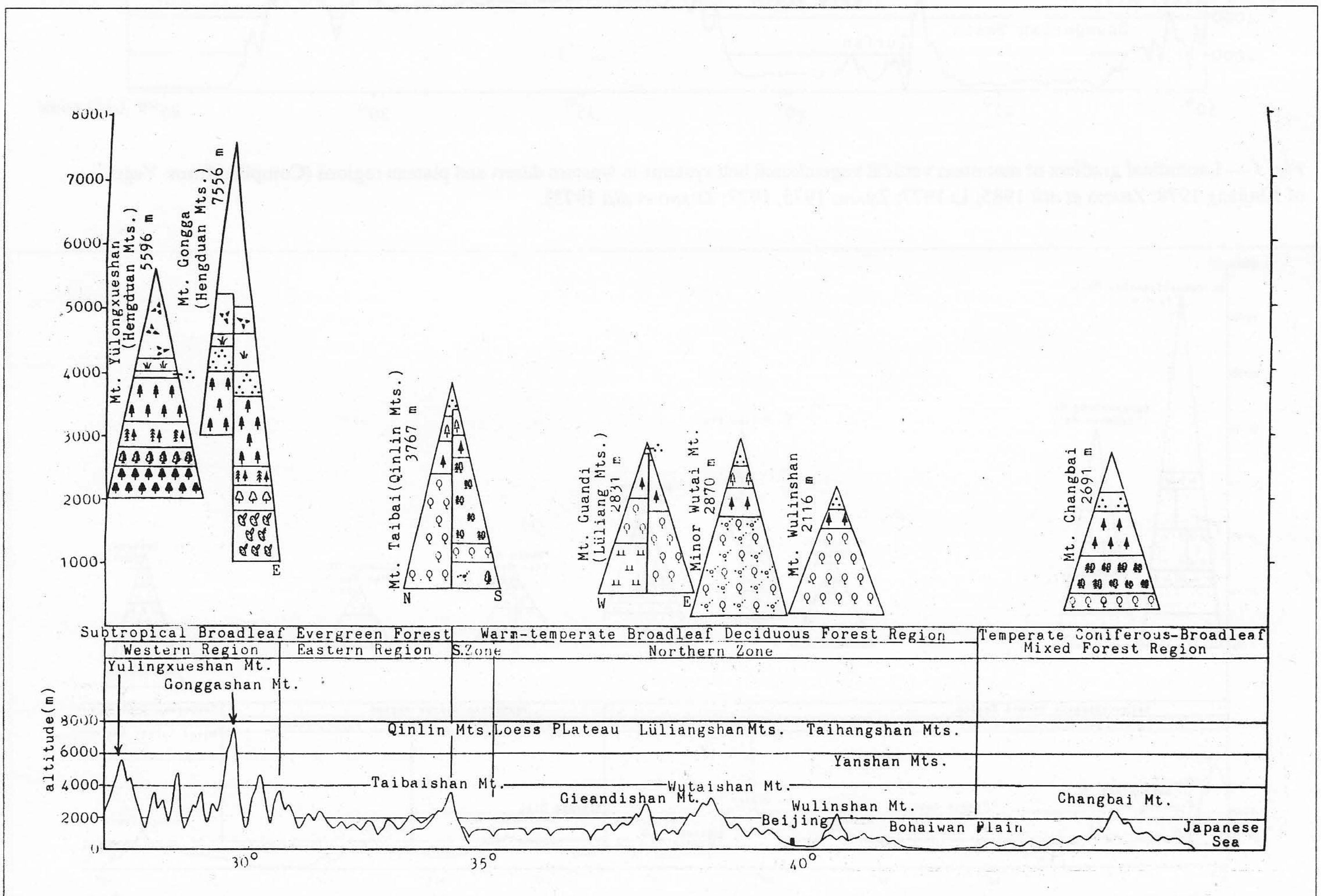

Fig. 2 — Latitudinal gradient of mountain vertical vegetational belt systems in eastern forest regions (Compiled from HOU 1982; Veget. of China 1980; LIU *et alii* 1985; JIANG 1980).

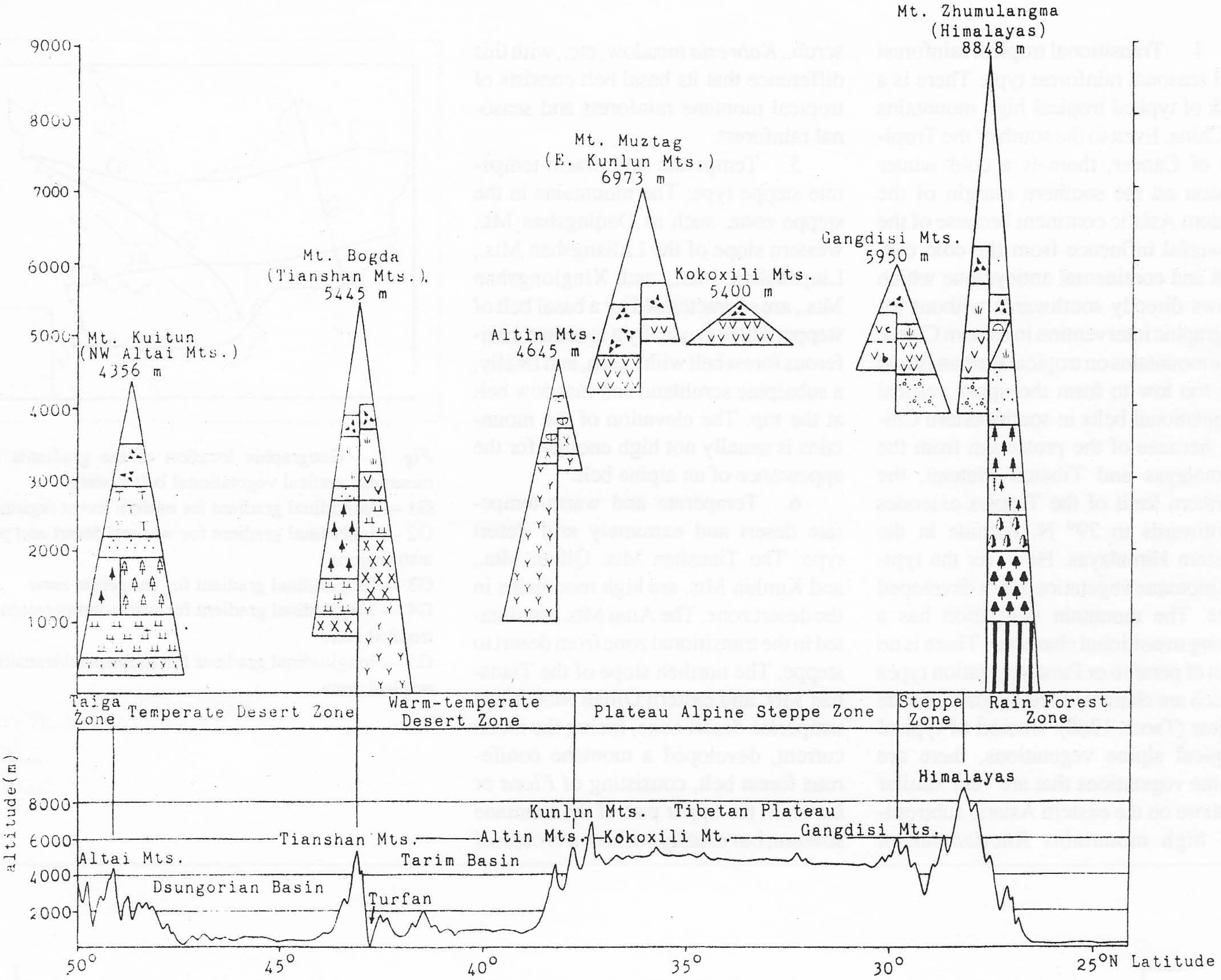

Fig. 3 — Latitudinal gradient of mountain vertical vegetational belt systems in western desert and plateau regions (Compiled from: Veget. of Xinjiang 1978; ZHANG *et alii* 1985; LI 1977; ZHANG 1975, 1977; ZHANG *et alii* 1973).

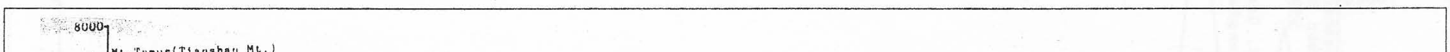

Fig. 4 — Longitidinal gradient of mountain vertical vegetational belt systems in temperate/warm-temperate zones (Compiled from: Veget. of In. Mongolia 1985; Xu et alii 1983; Zhao 1985; Veget. of China 1980; Veget. of Xinjiang 1978; Chen 1981).

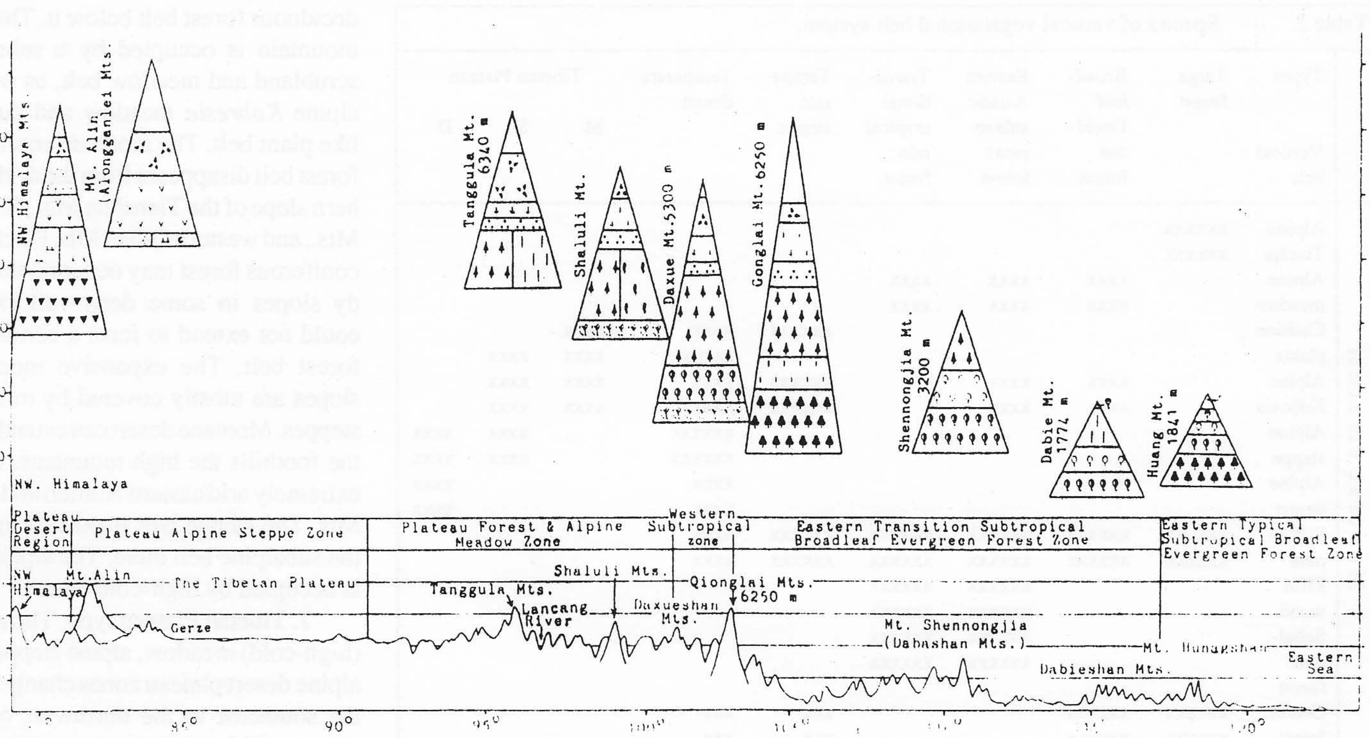

Fig. 5 — Longitudinal gradient of mountain vertical vegetational belt systems in warm-temperate/subtropical zones (Compiled from: Veget. of Anhui 1983; WUHAN 1980; JIANG 1964; LIU *et alii* 1985; ZHENG 1977; Veget. of China 1980)

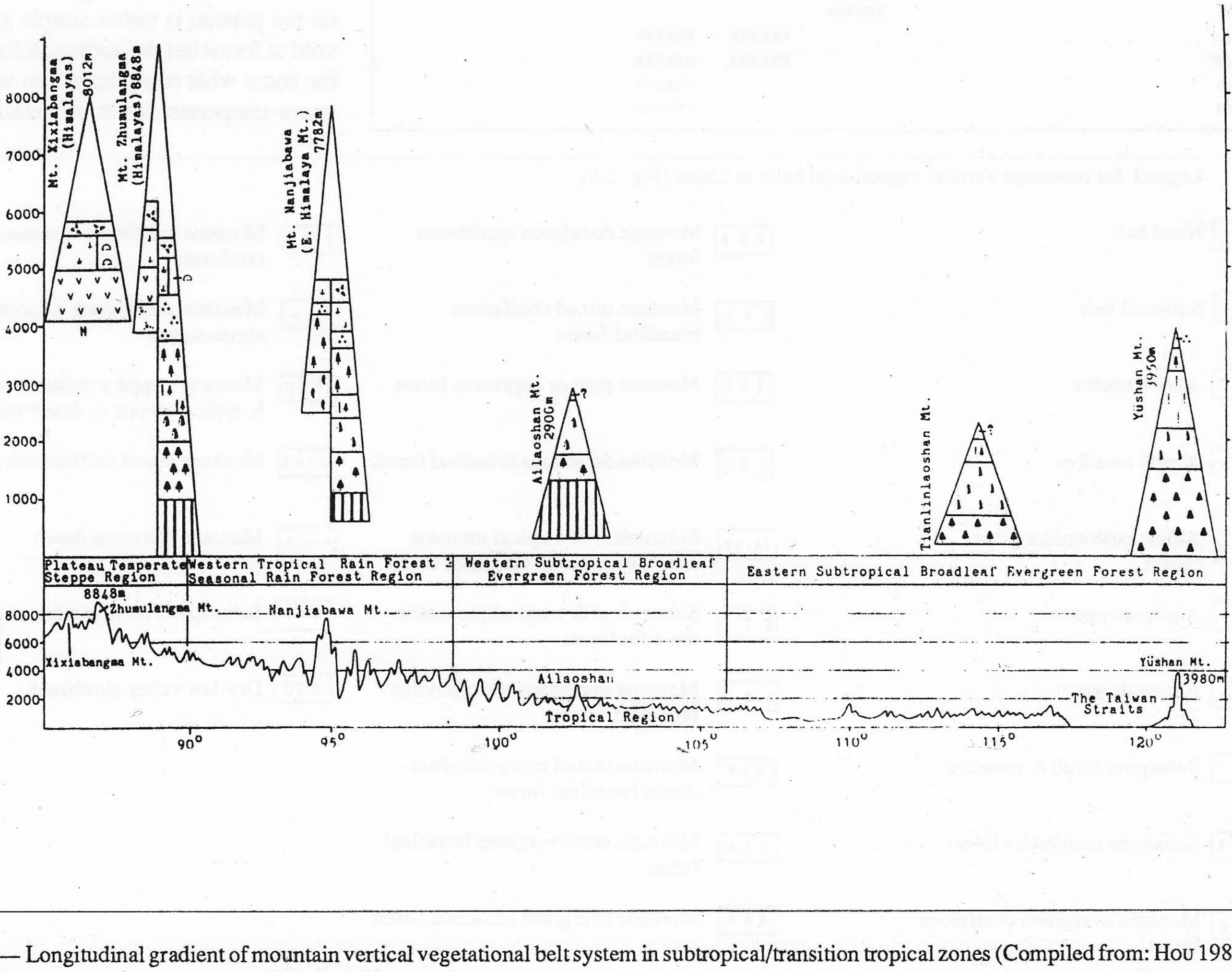

Fig. 6 — Longitudinal gradient of mountain vertical vegetational belt system in subtropical/transition tropical zones (Compiled from: HOU 1982; JIANG 1980: LI 1984; ZHANG *et alii* 1973; Veget. of China 1980)

deciduous forest belt below it. The high mountain is occupied by a subalpine scrubland and meadow belt, as well as alpine *Kobresia* meadow and cushion like plant belt. The montane coniferous forest belt disappears from the arid southern slope of the Tianshan Mts., Kunlun Mts., and western Qilian Mts. Patches of coniferous forest may occur on the shady slopes in some deep valleys, but could not extend to form a continuous forest belt. The expansive mountain slopes are mostly covered by montane steppes. Montane desert can extend from the foothills the high mountanis in the extremely arid eastern Kunlun and Altin Mts. The steppe belt is pushed up into the subalpine belt there. The alpine belt is occupied by high-cold desert.

7. Tibetan Plateau type: The alpine (high-cold) meadow, alpine steppe, and alpine desert plateau zones change from the southeast to the northwest on the plateau. This represents particular distribution pattern of vertical zones replacing one another horizontally on the plateau (Chang 1978).

Montane vegetational belts on different plateaux are determined by the characteristics of their own plateau zone. The structure of the vegetational belts on the plateau is rather simple and devoid of forest but the vertical belts become some what complicated on western warm-temperate desert mountains and

Table 2. — Spectra of vertical vegetational belt system.

	Types / Vertical belt	Taiga forest	Broad-leaf Deciduous forest	Eastern Asiatic subtropical forest	Transitional tropical rain forest	Temperate steppe	Temperate desert	Tibetan Plateau M	S	D
Montane stratum	Alpine	xxxxxx								
	Tundra	xxxxxx								
	Alpine		xxxx	xxxx	xxxx					
	meadow		xxxx	xxxx	xxxx					
	Cushion					xxxxxx	xxxx	xxxx		
	plants						xxxxxx	xxxx	xxxx	
	Alpine		xxxx	xxxx		xxxxxx	xxxx	xxxx	xxxx	
	Kobesia		xxxx	xxxx		xxxxxx	xxxx	xxxx	xxxx	
	Alpine						xxxxxx		xxxx	xxxx
	steppe						xxxxxx		xxxx	xxxx
	Alpine						xxxx			xxxx
	desert						xxxx			xxxx
	Subal-	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx			
	pine	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxx			
	Elfin			xxxxxx	xxxxxx					
	wood			xxxxxx	xxxxxx					
	Subal-			xxxxxx	xxxxxx					
	pine			xxxxxx	xxxxxx					
	forest									
	Conifer	xxxxxx	xxxxxx			xxx	xxx			
	forest	xxxxxx	xxxxxx			xxx	xxx			
	Decidu-		xxxxxx			xxx				
	ous f.		xxxxxx			xxx				
Alpine stratum	Mixed	xxxxxx		xxxxxx	xxxxxx					
	forest	xxxxxx		xxxxxx	xxxxxx					
	Scler.			xxx	xxx					
	forest			xxx	xxx					
	Everg.			xxxxxx	xxxxxx					
	bro. f.			xxxxxx	xxxxxx					
	Rain				xxxxxx					
	forest				xxxxxx					
	Temp.					xxxxxx	xxxxxx			
	steppe					xxxxxx	xxxxxx			
	Temp.						xxxxxx			
	desert						xxxxxx			

Legend for mountain vertical vegetational belts in China (Fig. 2-6).

- Nival belt
- Subnival belt
- Alpine tundra
- Alpine meadow
- Alpine cushionlike plant comm.
- Alpine steppe
- Alpine desert
- Subalpine scrub & meadow
- Subalpine coniferous forest
- Montane evergreen coniferous forest
- Montane deciduous coniferous forest
- Montane mixed coniferous-broadleaf forest
- Montane pine or cupressus forest
- Montane deciduous broadleaf forest
- Subtropical & tropical montane mixed coniferous-broadleaf forest
- Subtropical & tropical mountain top elfin forest
- Montane evergreen sclerophyllus broadleaf forest
- Montane mixed evergreen-deciduous broadleaf forest
- Montane semievergreen broadleaf forest
- Montane evergreen broadleaf forest
- Montane rainforest & seasonal rainforest
- Montane shrub-grass tussock or shrub-steppe
- Montane steppe a. meadow steppe, b. typical steppe c. desert steppe
- Montane drawf suffruticous desert
- Montane fruticous desert
- Subtropical montane desert
- Dry-hot valley shrubland

in the southern Y aluzangbu River Valley.

The structure of the above types is listed in Table 2.

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SOME PROBLEMS IN VEGETATION ZONATION ON MOUNTAINS

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ABSTRACT

Vegetation is usually stratified horizontally and altitudinally, not only on mountains, but also the vegetation belts from coast inland. Even in the intertidal zone, there are life zones consisting of algae and sedentary animals. The upper or northern limit of such zones is demarcated by the extreme physical conditions such as low temperature, and the lower or southern limit is demarcated by the biological factors such as interspecific competition. There are volcanoes (active and dormant) and no volcaneos in Japanese mountains. The example of immature vegetation is easily observed on volcanic mountains.

The *Fagus crenata* zone of Japan has the northern limit in southern Hokkaido and the southern limit in southern Kyushu. The *Fagus crenata* communities on the northern or southern border are ecotonal particularly in the undergrowth. In Hokkaido, there is a transitional type vegetation between the temperate East Asian region and subarctic Siberian taiga.

On hills or low mountains, there is a miniature or scale-down version of altitudinal zonation.

INTRODUCTION

There are various problems in vegetational zonation on mountains in relationship to climate, soil, geomorphology, geographical situation, geological history, flora and life-forms, etc. In textbooks, the altitudinal vegetation zones are described from the base to the top, such as tropical rain forest, subtropical monsoonal forest, warm temperate evergreen broad-leaved forest, cool-temperate mixed forest, cold-temperate coniferous forest, subalpine scrub, and alpine mat and cushion. This is an example on humid high mountains in tropical Asia, and there are variations and simplifications in different climates. Some aspects and conditions relating to vegetation zonation on mountains and the mechanism of vegetation zonation will be discussed.

THE MECHANISM OF THE ESTABLISHMENT OF VEGETATION ZONATION

Vegetation is usually stratified horizontally and altitudinally mainly indicated by physiognomy and landscape. This kind of physiognomic unit is a basis of sampling and measuring vegetation. On the other hand, a vegetational continuum corresponds to an environmental gradient, such as from wet to dry, from hot to cold, from lowland to highland, etc. A vegetational continuum is, in fact, an overlapping of distributional patterns of various species, each corresponding to an optimum habitat as a combination of species with high fidelity. At the same time, a dominance-subordination relationship occurs among those spatially overlapped species, and some species are excluded from a community dominated by a species. *Cynodon dactylon* is a dominant of the *Cynodon dactylon-Imperata cylindrica* pasture under 2500 m in altitude in eastern Nepal. However, it is excluded from the *Festuca rubra-Carex nubigena* pasture over 2500 m and sparsely distributed on the mountain path up to 2700 m (NUMATA 1965). It is no longer a dominant of highland pastures but it is distributed as a subordinate species outside the pasture. Factors settling the highest border of *Cynodon dactylon-Imperata cylindrica* belt are usually physical, such as low temperature. Tribes of Gramineae have their distribution areas corresponding to the temperature range > 10°C or < 10°C in the monthly temperature in mid-winter (HARTLEY 1950). However, the lowest border of the same belt is usually determined by biological factors, such as interspecific competition, and indirectly by physical factors, such as high temperature. Therefore, the ecological optimum range of a species is, in general, narrower than physiological optimum range.

I studied the limiting factor of the distribution of temperate bamboo forests, particularly *Phyllostachys bambusoides*. The first limiting factor for the northernmost distribution in Japan was found to be the average of the lowest minimum temperatures being -10° in the coldest month (NUMATA 1979). However, the first factor of the southermost distribution is not physical, such as high temperatures, but biological, such as interspecific competition with tropical bamboos.

The zonation of biotic communities and their successional sequence were observed in the denuded quadrats in the rocky littoral zone (ODAKA and NUMATA 1979). This is not zonation on mountains, however a common general principle for zonation is recognized. According to the environmental gradient, different life zones are established chronologically and spatially in the intertidal zone. Species in the upper belt were more pioneer-like than those in the lower belt. In general, pioneer plants and animals on the upper belt in the intertidal zone are small in size, short in life span, and broad in distribution in the littoral zone. Grazers caused retrogressive succession, however some seres were stabilized as disclimaxes. The uppermost border of life zone is limited by the environmental gradient caused by tidal action, such as drought for several hours, and the lowermost border is limited mainly by interspecific competition.

On the sandy seashore in central Japan, there is a characteristic zonation of coastal vegetation, such us unstable or frontal belt: *Zoysia macrostachya-Calystegia soldanella* community, semi-stable or intermediate belt: *Ischaemum anthroides-Fimbristylis sericea* community, stable or rear grass-shrub belt: *Imperata cylindrica-Vitex rotundifolia* community, and stable or rear forest belt: *Pinus thunbergii-Pittosporum tobira* community (NUMATA 1959). The factors regulating such a zonation are salt spray (NUMATA 1949), flying sands (MITSUDERA and NUMATA 1964), etc. The sandy soil is changed in its physical and chemical properties by plant cover, such as volume weight, porosity, and the amount of nitrogen and carbon. Changes in such soil properties regulate the development of vegetation (AONUMA 1976). Even in the stable or rear forest belt, tree species with leaves of a salt depositing type, such as *Persea thunbergii*, *Ilex integra*, *Cinnamomum japonicum*, *Daphniphyllum teijsmanni*, *Camellia japonica*, *Dendropanax trifidus*, *Pinus thunbergii*, etc. are in the frontal part of the coastal forest, and those with the leaves of the salt-invading type, such as *Clerodendron trichotomum*, *Celtis sinensis* var. *japonica*, *Mallotus japonicus*, *Ficus erecta*, *Zelkova serrata*, etc. are in the rear part (KURAUCHI 1956).

Salt-spray damage by typhoon was seen in the frontal coastal forest. The recovery process of coastal forests damaged by a typhoon in 1959 was observed later (KURAUCHI 1986). According to the results, the *Persea thunbergii* forest situated 60 m from the beach line did not recover even 25 years after demage by a typhoon. They are still scrub-like. The *Persea thunbergii* forests 50 m from the beach line had also suffered great salt spray demage 25 years ago. However, 16 years after the damage, they had almost recovered.

If we macroscopically observe the zonation of the forests from the coast inland in central Japan, the spatial sequence of *Pinus thunbergii* forest-*Persea thunbergii* forest- *Castanopsis cuspidata* var *sieboldii* forest and *Cyclobalanopsis myrsinaefolia* forest is seen. In this region, *Pinus densiflora* forests are an inland forest, and *P. thunbergii* forests make up the coastal forest. However, in the northeastern part of Honshu, there is no *P. thunbergii*, and *P. densiflora* forests are distributed as coastal as well as inland forests. In Hokkaido, *Quercus mongolica* var. *grosseserrata*, *Q. dentata* and *Abies sachalinensis* forests are sometimes coastal as well as inland forests. The resistance to salt spray is one possible reason for the establishement of coastal forests, but not the only one. The possibility of changing the spatial sequence in the zonation of vegetation according to the geographic situation is another aspect.

VEGETATION ZONES ON VOLCANOES AND EXTREME HABITATS

Mt. Fuji offers a good example for the nomination of altitudinal vegetation zones. HAYATA (1911) classified the altitudinal vegetation of Mt. Fuji such as 1) prairie zone (his term was region) or basal zone, 2) deciduous broad-leaved tree zone, 3) evergreen conifer zone, 4) *Larix* zone, 5) *Salix-Alnus* zone, and 6) higher grass zone. Miyoshi's observation (1888) was also similar, though it was simpler. HONDA (1928), the author of "The Forest Zones of Japan", criticized the Miyoshi-Hayata's idea of the basal prairie zone which was maintained by burning. The prairie zone is now almost completely covered by pine (*Pinus densiflora*) forests. The *Larix* zone by Hayata is also an early stage of succession, because the zonation of Mt. Fuji is not mature though it is not an active volcano at present. The subalpine scrub is composed by shrubby *Larix kaempferi*, *Abies veitchii* and *Tsuga diversifolia* (OHSAWA 1984). The subalpine scrub on ordinary high mountains of Japan is composed of *Pinus pumila* where ptarmigan is found. According to KHOMENTOVSKY (1983), *Pinus pumila* seems to be derived from *P. parviflora* from the evolutionary viewpoint.

Confusion in the nomination of vegetation zones of Mt. Fuij is closely related to whether a mountain is a volvano or not, and geologically new or old. Mt. Fujiis a relatively new volcano (the old part of Mt. Fujii erupted 20,000 years ago and the new part erupted in the Pleistocene epoch and up to 1707 (TSUYA 1971). After the 1707 eruption, Mt. Fujii became a dormant volcano, however, there has not been enough time for the formation of soil biota and vegetation. There are many volcanoes in Japan among which Mt. Fuji, Mt. Tateyama, Mt. Norikura, Mt. Ontake, Mt. Miyanoura and Mt. Hakusan are all dormant, while Mt. Asama, Mt. Mihara, and Mt. Sakurajima are active. When compared to non volcanic mountains, such as the Chichibu and Hida mountain ranges, there are various differences: 1) mountain flora of new volcanoes is not mature, and altitudinal vegetation zonation is not completed, and 2) und severe conditions, such as solfatara, alpine plants come down and vertical distribution is disturbed (cf. LÖTSCHERT 1969).

Mt. Fuji is an example of 1), therefore, it is the highest, but not a representative mountain in Japan in regard to the zonation of its vegetation. On the lava flow in 864 A.D., 1120 years ago, *Chamaecyparis obtusa-Tsuga sieboldii* forest, including *Quercus mongolica* var *grosseserrata*, *Fagus crenata*, *Picea polita*, *Abies homolepis*, etc., the so-called "Aokigahara Tree Sea" was established, and on the other lava flows, there are immature forests composed of *Chamaecyparis obtusa*, *Picea polita*, *Tsuga sieboldii* mixed with *Picea bicolor*, *Larix kaempferi*, *Pinus densiflora*, *Quercus mongolica* var. *grosseserrata*, *Quercus serrata*, *Alnus hirsuta* var. *sibirica*, etc.

The *Abies veitchii* zone develops as the highest coniferous zone however the *Fagus crenata* zone, the commonest montane zone, does not develop well. The influence of pioneer tree species, such as *Pinus densiflora* and *Larix kaempferi* is strong, and the altitudinal zones of climax forests are not completed. The examples of immature vegetation on volcanoes are easily observed after eruptions, such as was shown in a follow-up survey of environmental chages caused by the 1977-1978 eruptions of Mt. Usu, Hokkaido (ITO and HARUKI 1984).

FLORISTIC RELATIONSHIPS BETWEEN ALTITUDINAL AND HORIZONTAL VEGETATIONAL ZONES.

As a rule, the altitudinal vegetation zones correspond to the horizontal vegetation zones. For example, the cool-temperate *Fagus crenata* zone on the mountains of central and southern Honshu corresponds to the lowland climax forest of northeastern Honshu, and the cold-temperate *Abies* zone on mountains of Honshu corresponds to the lowland *Abies-Picea* forest in Hokkaido. In these two examples, *Fagus crenata* is similarly distributed on southern mountains and northern lowlands. There are *A. mariesii*, *A. veitchii*, *P. jezoensis* var. *hondoensis*, and *Chamaecyparis obtusa* on southern mountains. Northern lowland conifers corresponding to those are *A. sachalinensis*, *A. sachalinensis* var. *mayriana*, *P. jezoensis*, and *Thujopsis dolobrata*. The dominants of *Fagus* forests on mountains and lowlands are the same species, but the floristic composition differs depending on the geographical situation. In the southernmost natural *Fagus* forest in Kyushu, the dominant tree layar is occupied by *Fagus crenata*, but the undergrowth involves many evergreen broad-leaved subtrees and shrubs, such as *Illicium religiosum*, *Sapium japonicum*, *Camellia japonica*, *Symplocos myrtacea*, *Cyclobanopsis salicina*, and so on (SAKO 1960). Therefore, the subordinate species of *Fagus* forests are different depending on whether they are northern lowland forests or southern mountain forests.

From the Kuromatsunai depression of southern Hokkaido to the Schimidt line of Sakhalin and the Miyabe line in the Kulire Islands (Fig. 1) there is a transitional type of vegetation between the temperate East Asian region and subartic Siberian taiga (TATEWAKI 1958) which is called the cold-temperate district (ITO 1980). In the central and northern Sakhalin north of the Miyabe line, we cannot find *Abies sachalinensis*, *Picea jezoensis*, *Betula platyphylla* var. *japonica*, *Acer mono*, etc. and the *Pinus pumila* scrub stretches to the sea coast. On the other hand, the climax of northern Sakhalin is *Larix kamtchatica* forest. In Honshu and Hokkaido, *Larix kaempferi* is a pioneer tree, mainly used for plantations. The same situation is seen in *Pseudotsuga menziesii* in North America. *Pseudotsuga menziesii* is a pioneer or seral tree in some places of south-central Oregon and Washington, however it is a climax tree in drier parts on the eastern slopes of the central Oregon Cascade Range and British Columbia (FRANKLIN and DYRNESS 1973).

The *Distylium racemosum* association as the upper laurel-leaved forest zone is in southern Kyushu, while the *Distylium lepidotum* association (*Distylio Pouterietum dubiae*) as the lower laurel-leaved forest zone is found in the Bonin Islands. The *Distylium racemosum* zone appears betwenn the lower zone of *Castanopsis cuspidata* var *sieboldii* and *Persea thunbergii* and the higher zone af *Abies firma*, *Cyclobalanopsis acuta* and *Tsuga sieboldii*. This is an example from the warm-temperature (Kyushu) and sub-tropical (Bonin Is.) regions, and the other examples mentioned before are in the cool and cold temperate regions.

The floristic differences, already mentioned, are based on climatic, edaphic, and geologic differences. In Japan which is a long chain of islands from

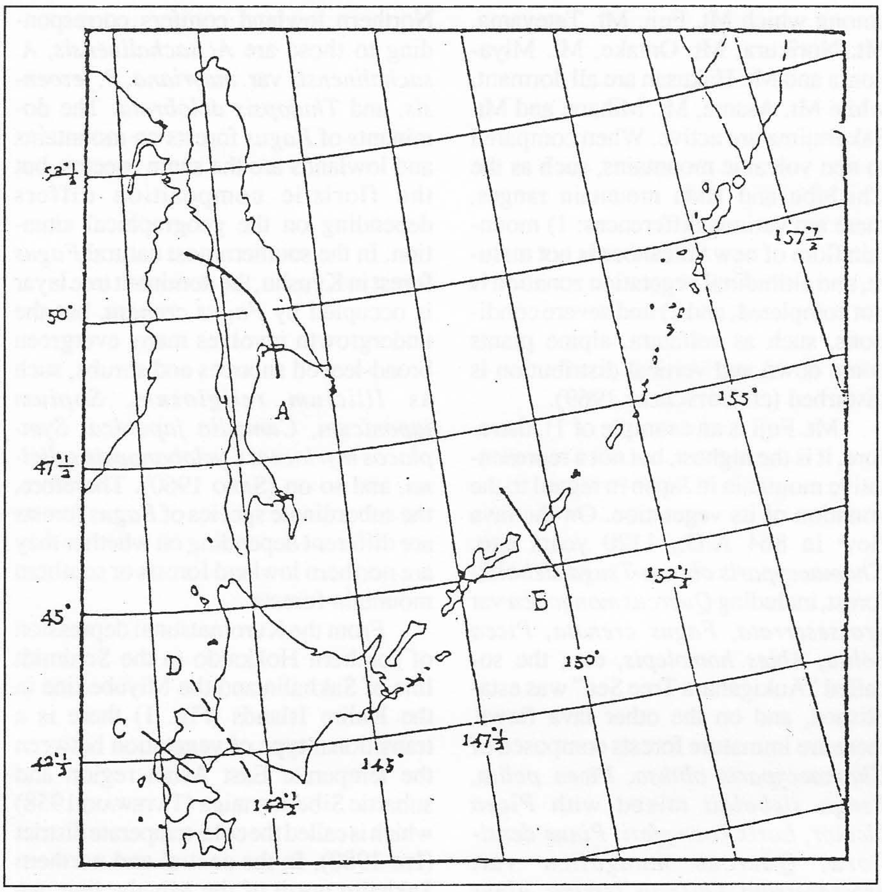

Fig. 1 — Important demarcation lines.
A. Schmidt's Line; B. Myabe's Line;
C. Kuromatsunai Depression; D. Ishikari Depression

north to south, the distribution of many species, climax and subordinate, are limited and closely related to temperature microclimatically, and then to rain and snow mesoclimatically, such as the south slope of Eastern Himalaya under the influence of monsoon rain and the north Tibetan Plateau rain shadow. The south-eastern slope of the Japan Alps under the effect of monsoon rain and the northwestern slope under monsoon snow are similar cases.

In the southern most part of the Kii Peninsula (Wakayama Prefecture), it is warm and very humid (4000 mm in rainfall), and the polydominant and multistratified structure or warm-temperate rain forest is observed. The warm-temperate climax forest in Japan is usually mono-dominant such as *Castanopsis cuspidata* var. *sieboldii*. Moreover, the altitudinal zontaion there is different from the normal one. *Rhododendron* spp. is usually found higher than *Fagus crenata* zone, but it grows there at 50 m in alt. along the river. *Quercus phylliraeoides* is characteristic of the coastal forest along the Seto Inland Sea, but it is found on the ridge of the mountains facing the sea. Alpine plants descend along the solfatara and on the windward slope of lowlands. However, the phenomena of highland plants descending and lowland plants ascending are very curious (Numata 1971).

The distribution of a five-leaved pine, *Pinus parviflora* on the Boso Peninsula, central Japan is a similar phenomenon. It is distributed at 170 m in altitude in the warm-temperate zone. The highest ridge is only 400 m in alt. which belongs to the laurel-leaved forest zone. It is a geomorphological limitation of plant distribution. The warmth index (the accumulated monthly temperature over 5°) of the highest altitude on the Boso Peninsula is 120°C which is out of the potential range of *Tsuga sieboldii* (40~110°C) and *Pinus parviflora* (40~115°) (Numata 1972).

If there were high mountains in the Boso Peninsula, the ranges of the cool-temperate, the upper warm-temperate and the lower warm-temperate zone might be higher than 1200 m, and 0~1200 m, and 0~600 m respectively. However, the three zones there, mentioned above, are actually higher than 400 m, 200~400 m, and 0~200 m respectively. This is a kind of miniature or scaled-down version of altitudinal zontaion according to the lowness in altitude.

Boysen-Jensen (1949) discussed the causes of plant distribution altitudinally and horizontally, based on positive net production, reproductive capacity, survival in the unfavorable season, and interspecific composition. In the differentiation of subalpine vegetation zone on Mt. Fuji, the basal area and biomass of dominant species of forest zones become lower in the ecotones between them (Ohsawa 1984).

The horizontal ranges of species distribution have been drawn based on existing data (Ohsawa 1975). The northern limits of the range of climax species of the laurel-leaved forest are converged on a line, however those of seral species are diversified. Vegetation and zones are an aspect of vegetational continuum, however according to several reasons, the vegetation zonation is typologically recognized. I compared altitudinal vegetation zonations based on climax and seral (secondary forests and grasslands) species in the Himalaya of Eastern Nepal (Numata 1966). In the zonation by seral species, it is only roughly classified by comparing climax species. This is similar to the previous case of the horizontal distribution of species.

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COMPARING THE NATURAL MONTANE VEGETATION TYPES OF EAST ASIA AND EASTERN NORTH AMERICA*

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Key words: vegetation belts, mountain vegetation, phytogeographical connections

INTRODUCTION

East Asia (China, Korea, and Japan) and eastern North America (including SE Canada, NE Mexico, and some Caribbean islands) occupy roughly the same latitudes on the east sides of the Northern Hemisphere's two large land masses. Due to the regularities of global atmospheric circulation, the two regions have similar climate and vegetation zones ranging from tropical-subtropical in the south, through warm-temperate and typical-temperate, to boreal in the north and temperate-continental toward the continental interiors (see Figure 1; cf. also TROLL and PAFFEN 1964; WALTER 1979, etc.). Mountain ranges in these corresponding climatic zones show corresponding altitudinal zonation. In fact, similar N-S orientation of the main East Asian and North American mountain ranges permits even more direct comparison, including (see Figure 1) the Appalachians and northern Sierra Madre Oriental in North America, the long Japanese mountain chain, and the Changbai Shan and other ranges of mainly northeastern China. Because the extensive mountain areas of central and western China (especially Qinghai-Tibet) are similar to some parts of the Rocky Mountains, our concept of "eastern North America" is actually extended to about 110°W longitude, in order to include the easternmost Rocky Mountains. On the other hand, eastern North America has no large subtropical region corresponding to southeastern China and perhaps no true warm-temperate mountains comparable to those of Yunnan and Sichuan, eastern-southeastern China or the southern islands of Japan, with possible exception of some parts of the Sierra Madre Oriental (at lower latitude and higher elevation).

* Manuscript completed in 1987.

MONTANE VEGETATION BELTS IN GENERAL

Whereas most mountain areas of East Asia and eastern North America occur in humid climates, the Rocky Mountains and much of the Qinghai-Tibetan Plateau and the Tien-Shan system occur in distinctly dry, temperate continental or even temperate arid climates. As a way of systematizing vegetation types in mountainous areas one can begin by identifying the climatic zones out of which the mountains rise and then identifying the different altitudinal belts of vegetation which occur in the different climatic regions. An attempt to summarize the characteristic potential natural vegetation types of the different altitudinal belts in the different east-side climatic zones of northern temperate continents is given in Table 1.

Within each altitudinal belt one expects a different characteristic vegetation formation type in each climatic zone (cf. WALTER and BOX 1976), even in the alpine belt. On the other hand, different occurrences of the same zonal-altitudinal combination are expected to show the same general vegetation type. If this does not happen, then an explanation is needed, which often yields new information. As a complicating factor, some species from lower altitudinal belts tend to recur in higher belts in adjacent, warmer climatic zones, e.g. lowland, dominant *Castanopsis sieboldii* of warm-temperate Kyushu and southern Honshu occurring also in montane forests of more southerly, subtropical Okinawa. This can yield a superficial similarity between the vegetation of different climatic zones and may lead to confusion about the true geobotanical "position" of some species. One might resolve this question by saying that the species in question belongs to the climatic zone where it occurs at lowest elevation. On the other hand, many genera which recur at higher elevations in warmer zones recur as similar but different species. In East Asia this has yielded, for example, an unusual diversity of warm-temperate montane species of genera such as *Abies*, *Picea*, and *Quercus*, especially in southern China.

MONTANE VEGETATION IN EAST ASIA AND EASTERN N. AMERICA

Based on the framework described above, an attempt is made in Table 2 to juxtapose the corresponding main natural zonal and topogenic vegetation components of the mountains of China, Japan, and eastern North America. This system is based on the general descriptions of natural vegetation types by NUMATA (1974) and ISHIZUKA (1974) for Japan, by HOU (1983) and WU (1980) for China, and by NUMATA (1983) and TROLL (1972) for the eastern Himalaya. Secondary vegetation types are generally not included. Additional vegetation information was obtained mainly from HOU and CHANG (1986), CHANG (1981), the CHINESE ACADEMY OF SCIENCE (1979) map, and WANG (1961) for China and from MIYAWAKI (1967, 1980-86, 1984) and NUMATA *et alii* (1972) for Japan. The treatment of eastern North America follows BRAUN (1950), MIRANDA and SHARP (1950), KÜCHLER (1964) and DAUBENMIRE (1978) but with some adaptations. More detailed, local information was obtained from many other sources, listed with Table 2. General floristic information comparing East Asia and eastern North America has been presented by LI (1952), GRAHAM (1972), KORNAS (1972), HARA (1972), and MISSOURI BOTANICAL GARDEN (1983), among others.

As one can see from the table, many vegetation types occur in all three regions and with many of the same genera. This has been seen before in many individual cases, but a more rigorous comparison requires a more systematic approach using some common classification basis for all three regions. This initial common framework is based mainly on vegetation structure, seasonality, and altitudinal position. The table attempts to be comprehensive geographically but has various gaps and classifies the vegetation at only this initial level.

The vegetation types in the table were identified by their importance in at least one of the three regions, yielding a total of 32 general types. Of these, Japan lacks the three truly tropical montane types and lacks three other types characteristic of drier climates (dry conifer forests, grasslands, and alpine cushion-shrubs), as well as the dry subalpine sclerophyll *Quercus* forests found only in eastern Qinghai-Tibet and western Sichuan. North America also lacks this type, plus montane vegetation dominated by evergreen broad-leaved trees (two types), bamboo (two types) and *Larix* (two types). Of all 32 types, China appears to lack only the dwarf bamboo (*Sasa*) stands and the treeline *Larix* krummholz of Japan.

MAIN SIMILARITIES AND DIFFERENCES

The greatest similarity between the mountains of East Asia and eastern North America is probably in the typical temperate, temperate continental, and boreal/subarctic zones. The montane

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Fig. 1a-1b — Locations and climatic situations of the Main Mountain Areas of East Asia and eastern North America.

The main mountain areas treated herein involve all of China plus the adjacent eastern Himalaya (mainly Nepal), all of Japan, and North America as far west as the easternmost "front range" of the Rocky Mountains (longitude about 110°W). Korea and Taiwan are not specifically included due to lack of local experience by the author.

Within China, the main mountain areas treated inclue the Chiang-Bai Shan along the Korean border, the Himalaya chain and Qinghai-Tibetan Plateau, the highlands of Yunnan and adjacent Sichuan, the uplands of southeastern China (including Hainan), and to a lesser extent the drier Tien-Shan system and highlands of Xinjiang, western Tibet, and Gansu. Within North America the mountain areas include mainly the Appalachians of the eastern U.S.A. (into SE Canada) but also the Sierra Madre Oriental of NE Mexico, the easternmost Rocky Mountains, and some subtropical mountains of the Caribbean islands. The climatic zonation is shown by the Roman numerals and follows the system of WALTER (1968, 1979, 1985).

Climate types:

I = equatorial
II = tropical wet-dry
V = warm-temperate
VI = typical temperate
VII = temperate continental (a = arid)
VIII = boreal

Subtropical climates may be transitional I-V or II-V.

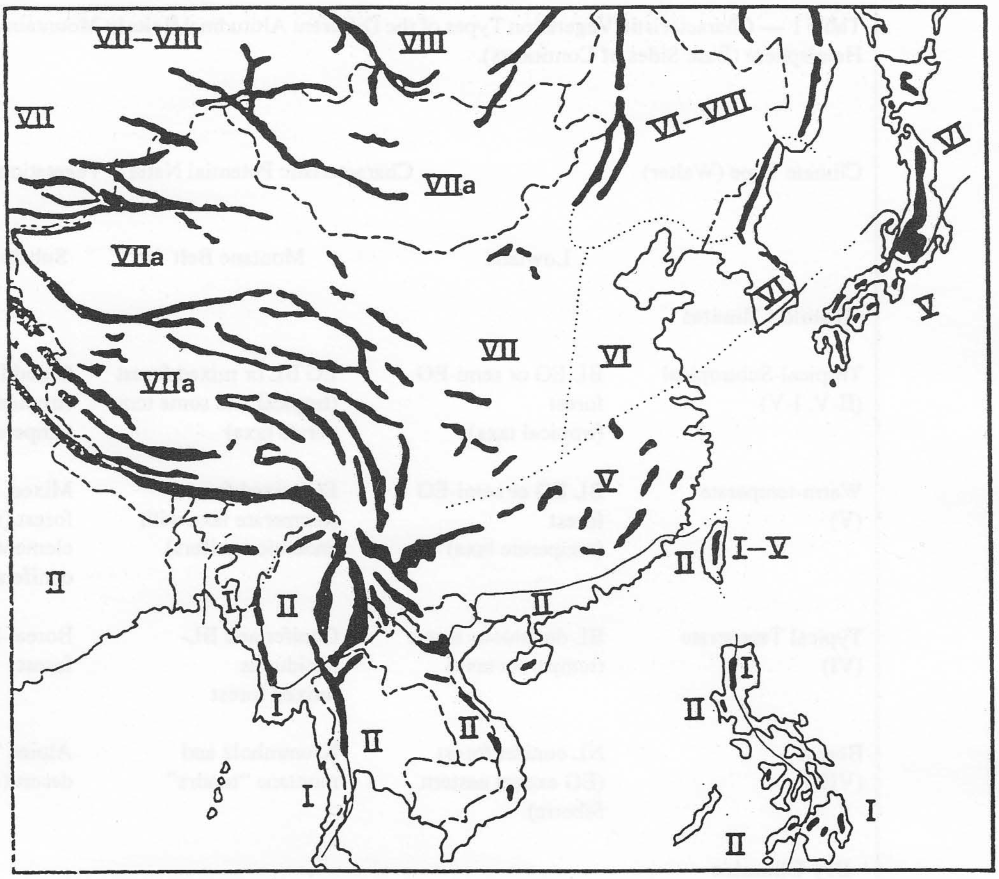

Fig. 1a

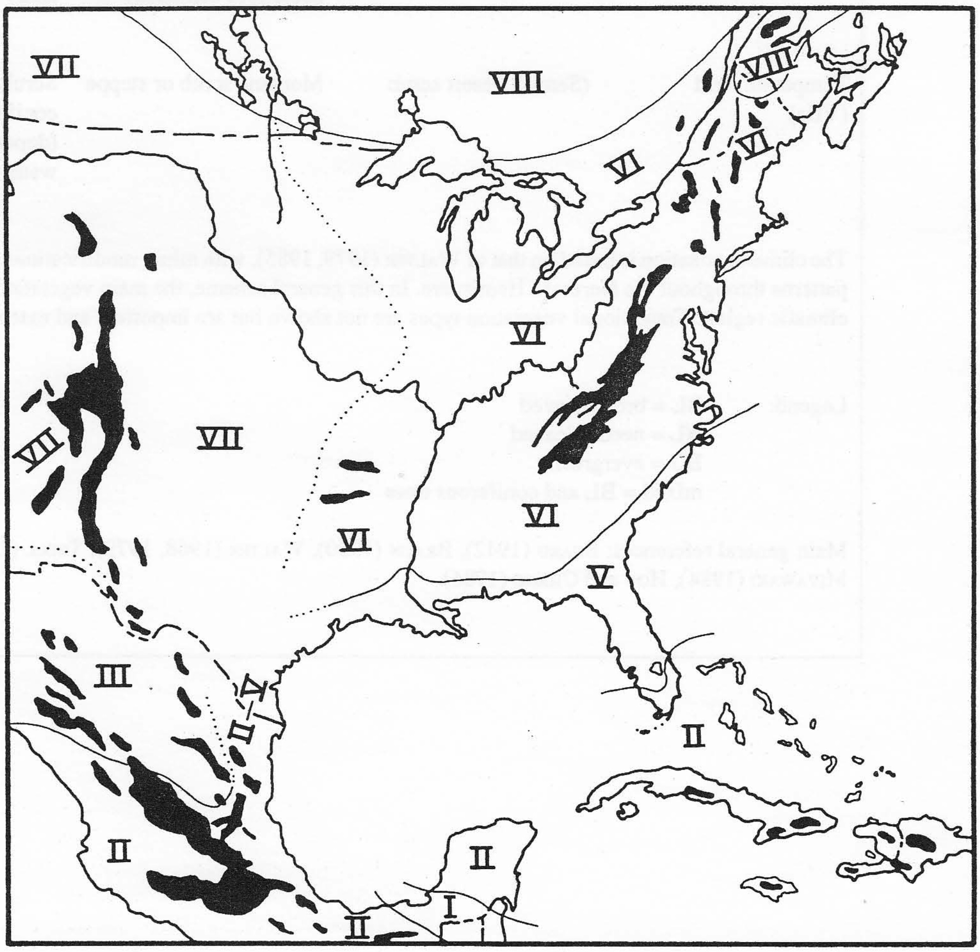

Fig. 1b

Table 1 — Characteristic Vegetation Types of the Different Altitudinal Belts in Mountains of Different Climatic Regions of the Northern Hemisphere (Ease Sides of Continents).

Climate Type (Walter)	Characteristic Potential Natural Vegetation Types			
	Lowland	Montane Belt	Subalpine Belt	Alpine Belt
Humid Climates				
Tropical-Subtropical (II-V, I-V)	BL EG or semi-EG forest (tropical taxa)	EG BL or mixed forest (tropical and some temperate taxa)	Cloud forest (tropical and some temperate taxa)	Grassy shrub-steppe (many local taxa)
Warm-temperate (V)	BL EG or semi-EG forest (temperate taxa)	EG mixed forest (temperate taxa with endemic conifers)	Mixed, mainly conifer forest (with BL-decid. elements and endemic conifers)	"Tundra" like grassy shrub-steppe (local and some more common temperate taxa)
Typical Temperate (VI)	BL deciduous forest (temperate taxa)	Conifer and BL-deciduous mixed forest	Boreal-like conifer forest	Wet alpine "tundra" (most typical, with snow-patch veg., etc.)
Boreal (VIII)	NL conifer forest (EG except eastern Siberia)	Krummholz and montane "tundra"	Alpine "tundra" or cold-desert (arctic taxa)	Alpine cold-desert or permanent snow
Dry Climates				
Temperate Continental (VII)	Grassland	Drier conifer forest (with some BL-deciduous elements)	More moist conifer forest (boreal or local taxa)	Dry alpine "tundra" (with cushion-shrubs, many snow-patch and other special elts.)
Temperate Arid (VIIa)	(Semi-) Desert scrub	Montane scrub or steppe	Scrub, steppe or conifer woodland (depending on water balance)	Driest alpine "tundra" (cushion-shrubs especially common)

The climatic zonation is based on that of WALTER (1979, 1985), with minor modifications. The vegetation types are based on characteristic patterns throughout the Northern Hemispere. In this general scheme, the main vegetation type of each altitudinal belt is different in each climatic region. Transitional vegetation types are not shown but are important and extensive in some areas.

Legend: BL = broad-leaved
NL = needle-leaved
EG = evergreen
mixed = BL and coniferous trees

Main general references: BEARD (1942), BRAUN (1950), WALTER (1968, 1979), TROLL (1972), NUMATA (1974), WU (1980), HOU (1983), MIYAWAKI (1984), HOU and CHANG (1986).

Table 2 — Some Corresponding Main Zonal and Topogenic Vegetation Components in Mountains of China, Japan, and Eastern North America.

The most important vegetation components of these mountain areas are juxtaposed here based mainly on physignomy, altitudinal location, and ecological relations, including climate and substrate. This comparison represents a very general, incomplete, first attempt, based on the most readily available literature.
Within this framework one can see many genera common to corresponding vegetation situations in at least two and often in all three regions. Many understorey genera are common or closely related also.

Legend: BL = broad-leaved EG = evergreen N, E, S, W = north, east, south, west

Vegetation Type	China	Japan	Eastern North America
MONTANE FORESTS (lower levels)	(NE mtns., E Qinghai Tibet, SE mtns., etc.)	(BL-EG in S only others throughout)	(mainly central-south Appalachians)
EG-BL forests	Subtropical mtns: *Cyclobalanopsis, Castanopsis, Laurac., Theaceae*, etc.	Lower mtns. S Japan: *Castanopsis, Cyclobalanopsis, Quercus, Cinnamomum*, etc.	------------------------
Mixed BL forests	Subtrop.-W temp. mtns.: *Cyclobalanopsis, Fagus*, etc.	Less developed: with *Quercus*, etc.	------------------------
Deciduous BL forests	Mixed mesic: *Acer, Tilia, Fraxinus, Ulmus, Betula* Cool-microphyll: *Betula, Populus* More xeric: *Quercus*	Pacific side: *Fagus crenata*, with *Quercus, Carpinus, Stewartia, Betula, Tsuga, Sasamorpha* Japan Sea side: *Fagus crenata*, with *Quercus, Magnolia, Kalopanax, Acer, Camellia, Sasa*	Appalach.: *Quercus* spp., *Castanea, Pinus, Carya* W foothills: *Fagus, Liriodendron, Acer, Quercus, Tilia, Tsuga*
Topographic forest types:			
Ridge/slope xeric conifers	*Pinus tabulaeformis, P. densiflora, P. massoniana* Taiwan: *P. taiwanensis*	*Pinus densiflora, P. pentaphylla*, with *Thuja, Quercus, Sciadopitys*	*Pinus rigida, P. pungens, P. virginiana*, with *Quercus*
Moist lower areas	*Tsuga, Acer, Quercus, Betula, Tilia, Fraxinus, Fagus, Castanopsis*, etc.	*Pterocarya, Magnolia obov., Fraxinus, Cercidiphyllum, Acer, Ulmus*, etc.	S Appal. "coves": *Liriodendron, Acer, Tilia, Tsuga, Carya, Quercus, Betula*, etc.
Wetland-margin "swamp" forests	*Alnus, Fraxinus, Salix, Ulmus*, etc.	*Alnus, Fraxinus, Ulmus, Pterocarya, Hydrangea, Picea*	*Alnus, Acer rubrum, Salix*, etc. "Spruce flats": *Picea rubens, Betula, Acer*
Special conifer stand	*Metasequoia, Tsuga, Cunninghamia, Cryptomeria*	*Cryptomeria, Thujopsis, Chamaecyparis, Tsuga, Sciadopitys, Thuja*	*Tsuga* only
MONTANE-SUBALPINE Forests	(NE mtns., E Qinghai-Tibet, some SE mtns.)	(throughout except for south)	(Appalachians, SE Can.)
Mesic conifer forests	NE mtns.: *Picea jezoen., P. koraiensis, Abies nephrolepis, A. holophylla, Pinus sylv.*, Subtrop.: many *Abies* & *Picea* spp., with *Qu., Rhodod., Tsuga, bamb.*	*Abies sachalinensis, A. veitchii, A. mar., Picea jez., P. gleh., Betula ermanii, Populus can.*	*Abies fraseri*, with *Sorbus americana, Acer spicatum, Picea rubens, Tsuga Cornus canadensis, Clintonia*, etc.

Secondary decid. forests	Temperate: *Betula plat.* Subtrop.: *Bet. albosin.* *B. plat. v. sz.*	*Betula ermanii*, etc.	*Betula populifolia*, etc.
Mixed forests	NE mtns.: *Abies*, *Picea*, *Larix*, with *Betula*, *Populus*, many others	Hokk.: *Abies sach.*, *Qu. mong. v. gross.*, *Betula*, *Ulmus*, etc.	North: *Betula* spp., *Picea rubens*, *Abies b.*, *Acer*, *Sorbus*, etc.
Larch forests	NE: *L. gmelini*, with *Ledum*, *Vaccinium*	Central: L. leptolep.	-----------------------
Floodplain forests	*Salix*, *Betula*, *Alnus*,	*Pop. max.*, *Salix* spp., *Toisusu*, *Alnus*, *Chosenia*, *Sasa*	N: *Acer*, *Ulmus*, *Salix*, *Populus*, *Alnus*
GRASSLANDS (montane, not alpine)	*Miscanthus*, *Pleioblastus* Drier: *Stipa*, *Festuca*, Kobresia	Meadows: *Pleioblastus*, *Miscanthus*, *Sasa* Pastures: *Poa-Festuca*, *Zoysia*, *Pleioblasus*	Uncommon except pastures: *Poa*, *Dechampsia*, etc.
SUBALPINE-ALPINE SCRUB Deciduous woodlands	(NE, E Qinghai-Tibet) NE: *Betula ermanii*	(J. Alps, Hokkaido) N: *Betula ermanii*, with *Alnus*, *Sorbus*	(North, few S Appalach.) N: *Betula*, *Salix*, with *Sorbus*, *Ericaceae*
Deciduous thickets	E Qinghai-Tibet: *Salix* spp., with *Caragana*, *Potentilla*	J. Sea side: *Quercus mong. v. undulatifol.*, *Alnus*, *Acer*, *Sorbus*, with *Sasa kurilensis*	-----------------------
Ericad scrub/ krummholz	Subtrop.: *Rhododendron* thickets, with *Salix*, bamboo, etc.	Xeric ridges with dense understoreys: *Rhodod.*, *Vacc.*, *Sorbus*, etc.	"Heath balds": *Rhodod.* spp., other *Ericac.*, *Viburnum*
Larch krummholz	-----------------------	*L. leptolepis*	-----------------------
Evergreen NL krummholz	*Pinus pumila* Sichuan: *Sabina*	*Pinus pumila*, with *Vacc.*, *Rubus*, etc.	N: *Abies balsamea*, with ericads
Deciduous BL scrub/ krummholz	*Betula albo-sinensis* (?)	*Alnus max*, *Sorbus*, *Salix*, *Acer*, *Junip.*, *Tripetaleia*, *Vacc.*	N: *Betula*, *Salix*, with *ericads*
Dwarf-bamboo scrub	-----------------------	J. Sea side: *Sasa kurilensis*	-----------------------
ALPINE VEGETATION Dwarf-shrub heath/ "tundra"	(NE, E Qinghai-Tibet) *Vaccinium vitis-idaea*, *Rhododendron*, *Phyllodoce*, *Arctous jap.*, *Empetrum sib.*, *Salix*	(J. Alps, Hokkaido) *Empetrum n. v. jap.*, *Arcteria nana*, *Loiseleuria proc.*, *Vacc.*, *Diapensia*	(N only exc. subalpine) *Diapensia lapponica*, *Loiseleuria procumb.*, *Rhodod. lapp.*, *Vacc.*, *Ledum*, *Empetrum*
Windward grassland (some subalpine)	Qinghai-Tibet: *Kobresia* spp., with *Polyg.*, *Thalictrum*, *Pedicularis*, etc.	*Kobresia*, *Carex*, with *Oxytropis*, etc.	N: *Carex*, *Deschampsia*, *Juncus*, etc. S "grass balds": *Deschamps.*, *Kobresia*
Snowbed communities	Espec. Qinghai-Tibet many geophytes, graminoids, etc.	many graminoid, geophyte, forb communities	N: *Veratrum*, *Deschamps.*, *Juncus*, *Houstonia*, *Vaccinium*, etc.
Topogenic deserts	rock slopes, fells, etc.	screes, earthflows, rock slopes, volcanic barrens, serpentine areas.	fells, screes, rock slopes, etc.

Sources:

China and Himalaya: CHANG (1981), CHANG (1982), CHEN *et alii* (1986), DING-HU STATION (1984-86), "FORESTS" ED. COMM. (1986), HOU and CHANG (1986), HOU (1983), JIANG (1960), JIANG (1980), JIN (1986, in prep.), LIN and YE (no date), LIU (1983), LU *et alii* (1986), NUMATA (1983), OHSAWA *et alii* (1986), QIU *et alii* (1982, unpubl.), TROLL (1972), WALTER and BOX (1983 a, 1983 b), WANG (1961), WU (1980), WU and ZHU (1986), XU (1986), YANG & COMM. (1985), YODA (1967), YU (1983).

Japan: FUJIWARA (1981-83, 1985), HARA (1972), HUKUSIMA (1972), ISHIZUKA (1974), KIKUCHI (1981), KIRA (1949), MIYAWAKI (1980-86; 1984), NAKAGOSHI (1981), NUMATA (1974), NUMATA *et alii* (1972), OHBA (1969), OHNO (1982, 1983), TAGAWA (1964).

deciduous, conifer-deciduous, and conifer forests are generally quite similar, involving familiar important genera such as *Fagus*, *Quercus*, *Acer*, *Ulmus*, *Pinus*, *Tsuga*, *Abies*, and *Picea* in all three regions. Understorey *Sorbus*, *Vaccinium*, *Rhododendron*, etc. are also important in all three regions. Warm-temperate and subtropical semi-evergreen montane forests similar to those in East Asia occur also in some small mountain areas of NE Mexico and on some Caribbean islands.

The main differences in mountain vegetation of East Asia and eastern North America occur in the warm-temperate and subtropical zones, where North America has few mountains. Extra-tropical evergreen broad-leaved montane forests appear to be generally lacking in North America. Southern China (especially Yunnan, Sichuan, Guizhou, Guangxi, and Guangdong, plus Taiwan and Hainan) and southern Japan (southern Honshu, Shikoku, and Kyushu, plus Yakushima), on the other hand, contain many smaller and some larger mountain areas which have very interesting warm-temperate and subtropical evergreen and mixed montane forests. These areas have a wealth of local taxa and may have no real counterparts in North America or anywhere else. Of perhaps particular interest here is the large number of endemic conifer species (in otherwise common genera, e.g. *Abies*) and endemic or at least highly localized conifer genera, including *Torreya*, *Keeteleria*, *Sciadopitys*, *Cunninghamia*, *Cryptomeria*, *Thujopsis*, and *Metasequoia*.

Of these, only *Torreya* occurs in North America, confined (as a relict) to a very small lowland area in northwestern Florida.

CONCLUSION

The similarity of East Asian and eastern North American mountain vegetation, to the extent that quasi-natural vegetation still exists, offers excellent opportunities for comparative work. Up to now such work has focused mainly on historical and taxonomic aspects of individual or closely related genera or families. The hypothetical framework presented here is at the level of general vegetation compositions. It is intended as a basis for comparative work on more integrative aspects of vegetation, such as vegetation structure, environmental relationships, productivity, and phytosociology, as well as processes of ecosystem recovery and restoration.

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HOCHSTAUDENFLUREN CHINAS IN PALAEARKTISCHEN VERGLEICH

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EINFÜHRUNG

Jedem Besucher, der die höheren Lagen zentral- und ostasiatischer Gebirge durchstreift, fallen nicht nur ausgedehnte Bambusdickichte, sondern auch Hochstaudenfluren auf. Vom Altai und Himalaya bis zu den japanischen Alpen zeigen sie viele gemeinsame Züge, die gelegentlich auch an die alpinen Vertreter erinnern. Auffallend sind indessen die östlichen von *Cacalia*-Arten beherrschten Fluren, womit sie sich allein schon farblich und physiognomisch von den westlichen unterscheiden.

In diesem Beitrag zur Struktur einer global verbreiteten Vegetationsform sollen die Gemeinsamkeiten ostasiatischer bis zentralasiatischer Bestände vom Lorbeerwaldbereich bis zu den subalpinen Uebergangslagen vorgestellt werden. Ein weiterer Beitrag geht den Lebensformen der Hochstauden i.w.S. und ihren spezifischen Strategien vergleichend nach (Klöetzli im Druck).

DEFINITION DER HOCHSTAUDEN UND DER VON IBNEN BEHERRSCHTEN BESTÄNDE

Unter den Begriff Hochstaude (vgl. z.B. Richard 1985) fallen krautartige, zumeist mindestens 70 cm hohe, in der Regel sommergrüne Arten von Hemikryptophyten, Chamaephyten und Geophyten sowie auch Therophyten. In kühleren Lagen überwiegen Arten mit unterirdischen Ueberdauerungsorganen (im Nadelwaldbereich). Stellenweise können die Bestände auch von Therophyten durchsetzt sein (Schwergewicht in Lorbeerwald-Uebergangsgebieten des feuchteren Ost-Nepal).

Solche Hochstaudenfluren werden häufig von wenigen Hochgräsern mitbeherrscht (*Calamagrostis*, *Festuca*, *Poa*) und sind in der Regel durchzogen von Rosettenpflanzen und von Bodenkriechern. Moose können grosse Flächen bedecken, und Holzpflanzen, z.B. Zwergsträucher, können je nach Höhenlage und Feuchte beigemischt sein (*Ericaceae*, *Salicaceae*, *Rosaceae* u.a.) Ein Grossteil der Arten sind nährstoff- und feuchtezeigende, Humuslager bevorzugende Arten, stellenweise und zeitweise erscheinen auch säure oder basenzeigende Arten (vgl. Tab. 2).

Der Standort ist mit Vorzug eine Zufuhrlage, also oft muldig und durchschnittlich feucht bis sehr feucht. Uebergänge zu Sumpf-Hochstaudenfluren oder dann zu subalpinen Gebüschen sind oft fliessend.

Eher xerophytische Hochstaudenfluren mit vielen Apiaceen werden hier nicht behandelt (vgl. Klein 1988).

VERBREITUNG

Die palaearktische Verbreitung der Hochstaudenfluren in den einzelnen Biomen, Zono- und Oro-Biomen, kann aus Abb. I entnommen werden. In diesem Zusammenhang werden vorwiegend Hochstaudenfluren der höheren. Lagen beschrieben, insbesondere solche der hochmontanen bis unteren alpinen Stufe. Demnach besteht ein gewisses Schwergewicht in Breitenlagen zwischen 70° und 40°NB, ohne dass sie in feuchteren subtropisch-tropischen Höhenlagen ganz zu fehlen brauchen. Allerdings sind schon dort und erst recht in der ozeanischeren südlichen Hemisphäre Farne und stellenweise auch Zingiberaceen die tonangebenden Gruppen. Echte Hochstaudenfluren gibt es dort kaum, ausser an gelegentlich oder dauerhaft feuchten, quellig überrieselten Standorten, z.B. in Lateinamerika mit *Gunnera*-Arten. Die Kausalität ihres Vorkommens wird in Klöetzli (im Druck) besprochen.

SPEZIFISCHE HOCHSTAUDENFLUREN

Wie Tab. 1 zeigt, werden Hochstaudenfluren Chinas (z.B. Wolong) durchschnittlich von den folgenden Gattungen dominiert: *Cacalia*, *Cirsium*, *Geranium*, *Ranunculus*, *Sanguisorba*, *Trollius*, *Apiaceae* (z.B. *Heracleum*), *Leguminosae* (*Papilionaceae*, z.B. *Astragalus*), *Calamagrostis*. Ferner vind beigemischt: *Aconitum*, *Anaphalis*, *Angelica*, *Aster* (*Heteropappus*), *Astilbe*, *Cicerbita*, *Euphorbia*, *Gentiana*, *Halemia*, *Parnassia*, *Potentilla*, *Rodgersia*, *Arisaema*, *Iris*, *Polygonatum*, *Scilla*, *Smilacina*, *Streptopus*, *Veratrum*, *Athyrium*, *Dryopteris*. Sie liegen somit wesensmässig zwischen den innerasiatischen (Himalaya Tab. 1.6., Altai (Sayan) Tab. 1.7.) und japanischen Typen (1.3.-1.5.). In allen Fällen können *Cacalia*-Arten zur Herrschaft gelangen und damit den Status von *Adenostyles* und anderen Asteraceen der Unterfamilien *Eupatoriae* (*Adenostyles* und *Eupatorium*) und *Senecionae* (*Petasites*, *Doronicum*, *Cacalia*, *Senecio*, *Ligularia*) in Europa einnehmen. In den von uns auf der Exkursion nach Westchina besuchten Gebieten kommen z.B. *Astragalus*, *Anaphalis*, *Aster*, *Euphorbia* und *Halemia* dazu. Dagegen ist in den östlichen Gebieten (z.B. Changbai Shan) eher die Dominanz von *Calamagrostis* typisch, aber auch von *Sanguisorba*. In Japan wiederum erscheinen z.B. neben den allgemein verbreiteten Gattungen der Tab. 2 vorzugsweise die Gattungen *Adenophora*, *Angelica*, *Astilbe* und *Rodgersia*, und können zusammen mit *Sasa*-Arten weite Flächen beherrschen, wo Nadelhölzer durch mechanische Faktoren (Schneedruck) benachteiligt sind. Weniger auffällig erschienen mir die Hochstaudenfluren im naßschneearmen, relativ trockenen Zentral-Sibirien (Sayan-, Baikal-Gebirge), die unsern zentralalpinen mit *Aconitum*, *Geranium*, *Heracleum*, *Ranunculus*, *Thalictrum* und *Calamagrostis* sehr ähnlich sind.

Besonders bekannt wegen Ihrer Masse sind die Hochstaudenfluren im klimatisch begünstigten südwestlichen kaukasus. in diesen üppigen, floristisch rech vertrauten Beständen kommt ein aggressiver Neubürger Mittel-Europas vor, nämlich Heracleum mantegazzianum.

Aber den Mssenrekord tragen sicherlich die von Polygonum beherrschten Krautfluren davon, die in Sacchalin und den umliegenden Inseln zu finden sind (Pietsch, mdl).

Vom gewohnten Bild stärker abweichend sind die Bestände des feuchteren Ost-Himalaya, namentlich diejenigen im Uebergangsgebiet zu den Lorbeerwäldern. Diese werden häufig von *Impatiens*-Arten mitbestimmt und in wärmeren Lagen schliesslich von immergrünen Farnen und vielen monokotylen* Gattungen (*Actaea*, *Angelica*, *Cacalia*, *Impatiens*, *Panax*, *Senecio*, *Calamagrostis**, *Roscoea**, *Sasa**, *Costus**, *Smilacina**, *Ariseama** u. a. m., *Dryopteris*, *Lastrea*, *Polystichum*, *Osmunda*) abgelöst (vgl. Tab. 2).

SCHLUSSFOLGERUNGEN

Die oft verblüffende Uebereinstimmung im Bauplan, ja auch die immer wiederkehrenden gleichen Gattungen bestätigen wieder einmal die These der Konvergenz. Einmal bewährte angepasste Strukturen setzen sich unter ähnlichen Bedingungen weltweit durch. Konvergente Erscheinungen lassen sich bis in detaillierte Muster von Bauplänen von Pflanzen, Pflanzengesellschaften und Oekosystemen nachweisen (z.B. Konvergenzen bei *Asteraceae*, *Apiaceae*, *Ranunculaceae* und ihren etwaigen vikariierenden Familien; vgl. auch Halloy 1983).

Von besonderem Interesse sind

namentlich die tropenwärtigen Grenzlagen mit sommergrünen Vertretern, die in logischer Folge bei zunehmender Wärme typische Hochstaudenfluren ablösen und zunehmend mit immergrünen Monokotylen und Farnen, sowie strauchförmigen Ericaceen durchsetzen. Besonders eindrücklich sind die Abfolgen in den Höhenstufen des östlichen Himalaya. Ebenso logisch gestalten sich die Verhaltnisse in der südlichen Hemisphäre, wo unter kühltemperierten perozeanischen Bedingungen Hochstaudenfluren durch Farnfluren bedrängt und meist abgelöst werden, öfters unter Einschluss von Baumfarnen.

Nur offene überrieselte Standorte geben hochstaudenartigen Gewächsen eine Chance (z.B. *Gunnera*), so dass unter diesen Umständen an *Petasites*-Fluren erinnernde "Rhabarberblatt-Bestände" entstehen.

Auch die eutropheren Feuchtgebiete weisen vergleichbare Strukturen auf. Indessen sind doch echte Helophyten eher verjüngend, also pagodenförmig aufgebaut, so dass der Lichtgenuss für jedes Blattstockwerk optimal ist. Im Waldschatten herrschen doch diffusere Lichtverhältnisse vor, so dass verwandte Hochstauden (*Urticaceae*, *Polygonaceae*, *Asteraceae*) ähnlich grosse Blätter wie die basalen auf der ganzen Sprosslänge entwickeln. Schliesslich kann "Nährstoff auch Wasser ersetzen" (RUEBEL 1930): Ueberdüngte gestörte Flächen (z.B. durch Tritt), feuchte Ruderalstandorte, weisen sich ebenfalls mit der Dominanz von Hochstaudenfluren aus, wie sie in ähnlicher Form in Sümpfen vorkommen (vgl. die Lägerfluren, z.B. mit *Senecio*, *Epilobium*, *Urtica*, *Polygonaceae*, teilweise mit *Artemisia*).

Alles in allem hat sich somit die Struktur der Hochstaudenflur überall dort bewährt, wo während gut 3-4 Monaten des Jahres kühltemperierte feuchte Verhältnisse herrschen, ausreichend Nährstoffe vorhanden sind und mechanische Faktoren das Aufkommen konkurrenzierender Holzpflanzen teilweise eindämmen (vgl. IMBECK und OTT 1987 für Konkurrenzverhältnisse).

Unter noch feuchteren oder trockeneren bzw. nährstoffärmeren Verhältnissen, die während der Vegetationsperiode vorherrschen müssen, ersetzen Hochgras- bzw. Büschelgras und Zwergstrauch-Fluren die breitblättrigen Bestände.

Tabelle 1 — Vorherrschende Arten und Gattungen in den einzelnen Regionen (nur aus Gebieten mit eigenen Aufnahmen)

1.1a Wolong (subalpin = sa)

Cacalia	ferner:
Cirsium	Anaphalis
Geranium	Aster
Ranunculus	Euphorbia
Sanguisorba	Gentiana
Trollius	Halemia
Apiaceae (z.B. Heracleum)	Parnassia
Leguminosae (Papilionaceae, B. Astragalus)	Potentilla
	Iris
	Polygonatum
Calamagrostis	Scilla
	Veratrum

1. 1b. Wolong (hochmontan = hm)

Aconitum (auch sa)	Rodgersia (auch sa)
Anaphalis	
Angelica	Arisaema
Aster (Heteropappus)	Smilacina
Astilbe	Streptopus
Cacalia	
Cicerbita	Athyrium
Potentilla	Dryopteris

(nach WANG LI und eigenen Aufzeichnungen; vgl. auch die übrige Literatur über Lorbeerwälder, z.B. HANELT 1963, LING und YE 1985 usw.; vgl. auch ANON. 1985)

1.2. Changbai Shan (sa)

Aconitum	Ranunculus
Adenophora	Sanguisorba
Aster	Saussurea
Cacalia	Senecio
Campanula	Thalictrum
Cirsium	Calamagrostis
Geranium	Athyrium
Heracleum	Dryopteris
Polygonum	

(nach DANERT 1960 und eigenen Aufzeichnungen)

1.3. Fuji San (sa)

Aconitum	Saussurea
Adenophora	Thalictrum
Angelica	
Cacalia	Calamagrostis

1.4. Mittel-Honshu (sa)

Adenophora	Calamagrostis
Angelica	Carex
Astilba	Sasa
Cacalia	
Cirsium	Athyrium
Conoselinum	Dryopteris
Oplopanax	Polystichum
Polygonum	
Rodgersia	
Thalictrum	

(nach Exkursionsführer MIYAWAKI *et alii* 1984 und eigenen Aufzeichnungen)

1.5. Hokkaido-S (m)

Actaea	Calamagrostis
Angelica	Sasa
Cacalia	Smilacina
Impatiens	
Panax	Dryopteris
Senecio	Lastrea
	Polystichum
	Osmunda

1.6. E-Nepal (feucht, hochmontan, also noch ziemlich stark laurophyll)

Aconitum	Dryopteris
Anaphalis	Polystichum u.v.a.m.
Cacalia	
Cirsium	ferner:
Geranium	Boehmeria
Gnaphalium	Circaea
Heracleum	Pedicularis
Impatiens	Pilea
Ligularia	Polygonum
Pleurospermum	Potentilla
Ranunculus	Sanicula
Saussurea	Senecio
Spiraea	Viola
Thalictrum	
Valeriana	Alpinia
	Clintonia
Arisaema	Costus
Carex	Smilax
Roscoea	
Smilacina	Hymenophyllaceae
Selaginella	

(nach NUMATA 1983, MALLA *et alii* 1976 und eigenen Aufzeichnungen)

1.7. Südliches zentralsibirien Baikal-Gebirge (hochmontan-subalpin) und Sayan-Gebirge (subalpin)

Aconitum	Calamagrostis
Cacalia	Carex
Crepis	Lilium
Fabaceae	Poa
Lathyrus	
Trifolium	(eher weniger Farne)
Vicia	
Geranium	ferner:
Heracleum	Epilobium
Ranunculus	Galium
Thalictrum	Polygonum
	Maianthemum
	(Vaccinium)

(nach WALTER 1975 und eigenen Aufzeichnungen)

Tab. 2 — Durchschnittszusammensetzung zentral- bis ostasiatischer Hochstaudenfluren

Dicotyledonen:	Aconitum, Cacalia, Geranium, Heracleum, Ranunculus, Saussurea, Senecio, Thalictrum
ferner:	Adenophora, Angelica, Cimicifuga, Epilobium, Galium, Impatiens, Ligularia, Pedicularis, Potentilla, Sanguisorba, Trollius, Valeriana
Monocotyledonen:	Calamagrostis, Poa , Smilacina, Bambuseen
ferner:	Carex, Lilium, Streptopus
Pteridophyten:	Athyrium, Dryopteris, Polystichum
ferner:	Lastrea
z.T. Lianen:	Clematis, Rubus, Smilax
z.T. Zwergsträucher:	Gaultheria Vaccinium
Kleinwüchsige:	Apiaceae, Ranunculaceae, Asteraceae, Rosaceae, Ericaceae, Rubiaceae, Gentianaceae, Onagraceae, Cyperaceae, Oxalidaceae, Poaceae, Liliaceae

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THE OAK FOREST IN NORTH CHINA

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Key words: Oak, Distribution, Life form

The oak forest is a zonal vegetation type in the warm-temperate deciduous broad-leaved forest region between 32° 30' - 42° 30' N and 103° 30' - 124° 10' E including parts of the provinces Liaoning, Hebei, Shanxi, Henan, Shaanxi, Gansu, Anhui, Jiangsu and province Shandong, Beijing, Tianjin (Editing Commitee of Vegetation of China, 1980).

The climate in the region is warm and subhumid. The annual mean temperature is 8° - 14° C, gradually increasing from north to south (Fig. 1). The mean temperature of the coldest month ranges from -13° to -2° C with a minimum temperature of -30° C. The mean temperature of the warmest month reaches 25°-28° C with a maximum temperature of 40° C. The frost-free period is about 150-230 days, vastes from north to south and from west to east. The annual precipitation is about 600-900 mm, decreasing from southest to northwest. The seasonal distribution of precipitation is uneven. The precipitation in winter and spring accounts for only 3-7% and 10-14% of the total amount of precipitation respectively. The rainfall is the most abundant during the summer. During this time nearly 60-70% of the total precipitation falls. Usually, it is dry from October to April and wet from May to September. The climate of the Liaodong Peninsula and the Jiaodong Peninsula such as Dalian and Qingdao is warmer with a longer frost-free period and higher moisture than in other areas in the same latitude.

The natural oak forest in the plain were destroyed by human disturbance. The oak forests on the hills and mountains have had a long and continuing history of cutting, burning, grazing and are highly modified; though many have regenerated spontaneously, some have been planted. Most oak forests have a coppice structure with trees and shrubs of either uniform or varying age. So oak forests are only sporidically present on the hills and mountains in north China.

Oak forests mainly consist of medium sized trees, characterized by a dominance of deciduous broad-leaved species whose leaves are shed in winter. The dominant trees are virtually all species of *Quercus*, such as *Quercus mongolica*, *Q. liaotungensis*, *Q. aliena*, *Q. variabilis*, *Q. dentata*, *Q. acutissima*, *Q. glandulifera* var. *brevipetiolata*, *Q. aliena* var. *acuteserrata*, *Q. baronii*. The last one is a semievergreen species.

THE DISTRIBUTION AND CHARACTERISTICS OF OAK FORESTS

The distribution of the various oak forests depends on climatic (Fig. 2) and edaphic factors.

Quercus mongolica forest as a dominant vegetation type is present in the northern part of the warm-temperate broad-leaved deciduous forest region including the hills and lower mountains between about 200 and 700 m in the eastern and southwestern parts of Liaoning Province (Dong, 1985) and the mountains about 800m above sea level in the northeastern part of Hebei province. The annual mean temperature in this part is 7°-9° C with a short frost-free period; it also occurs on the hills in the eastern part of Shandong province as small scattered stands.

Quercus mongolica is a constructive species in this type of oak forest. *Quercus liaotungensis*, *Fraxinus rhynchophylla*, *Celtis koraiensis*, *C. bungeana*, *Acer truncatum* as prominant subordinate trees are mixed in the overstorey, *Quercus dentata*, *Q. variabilis*, *Q. aliena*, *Betula dahurica*, *Ulmus macrocarpa*, *Populus davidiana*, *Tilia amurensis*, *T. mongolica* sometimes also appear the evergreen conifer *Pinus tabulaeformis* occurs as an admixture in the overstorey, *Pinus densiflora* appears in the *Quercus mongolica* forests located in the Liaoning Peninsula.

The deciduous shrubs, e.g. *Lespedeza bicolor*, *Spiraea trilobata*, *S. pubescens*, *Corylus heterophylla*, *Rhododendron mucronulatum* are dominants of the understorey in the different microhabitats, but some kinds of shrub, such as *Lindera obtusiloba*, *Symplocos paniculata*, *Zanthoxylum schinifolium*, *Rhus chinensis* are found only in *Quercus mongolica* forests on the hills of the Liaodong Peninsula. A part from these species, *Armeniaca sibirica*, *Andrachne chinensis*, *Myripnois dioica*, *Lespedeza floribunda* frequently present.

There is a ground cover consisting of sedges and herbs. Dominants *Carex lanceolata*, *C. siderostica* and associated herbs *Sanguisorba officinalis*, *Convallaria keiskei*, *Polygonatum odoratum*, *Cacalia aconifolia* and grasses *Spodiopogon sibiricum* etc. constitute a well developed ground layer.

Quercus mongolica forest is widespread over the northeast temperate mixed coniferous and deciduous forest region in China.

Quercus liaotungensis forest extends over large areas of the warm-temperate deciduous broad-leaved forest region, but is mainly present in the middle part of the region (Zhu, 1982; Chen, 1985). From north to south the elevation of the oak forest gradually increases. The oak forest occurs on the hills at altitudes of 80-600 m in the northern part, on the mountains at 500m or 1000m to 1700m in the middle part of the region, attaining its maximum altitude of 1800-2300 m on the northern slope of the western section of the Qinling mountains at the transition between warm-temperate deciduous broad-leaved forest and subtropical evergreen broad-leaved forest region. *Quercus liaotungensis* forest displays a diversity of species in the tree, shrub and ground layers. *Quercus liaotungensis* is a constructive species. The composition and structure of this oak forest is similar to *Quercus mongolica* forest, but there are more trees, such as *Ulmus davidiana*, *U. propinqua*, *Maackia amurensis*, *Juglans mandshurica* growing in the overstorey of *Quercus liaotungensis* forest in the northern part of the region. *Quercus aliena* var. *acuteserrata*, *Rhus verniciflua*, *Acer ginnala* are restricted to the southern part of the region due to the warm climate with a long frost-free period.

Pinus tabulaeformis and *Platycladus orientalis* occasionally are mixed in the overstorey. *Pinus armandii* is only present in the oak forest occurring in the southwestern part of the region.

Quercus liaotungensis forest has shrubs in common with those in *Quercus mongolica* forest. Besides these, the understorey may also be dominated by *Spiraea frischiana*, *Ostryopsis davidiana*, *Elaeagnus umbellata*, *Rosa hugonis* and *Sinarundinaria nitida* - a shrub bamboo with a lot of accompanying species - *Abelia biflora*, *Deutzia grandiflora*, *Campylotropis macrocarpa*, *Rhododendron micranthum*, *Rhamnus globosa*, *R. parvifolia*, *Cotoneaster multiflorus*, *C. zebelii* in the different sites.

Carex lanceolata, *C. siderosticta*, *C. humilis* var. *nana* dominate in the ground layer. There is a variety of herbs and grasses associated with sedges, for example, *Bupleurum pekinensis*, *B. falcatum*, *Atractylodes chinensis*, *Convallaria keiskei*, *Rhaponticum uniflorum*, *Scorzonera glabra*, *Vicia unijuga*, *Potentilla chinensis*, *Sedum aizoon*, *Polygonatum sibiricum*, *Sanguisorba officinalis*, *Cleistogenes squarrosa*, *C. caespitosa*, *Spodiopogon sibiricus*, *Arundinella hirta*, *Selaginella sinensis* often covers the ground.

Toward the west, this type of oak forest may penetrate into the mountains of the temperate forest-steppe region in China.

Quercus aliena forest is the major

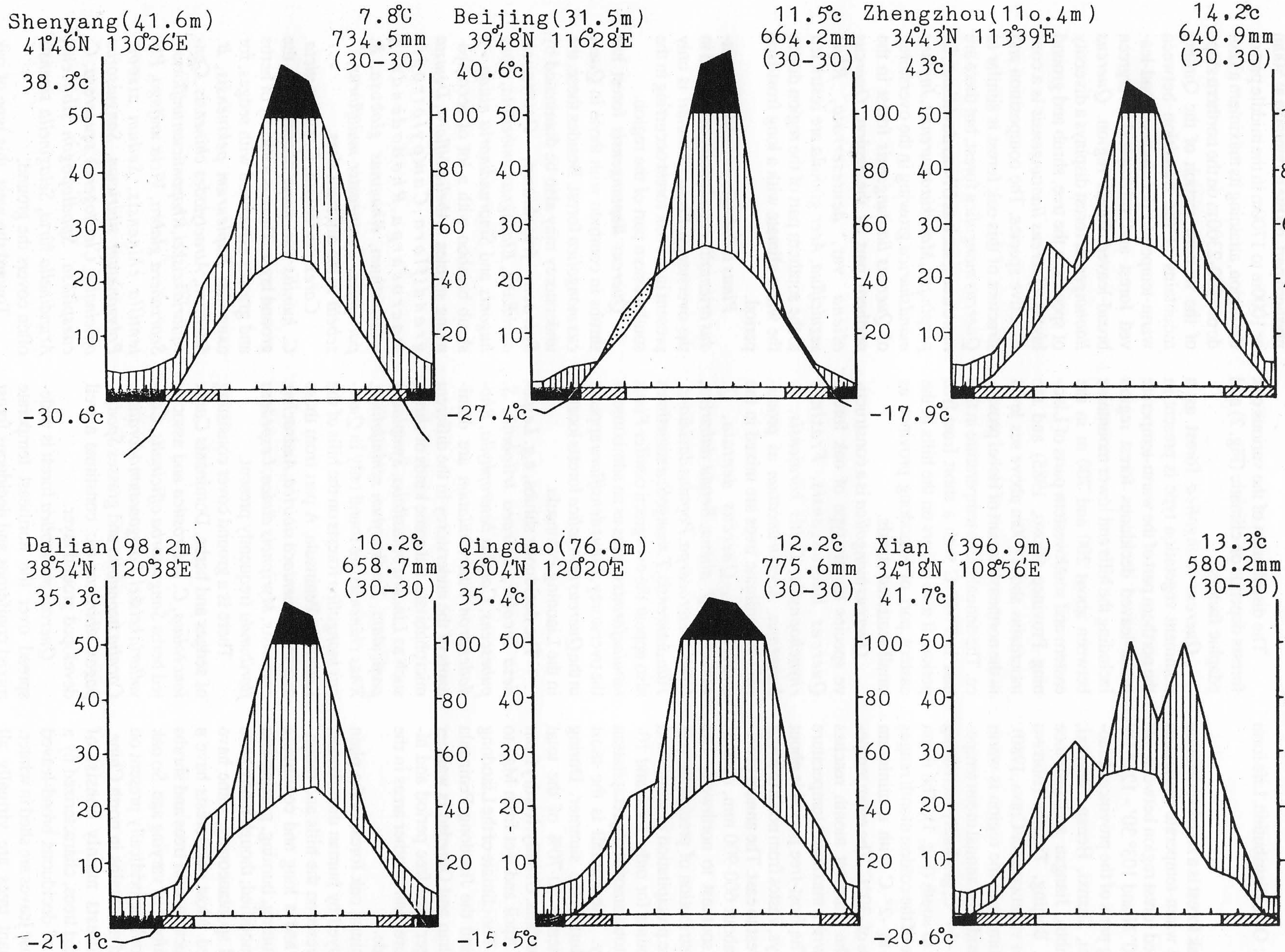

Fig. 1 — The Climayograph of Warm-temperate Deciduous Broad-leaved forest region.

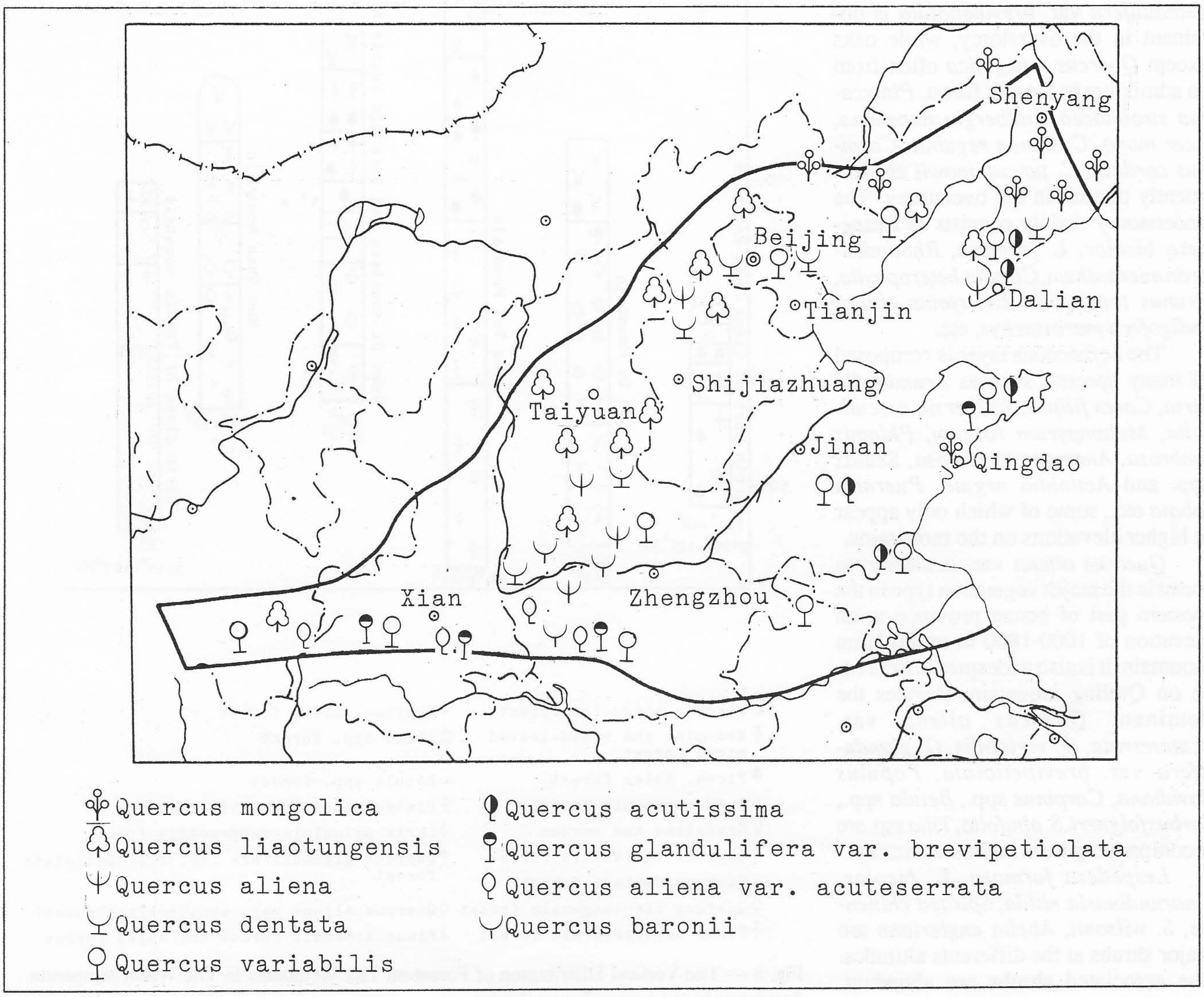

Fig. 2 — The Distribution of Oak Forests in North China.

vegetation type on the mountains at an elevation of 1000-1500 m in the southern part of the region. In the central part *Quercus aliena* forest appears at 600-1350 m, while to the north it is found at an altitude of 150-600 m. *Quercus aliena* forest has scattered stands in these two parts of the region.

Quercus aliena is a constructive species in this oak forest, its floral composition is close to the above-mentioned types of oak forests. *Pistacia chinensis*, *Quercus glandulifera* var. *brevipetiolata* are restricted to the oak forest in the southern part of the region.

Vitex chinensis, *Armeniaca sibirica*, *Spiraea tribolata* and *Carex humilis* var. *nana* dominate the shrub and herbaceous layers respectively. The accompanying shrubs, herbs and grasses are similar to the *Quercus liaotungensis* forest; besides these, *Cotinus coggygria* var. *cinerea* and *Evonymus* ssp. are frequent species in the shrub layer.

Quercus variabilis forest is found all over the warm-temperate deciduous broad-leaved forest region, but mainly appears on the mountains at 400-1500 m above sea level in the southern part and on the hills of the central part of the region. It is also present on the hills of Liaodong and Jiaodong Peninsula. Various oak species and *Ailanthus altissima*, *Koelreuteria paniculata*, *Morus mongolica* etc. are occasionally mixed in the oak forest. *Dalbergia hupehana*, *Rhus chinensis*, *Albizia kalkora*, *Quercus baronii*, *Melia azedarach* and several shrubs - *Forsythia suspensa*, *Lindera obtusifolia*, *Symplocos paniculata*, *Zanthoxylum schinifolium* are restricted to *Quercus variabilis* forest distributed in the Peninsula or southern part of the region. Most of the shrubs are similar to components in *Quercus aliena* forest, but *Grewia biloba* var. *parviflora*, *Leptodermis oblonga* appear frequently in the understorey of the oak forest.

Carex humilis var. *nana*, *Bothriochloa ischaemum* are dominants in the ground layer. *Themeda trianda* var. *japonica*, *Arthraxon hispidus*, *Setaria viridis* and other grasses as well as *Platycadon grandiflorum* and *Codonopsis lanceolata* are present as associated components in the ground layer.

Quercus dentata forest is of limited extent at the lower altitude in the warm-temperate deciduous broad-leaved forest region. The floristic composition is close to *Quercus aliena* forest in the northern part and close to *Quercus variabilis* forest in the central and southern parts of the region.

Quercus acutissima forest appears on the hills and low mountains. It is the major vegetation type in the eastern part of Shandong Province, while also present in the Liaodong Peninsula. In the southern part of the region *Quercus acutissima* forest is distributed on the mountain slopes below 1000 m. There is a similarity in floristic composition and structure between *Quercus acutissima* and *Quercus variabilis* forests.

Quercus glandulifera var. *brevipetiolata* forest as a vertical belt is present on Fu Hiun mountain at an elevation of 1000-1300 m, forming a transitional belt between *Quercus variabilis* and *Quercus aliena* var. *acuteserrata* forest belts in the western part of Henan Province. It rarely appears below 400 m in altitude in the Jiaodong Peninsula. *Quercus* *glandulifera* var. *brevipetiolata* is dominant in the overstorey, while oaks except *Quercus mongolica* often from an admixture in the oak forest. *Platycarya strobilacea, Dalbergia hupehana, Acer mono, Castanea seguinii, Carpinus cordata, C. turczaninowii* are frequently present in the overstorey. The understorey mainly consists of *Lespedeza bicolor, L. formosa, Rhododendron micranthum, Corylus heterophylla, Prunus tomentosa, Evonymus alatus, Indigofera marostachys*, etc.

The herbaceous layer is composed of many species, such as *Arundinella hirta, Carex filipes, Rodgersia aesculifolia, Melampyrum roseum, Phlomis umbrosa, Anemone tomentosa, Smilax* spp. and *Actinidia arguta, Pueraria lobata* etc., some of which only appear at higher elevations on the mountains.

Quercus aliena var. *acuteserrata* forest is the major vegetation type in the western part of henan province at an elevation of 1000-1800 m on Fu Hiun mountain; it is also widespread occurence on Qinling mountain. Besides the dominant *Quercus aliena* var. *acuteserrata, Q. variabilis, Q. glandulifera* var. *brevipetiolata, Populus davidiana, Carpinus* spp., *Betula* spp., *Sorbus folgneri, S. alnifolia, Tilia* ssp. are accompanying tress in the overstorey.

Lespedeza formosa, L. bicolor, Sinarundinaria nitida, Spiraea chinensis, S. wilsonii, Abelia engleriana are major shrubs at the differents altitudes. The associated shrubs are abundant. Besides the shrubs and herbs which are similar to those in the above-mentioned oak forests, there are *Buckleya lanceolata, Philadelphus incanus, Cotinus coggygria, Forsythia suspense, Cotoneaster* spp., *Lonicera* spp., *Viburnum* spp. in the shrub layer.

Quercus baronii forest is only present in the western part of Henan Province and the southern part of Shanxi Province with only a very limited area on the mountains at an elevation of 900-1400 m. *Quercus baronii* often mixed with *Carpinus turczaninowii* are codominants. *Carpinus cordata, Quercus variabilis, Q. aliena, Pinus tabulaeformis, P. armandii, Acer* spp. occasionally occur in the overstorey. The composition and structure of the *Quercus baronii* forest are close to the *Quercus aliena* var. *acuteserrata* forest but have fewer species.

At presaent *Quercus variabilis, Q. altissima* and *Q. baronii* forests are widely distributed in the subtropical evergreen broad leaved forest region of China.

Fig. 3 shows the vertical distribution of forests on the mountains at different latitudes in the warm-temperate deciduous broad-leaved forest region.

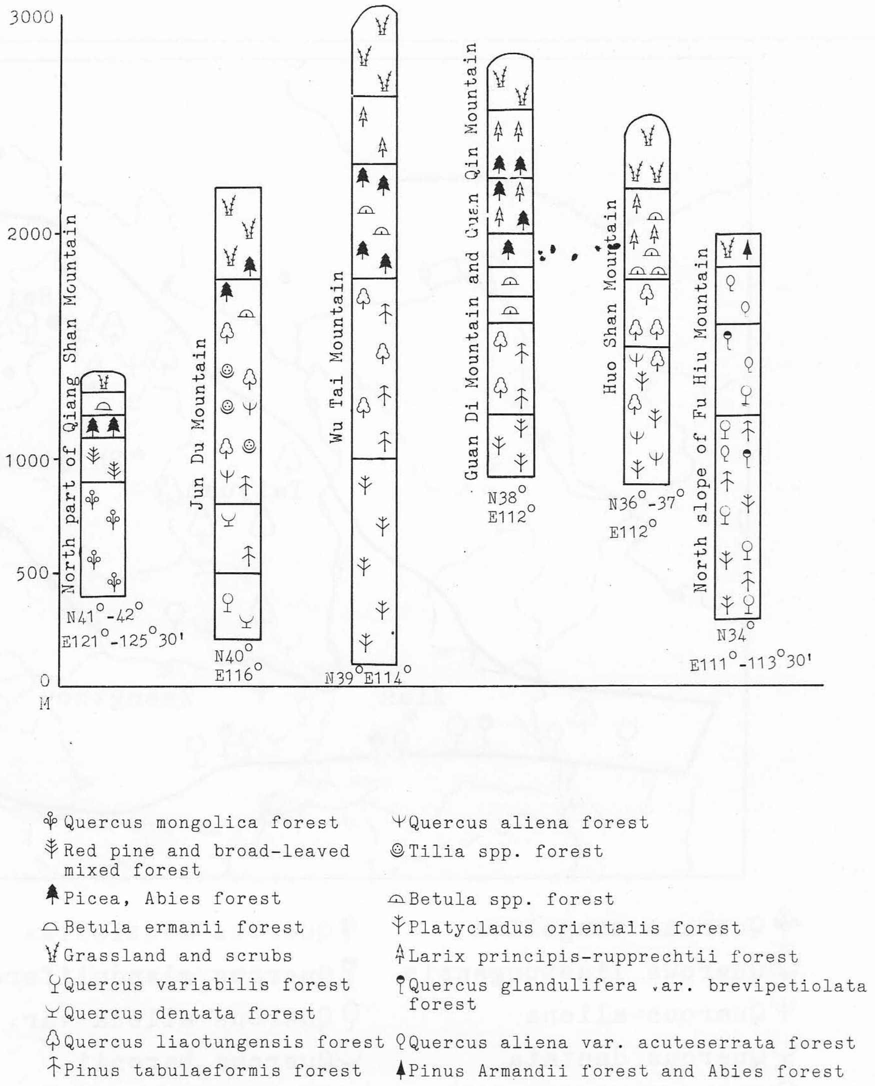

Fig. 3 — The Vertical Distribution of Forest on The Mountains in The Warm-temperate deciduous broad-leaved Forest Region.

THE FLORA AND LIFE FORMS OF THE OAK FOREST

The flora of the oak forest in northen China consists of northern temperate elements (Editing Committee Physical Geography of China, 1983), sauch as *Quercus, Fraxinus, Acer, Betula, Spiraea, Tilia, Ulmus, Carpinus, Pinus, Corylus, Rhododendron, Morus, Arundinella, Lonicera, Cotoneaster, Sanguisorba, Deyeuxia* and *Convallaria, Polygonatum, Caragana, Campylotropis* and *Armeniaca* belong to the temperate Asiatic element. The oak forest also comprises EasternAsiatic elements (*Platycladus, Platycarpa, Sinarundinaria, Leptodermis, Deutzia, Codonopsis, Actinidia*, etc.) and Old World temperate elements (*Cleistogenes, Syringa, Forsythia* etc.). Some tropical elements are also present in the oak forest, such as tropical-Asian and tropical-African elements (*Themeda* and *Arthraxon*), Pan-tropical elements (*Dalbergia, Celtis, Zanthoxylum, Symplocos, Vitex, Evonymus* and *Bothriochloa*). Species of Compositae, Rosaceae, Gramineae and Leguminosae are very abundant in the oak forest, but the plants playing the predominant role are *Quercus* spp. along with some deciduous trees of Aceraceae, Tiliaceae, Ulmaceae, Betulaceae and Oleaceae. The oak forest also contains an admixture of evergreen coniferous trees, such as *Pinus tabulaeformis* and *Platycladus orientalis*. According to Icon. Corm. Sin (1972) Fl. Reip. Chin (1978) is *Pinus densiflora* present in both Shantgdong and Liaoning peninsula and *Pinus armandii* mixed with oak only appears in the southwestern part of the region. The species of Rosaceae and Leguminosae are very rich in the shrub stratum. The shrubs of Ericaceae (*Rhododendron*), Caprifoliaceae, (*Lonicera, Viburnum*), Rhamnaceae (*Rhamus*) and Verbenaceae (*Vitex*) are also frequent. The dominant or frequent species in the herbaceous stratum are mostly Cyperaceae and Gramineae, such as *Carex, Cleistogenes, Arundinella, Spodiopogon, Bothrichloa, Themeda*, etc. The herbs of Compositae, Ranunculaceae, Campanulaceae although rich in species, have, with the exception of *Artemisia*, not made a great contribution to the plant community.

The different types of the oak fores show a similar spectrum of life forms. The spectra of the life forms of oak forests in Beijing can be taken as a good example to demonstrate the general characteristicsof life forms in the oak forest. Depending on the habitat and human disturbance hemicryptophytes or phanerophytes in the oak forest prove to be the most abundant life forms. Phanerophytes, especially mesophanerophytes always play the most important role in the overstorey which possesses both mesophylls and microphylls. Usually, several species of nanophanerophytes are codominants in the undrstorey mainly with microphyllous leaves. The hemicryptophytes are the richest in the ground layer, some of thembeing dominants. The geophytes are less common than hemicryptophytes. The chamaephytes comprise only a few species, but sometimes they occur in dense stands. There are plenty of microphyllous plants in the oak forest. Fig. 4 and 5 illustrate the spectra of life forms and leaf size of oak forests on the mountains of Beijing.

Nowadays, due to human disturbances the oak forests occupy a very limited area on the mountains. Nonetheless, they still make a great contribution to water and soil conservation and improvement of since they have been destroyed by cutting and displaced by pure coniferous plantations. The oak is not only native to northern China, but can be used as an excellent silvicultural species for the restoration of forests on the mountains.

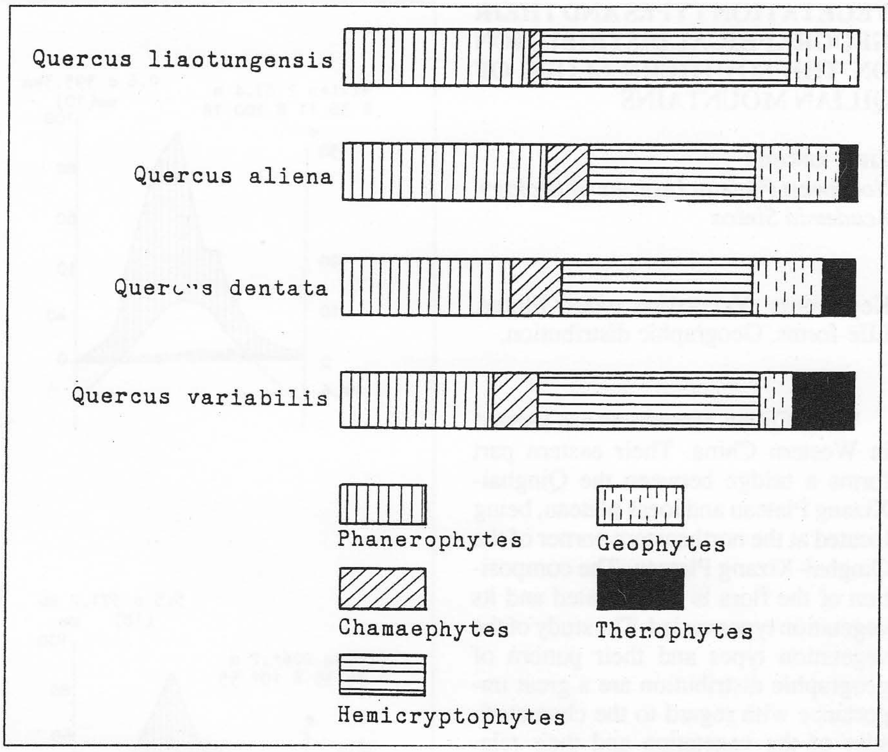

Fig. 4 — The Spectra of Life Form in Oak Forests.

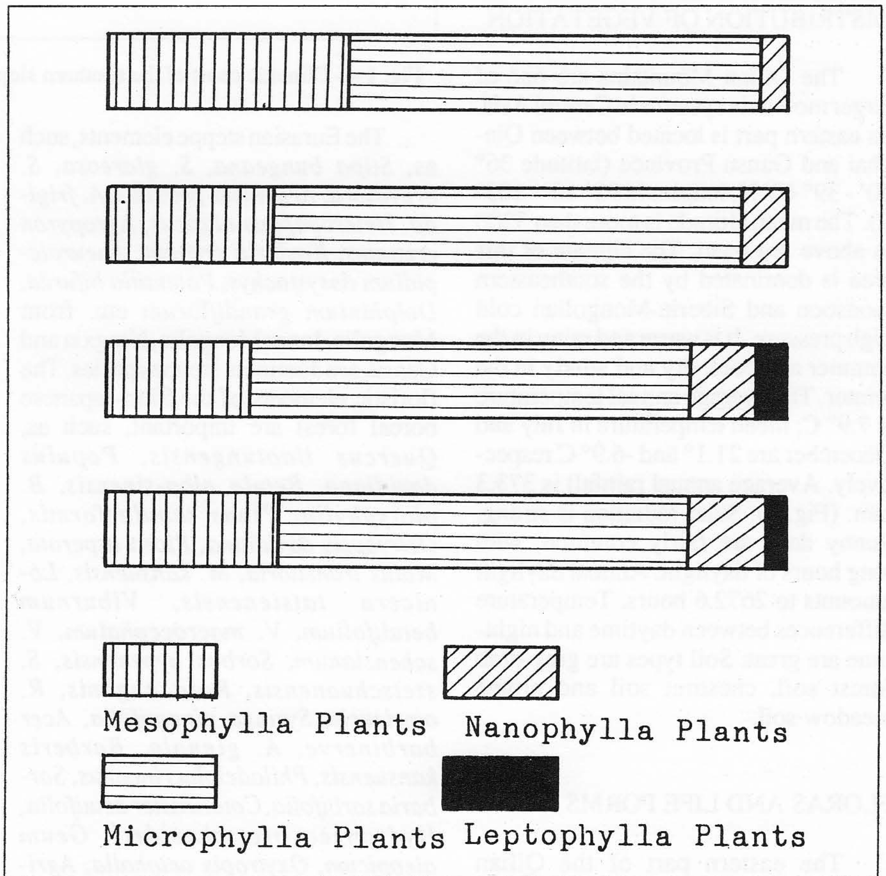

Fig. 5 — Leaf Size of Plants in Oak Forests.

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VEGETATION TYPES AND THEIR GEOGRAPHICAL DISTRIBUTION ON THE SOUTHERN SLOPE OF QILIAN MOUNTAINS

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Key words: Vegetation types, Floras, Life-forms, Geographic distribution.

The Qilian Mountains are located in Western China. Their eastern part forms a bridge between the Qinghai-Xizang Plateau and loess plateau, being located at the northeastern corner of the Qinghai-Xizang Plateau. The composition of the flora is complicated and its vegetation types varied. The study of the vegetation types and their pattern of geographic distribution are a great importance with regard to the characteristics of the vegetation and their relationship with contiguous zoner, and will provide a scientific basis for regional vegetation in China.

ENVIRONMENTAL CONDITIONS AFFECTING THE GROWTH AND DISTRIBUTION OF VEGETATION

The Qilian Mountains are one of larger mountain systems in Central Asia. Its eastern part is located between Qinghai and Gansu Province (latitude 36° 20' - 39° 40' N, longitude 98° 10' - 103° E). The mean altitude is more than 3200 m above sea level. The climate of this area is dominated by the southeastern monsoon and Siberia-Mongolian cold high pressure. It is warm and rainy in the summer and cold, dry and windy in the winter. The average annual temperature is 7.9° C; mean temperature in July and December are 21.1° and -6.9° C respectively. Average annual rainfall is 373.3 mm. (Fig. 1). Solar radiation is strong. Sunny days are fairly common, with long hours of daylight. Annual daylight amounts to 2672.6 hours. Temperature differences between daytime and nighttime are great. Soil types are gray-drab forest soil, chestnut soil and alpine meadow soil.

FLORAS AND LIFE FORMS

The eastern part of the Qilian Mountains is located at the cross roads of the Eurasian steppe zone, the Asian-African desert zone and the alpine vegetation regions of the Qinghai-Xizang plateau. It is a place where a number of different floristic elements meet.

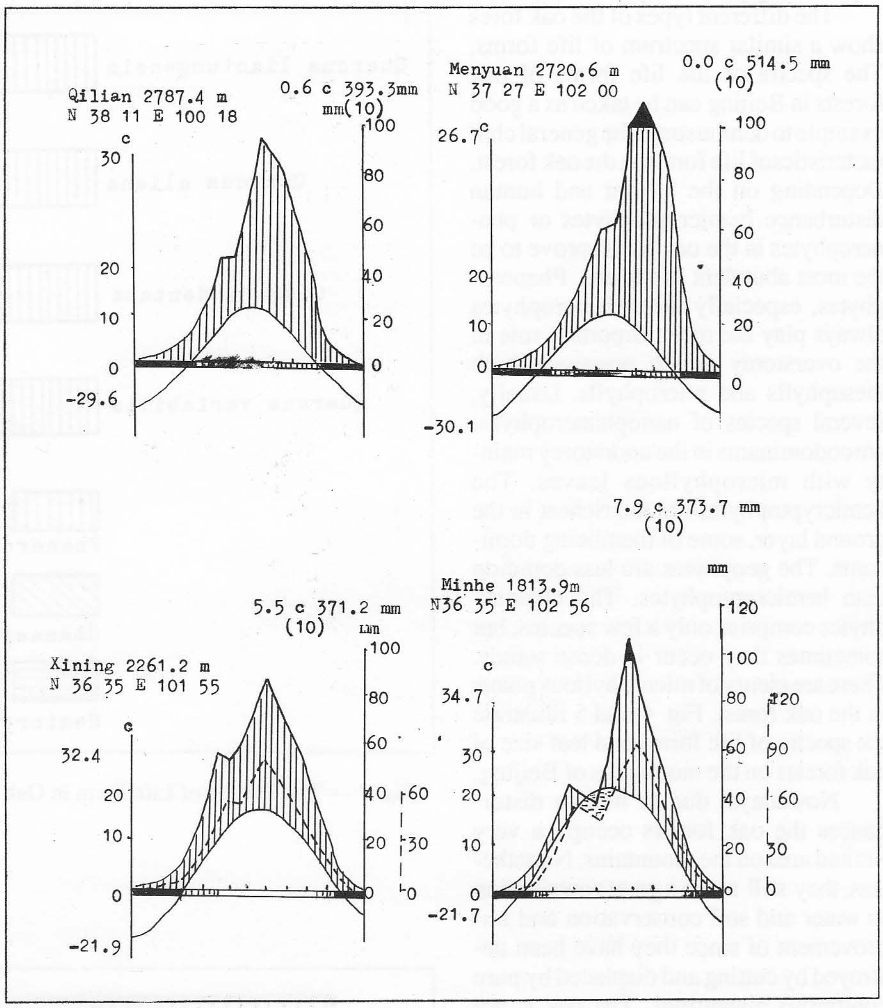

Fig. 1 — Climatic chart of the southern slope of the Qilian Mountains.

The Eurasian steppe elements, such as, *Stipa bungeana*, *S. glareosa*, *S. breviflora*, *Artemisia gmelinii*, *A. frigida*, *Heteropappus altaicus*, *Agropyron cristatus*, *Koeleria cristata*, *Aneurolepidium dasystachys*, *Potentilla bifurca*, *Delphinium grandiflorum* etc. from Mongolia, Inner Mongolia, Ningxia and Gansu, are dominant steppe species. The floristic elements of the Sino-Japanese boreal forest are important, such as, *Quercus liaotungensis*, *Populus davidiana*, *Betula alba-sinensis*, *B. platyphylla*, *Pinus tabulaeformis*, *Ostryopsis davidiana*, *Picea asperata*, *Malus transitoria*, *M. kansuensis*, *Lonicera tatsienensis*, *Viburnum betulifolium*, *V. macrocephalum*, *V. schensianum*, *Sorbus hypenensis*, *S. szetschuanensis*, *Rosa hugonis*, *R. omeiensis*, *Syringa pinnatifolia*, *Acer barbinerve*, *A. ginnala*, *Barberis kansuensis*, *Philadelphus incanus*, *Sorbaria sorbifolia*, *Cotoneaster acutifolia*, *Hydrangea bretschneideri*, *Geum aleppicum*, *Oxytropis aciphalla*, *Agrimonia pilosa*, *Sanguisorba officinalis*, *Fargesia spathacea*, *Clintonia udensis*, *Paris polyphylla*, *P. verticillatum*, *Convolvulus tragacanthoides* etc. *Quercus liaotungensis*, *Populus davidiana*, *Betula alba-sinensis* and *P. platyphylla* are typical of the deciduous broad-leaf forest. *Pinus tabulaeformis* forest and *Ostryopsis davidiana* scrub and typical vegetation of evergreen coniferous forest and temperate deciduous broadleaf scrub in Northern China. Subtropical floristic elements such as are: *Pinus armandii*, *Lindera umbellata*, *Podophyllum emodi* var. *chinensis*, *Aralia chinensis*, *Juniperus formosana*, *Cornus alba*, *Smilax vaginata*, *Dioscorea nipponica* only appear in the warmer parts. On mountains higher than 3200 m floristic elements are alpine-artic and Sino-Hymalayan elements such as *Potentilla fruticosa*, *Salix oritrepha*, *Rhododendron thymifolium*, *Rh. capitatum*, *Caragana jubata*, *Kobresia pygmaea*, *K. humilis*, *K. capillifolia*, *K. tibetica*, *Polygonum viviparum*, *P. sphacrostachyum*, *Gentiana algida*, *Arenaria kansuensis* etc. They are dominant in the alpine deciduous broadleaf scrub, alpine evergreen broadleaf scrub and alpine meadow.

According to the system of RAUNKIAER (1937), the plants of this area belong to phanerophytes, chamaephytes, hemycriptophytes and geophytes, with geophytes and hemicryptophytes being the most important (Fig. 2).

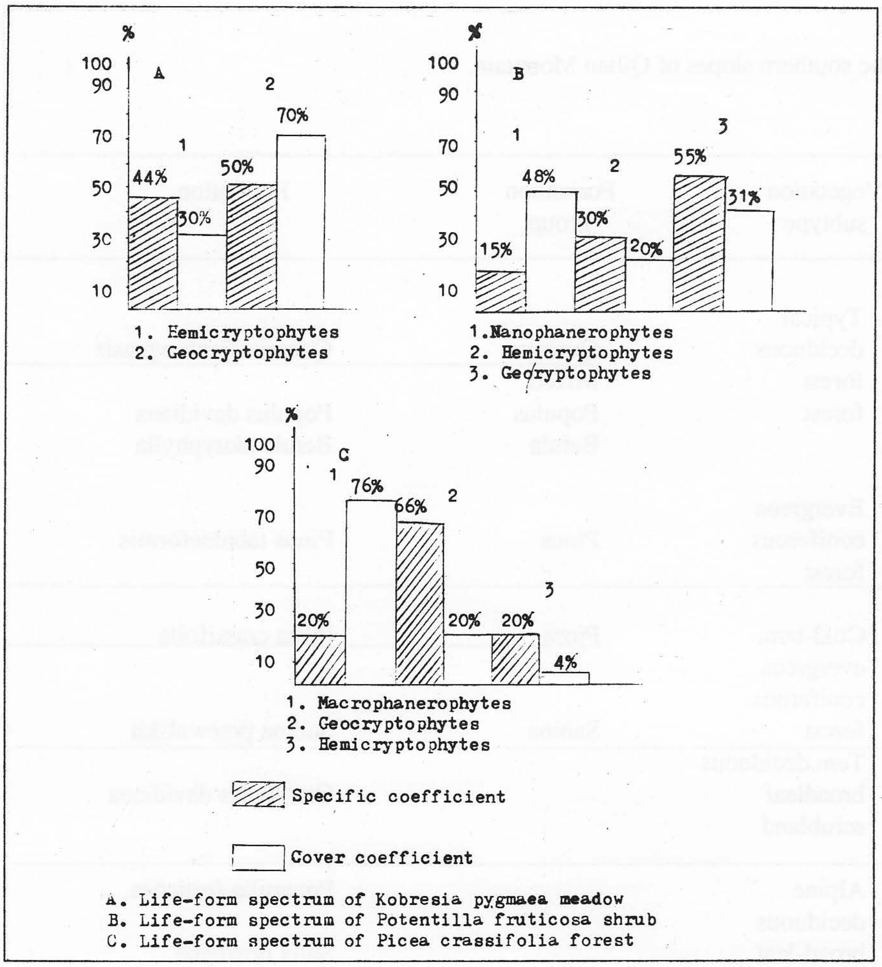

Fig. 2 — Life-form spectrum of vegetation types at eastern part of Qilian Mountain.

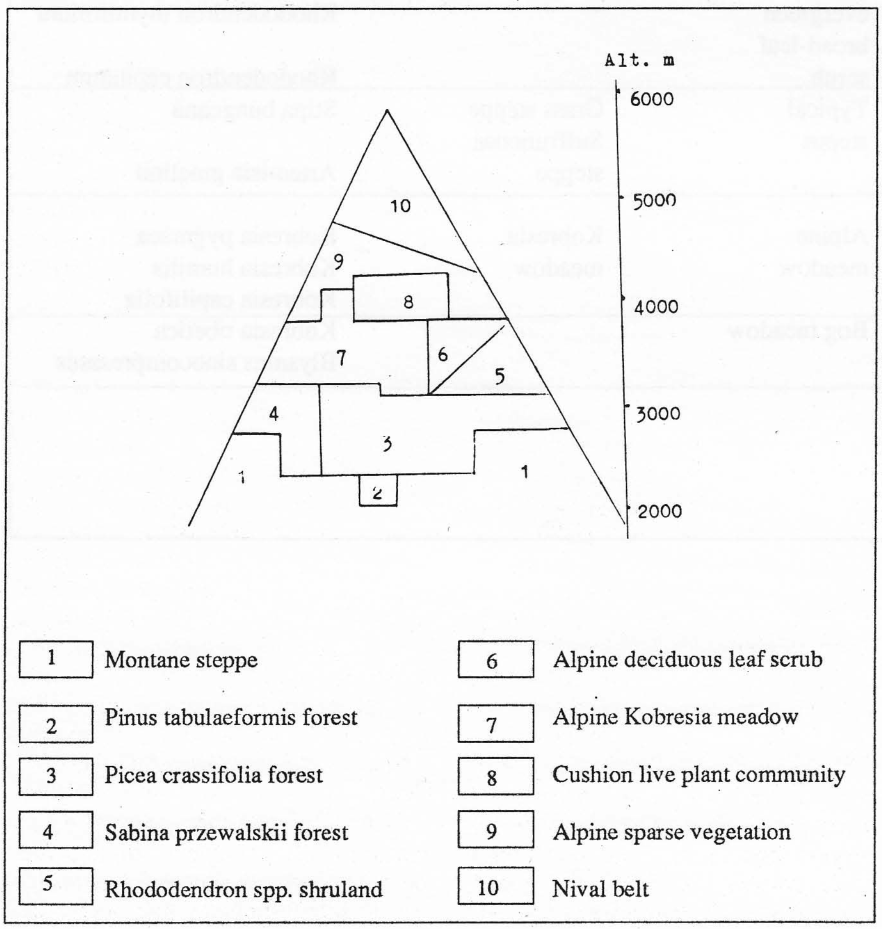

Fig. 3 — Vertical distribution of vegetation in the eastern part of the Qilian Mountains.

VEGETATION TYPES

Based on community physiognomy, synusial structure and life forms of dominant ecological factors and vegetation types in the area the following types can be recognized (Table 1). The vegetation types in the area are very complex. The deciduous broadleaf forests and the temperate coniferous forests are found in the eastern part of the Qilian Mountains, where they occupy a very limited area. The former represents the extention of the deciduous broadleaf forest zone in North China. There is steppe on both sides along the valleys on the Datong, Huang and Yellow Rivers. This indicates that the area is part of the Eurasian steppe zone on the mountains over 3200 m. Alpine shrub and alpine meadow are found. They are related in vegetation on the Qinghai Xizang and high mountains in Central Asia.

GEOGRAPHIC DISTRIBUTION PATTERNS OF VEGETATION.

The most prominent feature of vegetation geographic patterns in the eastern part of the Qilian Mountains is its vertical distribution. The structure of vertical belt spectra is shown in Fig. 3. Its basal belt consists of steppe. The forest vegetation is restricted in its distribution and does not form a complete belt. The vegetation on the southern slopes of the Qilian Mountains should be considered as belonging to the Eurasian steppe.

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Table 1. — Vegetation types on the southern slopes of Qilian Mountain.

Vegetation type	Vegetation subtype	Formation group	Formation
Deciduous broadleaf forest	Typical deciduous forest forest	Quercus	Quercus liaotungensis
		Mixed Populus Betula	Populus davidiana Betula platyphylla
Temperate coniferous forest	Evergreen coniferous forest	Pinus	Pinus tabulaeformis
Cold-tem. coniferous forest	Cold-tem. evergreen coniferous forest	Picea	Picea crassifolia
		Sabina	Sabina przewalskii
Deciduous broad-leaf scrubland	Tem.deciduous broadleaf scrubland		Ostryopsis davidiana
	Alpine deciduous broad-leaf scrub		Potentilla fruticosa Salix oritrepha
Evergreen broad-leaf	Alpine evergreen broad-leaf scrub		Rhododendron thymifolium Rhododendron capitatum
Steppe	Typical steppe	Grass steppe Suffruticosa steppe	Stipa bungeana Artemisia gmelinii
Meadow	Alpine meadow	Kobresia meadow	Kobresia pygmaea Kobresia humilis Kobresia capilifolia
	Bog meadow		Kobresia tibetica Blysmus sinocompresssus
Cushion plant community Alpine sparse vegetation			

FLORISTIC CHARACTERISTICS OF MOUNTAIN VEGETATION IN BEIJING-TIANJING REGION IN CHINA

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Key words: China, Mountain vegetation, Flora, Distribution patterns, Origin.

GEOGRAPHICAL BACKGROUND OF VEGETATION AND FLORA AND ALTITUDINAL VEGETATION BELTS IN BEIJING-TIANJING MOUNTAIN AREA

Beijing and Tianjin mountain area, a part of Taihangshan and Yanshan ranges, lies between 39° 23' and 41° 05' N, 115° 30' and 117° 42' E. They occupy the eastern border on the Eurasian continent, the north-western part of N. China plain with an area of about 13,900 km². These ranges were built during the Yanshan movement in the Mesozoic Era and uplifted again during the Himalayan orogeny. Most of the mountains are about 1,000-1,500 in altitude with a few peaks over 2,000 m. Around them, there are lower mountains and hills as little as 100-200 m high, as well as some basins and broad valleys.

The climate of this region is continental warm-temperate monsoon being more arid than Europe, Japan and N. America in homologous vegetation zone. Characteristic are the rainy summer, cold winter and spring with a more or less pronounced arid period. The montane climate is cool and humid and displays an obvious vertical change. The mean annual temperature is generally less than 10° C and total annual precipitation is between 500 and 800 mm (see Fig. 1).

The zonal vegetation consists of broad-leaved deciduous forests belonging to the warm-temperate zone of China. They are mainly composed of xerophilous *Quercus* and *Pinus* without the *Fagus* typical at Europe, Japan and N. America. Altitudinal vegetation belts are as follows:

a) Subalpine meadow and scrub belt.
Alt. 2,000 (2,200) - 2,300 m

b) Montane cool-temperate needle-leaved forest belt.
Alt. 1,500-2,000 (2,200) m

c) Montane temperate needle and broad leaved mixed forest belt.
Alt. 1,200-1,500 m

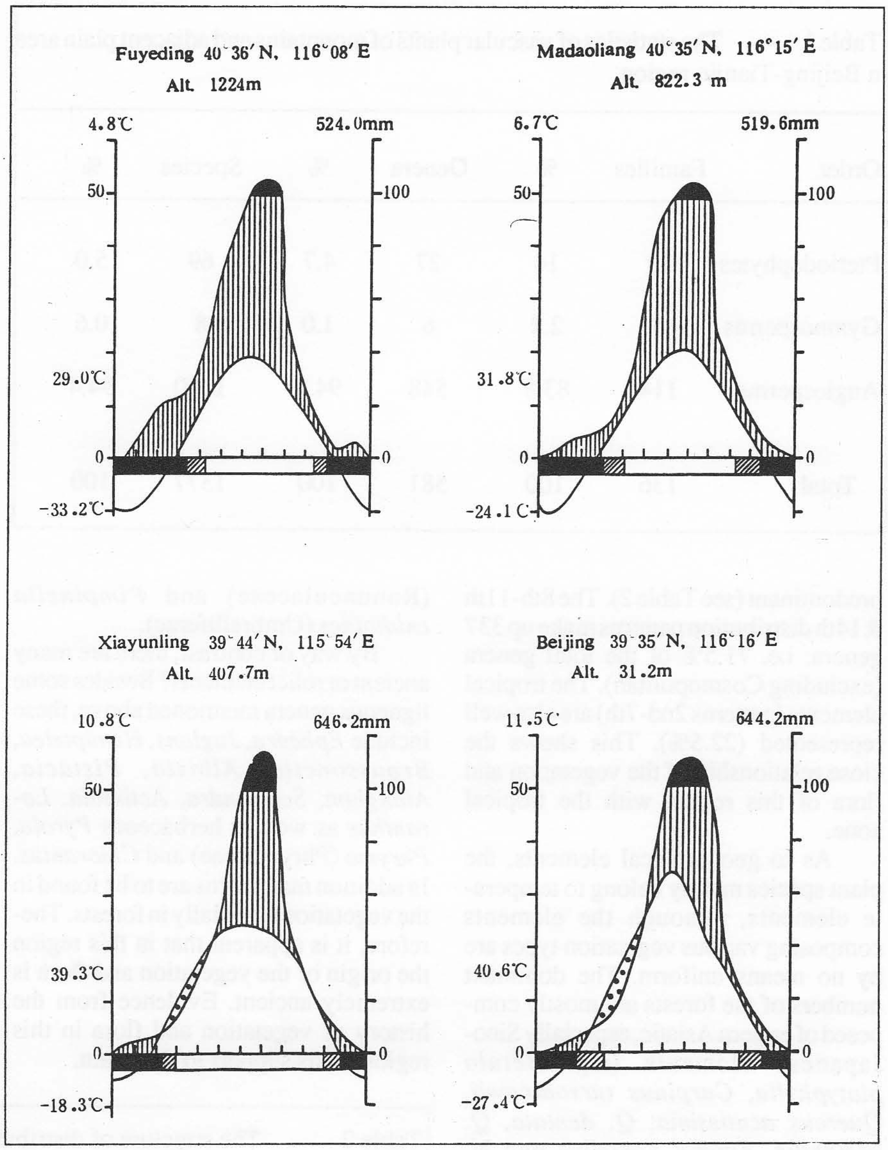

Fig. 1 — The climate diagrams in Beijing-Tianjin mountain area (according to H. Walter's method).

d) Montane temperate broad-leaved deciduous forest belt.
Alt. 800-1,200 m

e) Lower montane and hilly warm-temperate broad-leaved deciduous forest belt with needle broad-leaved mixed forest.
Below Alt. 800 m

THE FLORISTIC CHARACTERISTICS OF VEGETATION

The floristic characteristic of vegetation in this mountains area may be described as follows:

a) Plant species are very numerous. Natural vascular plants in the mountains and adjacent plain area include 136 families, 581 genera and 1377 species representing about 5.1% of all Chinese species (see Table 1). Every type of vegetation includes about 40-50 families and 150-200 species.

The principal families are Compositae (51 gen./136 spp.), Gramineae (61/119), Leguminosae (24/75), Cyperaceae (10/69), Rosaceae (11/67), Ranunculaceae (15/56) and so on in order. Mountain vegetation is mainly composed of plants belonging Pinaceae, Salicaceae, Betulaceae, Fagaceae, Ulmaceae and Tiliaceae.

b) The life forms are diverse. Perennial herbs (832 spp.) are predominant constituting 60.5% with annuals composing 16.6%. Trees (78 spp.) and shrubs (141 spp.) are represented by 5.6% and 10.3% respectively. The rest are lianas (41 spp.) and a few parasitic and saprophytic plants. Most of the dominant plants composing the vegetation are deciduous species and perennial herbs.

c) The geographical elements are complex. All fifteen distribution patterns of Chinese spermatophytic (WU and WANG, 1983) exist in this region. Among them, the patterns of temperate, especially N. temperate elements are

Table 1 — The statistics of vascular plants of mountains and adjacent plain area in Beijing-Tianjin region.

Order	Families	%	Genera	%	Species	%
Pteriodophytes	19	14	27	4.7	69	5.0
Gymnosperms	3	2.2	6	1.0	8	0.6
Angiosperms	114	83.8	548	94.3	1300	94.4
Total	136	100	581	100	1377	100

predominant (see Table 2). The 8th-11th & 14th distribution patterns make up 337 genera, i.e. 71.5% of the total genera (excluding Cosmopolitan). The tropical elements (patterns 2nd-7th) are also well represented (22.5%). This shows the close relationship of the vegetation and flora of this region with the tropical zone.

As to geographical elements, the plant species mainly belong to temperate elements, although the elements composing various vegetation types are by no means uniform. The dominant numbers of the forests are mostly composed of eastern Asiatic, especially Sino-Japanese elements (e.g. *Betula platyphylla*, *Carpinus turzaninowii*, *Quercus acutissima*, *Q. dentata*, *Q. variabilis*, *Evodia daniellii*) and N. Chinese elements (*Larix principis-rupprechtii*, *Pinus tabulaeformis*, *Quercus liaotungensis*, *Acer truncatum*, etc.).

The shrubs are mostly Temperate Asiatic and N. Chinese elements, e.g. *Corylus heterophylla*, *Deutzia grandiflora*, *Spiraea tribolata*, *Caragana jubata*, *Lespedeza bicolor*, *Zizyphus jujuba*, *Vitex negundo* var. *heterophylla* and *Myripnois dioica*, etc. They all cover N. China and most of them spread to NE China, Inner Mongolia, Shanxi, Gansu and southward to subtropic China. Meadow with mixed elements are not important here.

Thus this mountain vegetation displays affinities with part of East Asia and the N. Chinese forest region, and there are close floristic relationships with many regions mentioned above.

d) Endemic elements are very poor by represented 200 endemic genera in China only 6 genera occur of the ca. here, i.e. *Ostryopsis*, *Pteroceltis*, *Pteroxygonum*, *Oresitrophe*, *Bolbostemma* and *Myripnois*. Local endemic species are only represented by *Batrachium pekinense*, *Clematis pinnata* (Ranunculaceae) and *Pimpinella cnidioides* (Umbrelliferae).

By way of contrast, there are many ancient or relict elements? Besides some ligneous genera mentioned above, these include *Ephedra*, *Juglans*, *Hemiptelea*, *Broussonetia*, *Albizia*, *Pistacia*, *Alangium*, *Schisandra*, *Actinidia*, *Loranthus* as well as herbaceous *Pyrola*, *Phryma* (Phrymaceae) and *Chlorantus*. In addition many ferns are to be found in the vegetation especially in forests. Therefore, it is apparent that in this region the origin of the vegetation and flora is extremely ancient. Evidence from the history of vegetation and flora in this region lends support to this clain.

ORIGIN OF VEGETATION AND PAST FLORA

According to paleobotanical reports (Kong & Tu, 1976; Kong & Du, 1980; 1982), the history of the present vegetation and flora may at least be traced to the Paleogene in this region. The early Cretaceous vegetation and flora displayed tropical-subtropical characteristics. Coniferophytes existed at that time; Angiosperms did not appearuntil late Cretaceous.

In the Paleogene, the vegetation was similar to evergreen deciduous leaved mixed forests in the southern part of the northern subtropical zone; however, the floristic composition was very different. Past flora decreased greatly or disappeared, while the conifers (mainly Pinaceae) increased, e.g. *Cedrus*, *Keteleeria* and *Tsuga*. Angiosperms were more diverse being chiefly represented by *Juglans*, *Pterocarya*, *Quercus*, *Betula*, *Carpinus*, *Corylus*, *Ulmus*, etc. Some typical subtropical and tropical elements still exist.

The Neogene vegetation belonged to warm-temperate broad-leaved deciduous and needle-leaved mixed forests containing numerous Amentiferae. The flora of the Paleogene decreased greatly although some elements were retained as relicts. In late Neogene, broad-leaved deciduous forests composed mainly of xerophilous *Quercus* covered the base of the hills in Beijing, while shrubs and

Table 2 — The structure of distribution patterns of spermatophytic genera in the mountains and adjacent plain of the Beijing-Tianjin region.

	Distribution Pattern	Genera	%*
1.	Cosmopolitan	83	—
2.	Holotropical	62	13.2
3.	Tropical Asia-Tropical American	5	1.1
4.	Old-world Tropical	11	2.3
5.	Tropical Asia-Tropical Australian	11	2.3
6.	Tropical Asia-Tropical African	10	2.1
7.	Tropical Asian	7	1.5
8.	North Temperate	177	37.6
9.	East-North American	32	6.8
10.	Eurasia Temperate	63	13.4
11.	Asia Temperate	27	5.7
12.	Mediterranean-Central Asian	17	3.6
13.	Central Asian	5	1.1
14.	East Asian	38	8.0
15.	Endemic to China	6	1.3
	Total	554	100

* Excluding Cosmopolitan

steppe plants expanded. It is evident that the vegetation and flora was basically formed in the Neogene here.

During the Quaternary glacial periods, *Picea* and *Abies* forests became predominant and extended down the hills to the plain in Tali glacial period. In the postglacial, they retreated to the higher mountains and were replaced by warm-temperate deciduous forests on the lower mountains and hills; the grasslands increased in amount here. In the late Holocene 2500 B.P. caused the pine forest to expand climatic cooling. Today, because of human exploitation and disturbance over a long period of, the natural stands are mosly secondary. All the same, there are still many subtropical Tertiary descendants and relicts remaining here.

CONCLUSION

a) The vegetation types are relatively diverse in the Beijing and Tianjing mountains and display an obious al titudinal zonation

b) The floristic composition is con siderably rich, principally of various temperate elements and perennial herbs. However the dominant plants in the communities belong to deciduous trees and shrubs which are mostly Sino-Japanese, Temperate Asiatic and N. Chinese elements. The endemics are very poorly represented.

c) The original vegetation and present flora were basically formed in the Neogene. As a result they display a close relationship with the subtropical flora and many kinds of ancient or relic elements remained.

d) The present vegetations are mostly secondary. They must be conserved and managed reasonably.

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THE STUDY ON THE MOUNTAIN VEGETATION RESOURCES OF THE HILL COUNTRY IN SOUTHERN ANHUI, WESTERN ZHEJIANG AND NORTHEASTERN JIANGXI PROVINCE

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Key words: Mountain vegetation, Southeast China, Anhui, Jiangxi.

The district including parts of Anhui, Zhejiang and Jiangxi Provinces, is a hilly country to the south of the Yangtze River, to the northwest of the Zhejiang-Jiangxi railway and to the northeast of Poyang lake (Fig. 1). The district is located between 27° 47' - 31° 12' N and 116° 16' - 119° 40' E, with a total area of 79786 km², of which 76.7% or 61228 km² are mountainous area. It forms a resource base for Shanghai economic region and as an important tourist area.

THE NATURAL ENVIRONMENT

The topography and landforms of the district are basically middle-low hills, belonging to the Huangshan, Wuyishan, and Western Tianmushan mountains. The mountains above 1700 m in altitude within the district are Huangshan, Mount Sanqingshan, Mount Qinglianfeng, and Mount Guniujinag. The river systems are divided by the Huangshna mountains into two parts. The northwestern one belongs to the Yangtze River, while the southern one, the Xinanjiang River and the Fuchunjiang River belong to the river system of the Qiantang-jiang River. Its climate is in the central subtropical humid region influenced by the southeast monsoon, i.e. the temperature: mean annual temperature 16.9° C, extreme maximum temperature 39.9° C, extreme minimum temperature -11.5°, ≥ 10°C accumulated temperature 5159° C; frostless season 239 daysa; a mean rainfall of 1572.9 mm and a relative humidity of 79% (Table 1), which are factors favourable for plant growth.

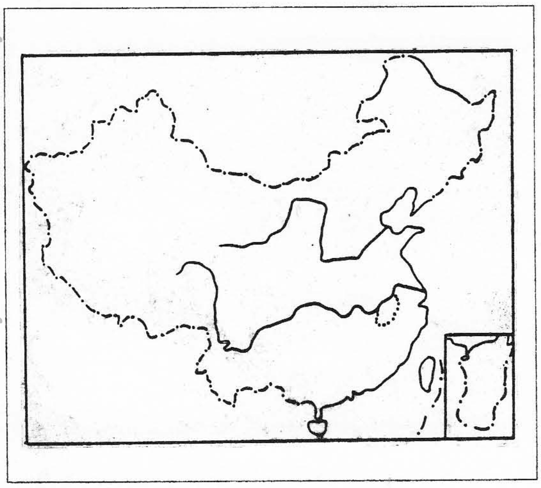

Fig. 1 — Geographic location.

The underlying rocks are mainly granite and phyllite in the central mountains, phyllite and sandstone in the low-mountains and hilly country. The differences substrate lead to different kinds of soil, such as red earth, yellow-red earth, yellow earth, yellow brown earth, meadow soil and lime stone soil, etc. These represent physicochemical parameters (Table 2).

Table 1. — The climatic resources

climatic factor / place name	mean annual T (°C)	mean annual rainfall (mm)	extreme max T (°C)	extreme min T (°C)
Mt. Huangshan	7.8	2941.5	23.8	-25.8
Mt. Tainmushan	8.9	1625.9	24.1	-20.6
South Anhui	16.2	1516.4	39.7	-13.5
West Zhejiang	16.4	1469.4	40	-11.3
Northeast Jiangxi	18.2	1733	40.1	-9.8

THE PRINCIPAL NATURAL VEGETATION TYPES AND THEIR DISTRIBUTION

The district is rich in plant resources with relatively complicated vegetation types, especially in the relatively undisturbed regions, such as the West Tainmushan, Huangshan, Sanqingshan, and Guniujiangshan reserves. In other parts, because of irrational human activities, these have been more or less destroyed. The broad-leaved forest consists mainly of genera such as *Castanopsis*, *Lithocarpus*, *Cyclobalanopsis*, *Cinnamomum*, *Machilus*, *Phoebe*, *Schima*, *Eurya*, *Manglietia*, *Fagus*, *Quercus*, *Lindera*, *Liquidambar*, *Platycarya*. The nnedle-leaved forest is composed mainly of *Pinus*, *Cunninghamia*, *Cryptomeria* and *Metasequoia*.

The vegetation types are classified into the following categories:

1. Neede-leaved forest, mainly *Pinus massoniana*, *Pinus taiwanensis*, mostly distributed 800 m above sea level; *Pseudotsuga gaussenii* and *Tsuga chinensis*; *Cunninghamia lanceolata*, *Cryptomeria fortunei*, etc.
2. Deciduous and evergreen broad-leaved mixed forests, predominated by *Cyclobalanopsis multinervis* and *Liquidamber acalycina*, *Cyclobalanopsis myrsinaefolia* and *Nyssa sinensis*, *Fagus longipetiolata* and *Daphniphyllum glaucescens*, *Cyclobalanopsis gracilis* and *Carpinus fargesii*.
3. Evergreen broad-leaved forest, mostly *Cyclobalanopsis glauca* forest (*C. glauca* and *Lithocarpus glaber*, *C. glauca* and *Castanopsis fargesii*), *Castanopsis sclerophylla* forest (*C. sclerophylla* and *Cyclobalanopsis glauca*, *C. sclerophylla* and *Cleyeria japonica*), *Castanopsis eyrei* forest (*C. eyrei* and *C. tibetana*, *C. eyrei* and *Elaeocarpus japonicus*), *Schima superba* forest, *Machilus thunbergii* forest (*M. thunbergii* and *Manglietia fordiana*), *Phoebe sheareri* forest, and *Michelia skinneriana* forest.
4. Bamboo forest, the main species being *Phyllostachys pubescens* and *Phyllostachys congesta*.
5. Shrub forest, mainly *Rhododendron simiarum* and *Pieris formosa*, *Rhododendron anwheiense* and *Enkianthus chinensis*, *Viburnum sargentii teatum*, *Quercus serrata* var. *brevipetiolata* and *Rhododendron simsii*, *Castanea sequinii* and *Quercus serrata* var. *brevipetiolata*.
6. Herbosa, principally *Themeda triandra* var. *japonica* and *Imperata cylindrica*, *Imperata cylindrica* and *Anaphalis sinica*, *Miscanthus sinensis*.
7. Swamp, mainly *Alisma canaliculatum* and *Sparganium simplex*.

We will also discuss the vertical vegetation zonation based on the investigation in West Tianmushan. The vertical distribution of the forest vegetation is evergreen broad-leaved forest, deciduous-evergreen broad leaved mixed forest, diciduous broad-leaved forest, deciduous dwarfed forest, and *Cryptomeria fortunei* forest (Fig. 2).

EXPLOITATION AND MANAGEMENT OF VEGETATION RESOURCES

1. Analysis of vegetation resources. According to the analysis of 29 samples of main vegetation types, the forest volume of timber (V) per mu is calculated using the formula V = G (H+3)f3 where G = cross section of trunk, H = height of tree, f_3 = coefficient (Table 3).

Braycurtis and Euclidian methodologies used to group the forest vegetation:

$$Bjk \frac{\sum_{i=1}^{m} (Xij-Xik)}{\sum_{i=1}^{m} (Xij-Xik)}$$

$$Ejk = \sqrt{\sum_{i=1}^{m} (Xij-Xik)}$$

Initially the distance were calculated followed by grouping (Table 4), and finally a diagram of the total cluster was made (Fig. 3). It shows the complexity and multiplicity of the vegetation types in this mountainous country.

PROTECTION, MANAGEMENT AND UTILIZATION OF THE VEGETATION.

1. Changing the logging methods: stopping large-area clear cutting and abandoning "burning-and-reclaiming", turning from forest coverage.
2. Changing the tree species used in afforestation, avoiding pure stands of *Pinus massoniana* and *Cunninghamia lanceolata*, increasing the proportion of broad-leaved forest, shelter belts and fuel forest, improving the habitat environment and diminishing erosion.
3. Planting trees on barren hills. The district has 12134.17 km of barren hills in the area. Part of the hilly country problem of rural energy shortage could be solved.
4. Establishing nature reserves to protect plant and vegetation resources. Appropriate tourism could be developed.

Table 2. — The physicochemical characteristics of different soils

Soil groups	Chemical composition SiO_2	Al_2O_3	Fe_2O_3	Physocochemical properties pH	Organic matter	Total N	Total P
red earth	42.74-48.83	14.1-26.9	5.13-5.91	4.5-5.5	3.15-4.85	0.185-0.124	0.113-0.163
yellow earth	41.02-32.75	10.4-21.2	5.29-7.59	4.5-6	8.75-2.34	0.148-0.471	0.076-0.084
yellow brown earth	34.12-37.23	31.3-36.2	7.35-9.78	5.8-6.2	6.47-11.23	0.231-0.374	0.054-0.075
meadow soil	54.70-60.58	16.8-20.7	4.46-5.54	4.9 5.4	10.5-15.48	0.23-0.57	0.09-0.18
limestone soil				6.9-7.5	2.09-6.47	0.09 0.20	

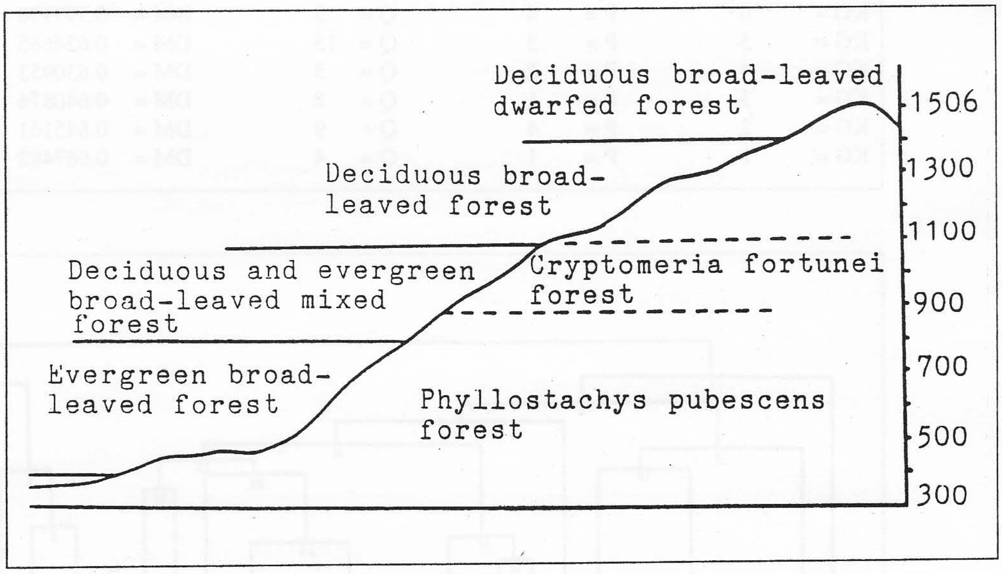

Fig. 2 — West Tianmushan vertical distribution of the vegetation.

Table 3. — Timber volume of the cross section.

H G V / Species name \ P	0.3 H	G	V	0.4 H	G	V	0.7 H	G	V	1.0 H	G	V
Ciclobalanopsis glauca										7.2	3.45	25.87
Castanopsis sclerophylla				7	0.56	2.4						
Castanopsis eyrei										12.7	3.47	29.53
Castanopsis sclerophylla										12.4	2.81	23.53
Castanopsis eyrei							10	1.38	6.95			
Liquidambar formosana										9	1.97	8.32
Pinus massoniana	7	0.42	1.72									
Pinus massoniana										13.3	3.36	26.33

Table 4. — The calculated distances and groupings.

KG = 28	P = 12	Q = 13	DM = 0.137405
KG = 27	P = 18	Q = 19	DM = 0.243697
KG = 26	P = 21	Q = 22	DM = 0.258907
KG = 25	P = 17	Q = 18	DM = 0.276596
KG = 24	P = 6	Q = 7	DM = 0.298893
KG = 23	P = 15	Q = 16	DM = 0.331445
KG = 22	P = 21	Q = 24	DM = 0.336323
KG = 21	P = 20	Q = 28	DM = 0.425868
KG = 20	P = 6	Q = 8	DM = 0.436975
KG = 19	P = 12	Q = 14	DM = 0.438356
KG = 18	P = 15	Q = 17	DM = 0.448029
KG = 17	P = 20	Q = 21	DM = 0.454546
KG = 16	P = 11	Q = 23	DM = 0.456790
KG = 15	P = 9	Q = 10	DM = 0.473684
KG = 14	P = 11	Q = 12	DM = 0.506024
KG = 13	P = 25	Q = 26	DM = 0.518625
KG = 12	P = 5	Q = 6	DM = 0.522124
KG = 11	P = 20	Q = 29	DM = 0.524862
KG = 10	P = 20	Q = 25	DM = 0.538462
KG = 9	P = 11	Q = 20	DM = 0.559322
KG = 8	P = 15	Q = 27	DM = 0.560166
KG = 7	P = 2	Q = 11	DM = 0.574468
KG = 6	P = 4	Q = 5	DM = 0.597990
KG = 5	P = 3	Q = 15	DM = 0.624665.
KG = 4	P = 2	Q = 3	DM = 0.630953
KG = 3	P = 1	Q = 2	DM = 0.640876
KG = 2	P = 4	Q = 9	DM = 0.645161
KG = 1	P = 1	Q = 4	DM = 0.667482

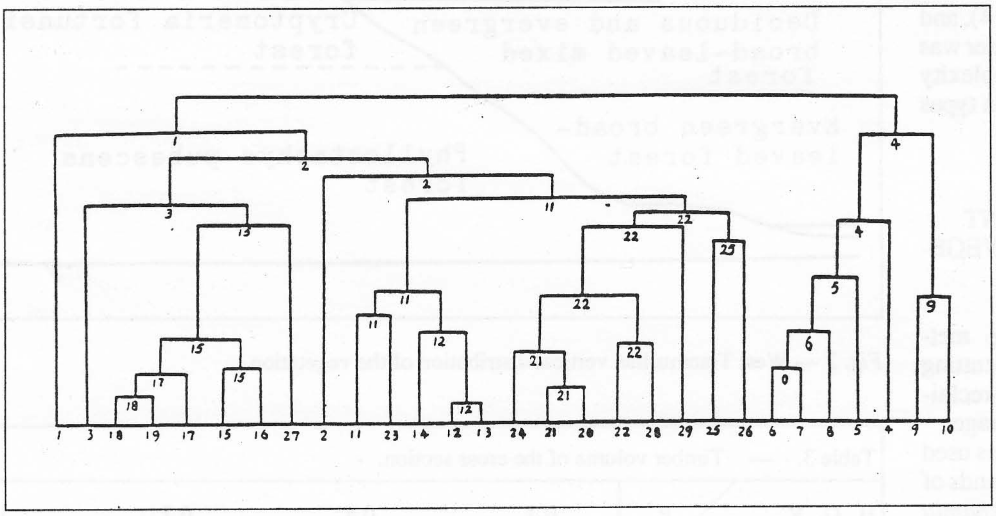

Fig. 3 — Plant community diagram of the total clusters.

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THE VEGETATION OF CHANGJIANG SANXIA (THREE GORGES) REGION IN WESTERN HUBEI

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Key words: Changjiang Sanxia Region; Western Hubei; Vegetation; Formation

The Changjiang Sanxia (Three Gorges on the Yangtze River) Region in Western Hubei is located north of the southwest mountains of Hubei Province, with its drainage area located at 30° 34' - 31° 34' N and 110° 07' - 111° 18' E. The region is composed of two parts, the region of Xilingxia and the eastern sector of Wuxia, including a watershed area in the four counties of Zigui, Xingshan, west of Nanjinguan in Yichang, and the north of Badong (see map).

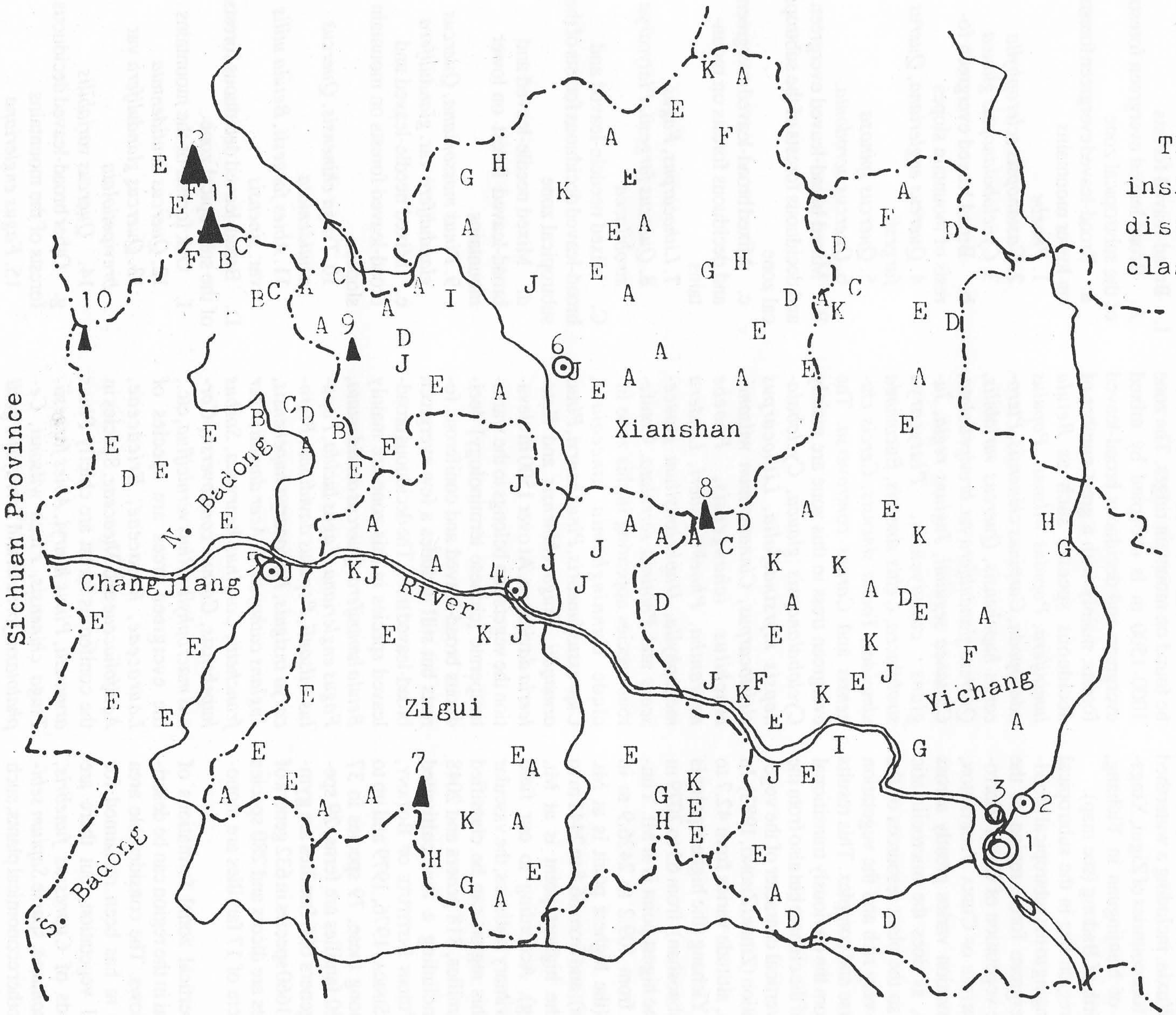
This region lies in the subtropical zone, belonging to the subtropical broad-leaved evergreen forest region of the map of the vegetation of China (EDITORIAL COMMITTEE OF CHINA VEGETATION, 1980). Elevation varies greatly across the region, as does the microclimatic character, so the plant resources of the region are very rich and the vegetation types diverse and complex. This results not only from the obviously transitional character of the climate but also from the distinctly vertical character of the vegetation zonation (ZHENG ZHONG, 1983). In this region, altitude varies from 42.7 to 2005 m in Yichang (the highest point is at Mt. Tianbaoshan); from 65 to 2079 m in Zigui (the higest point is at Mt. Yuntaihuang); from 109.2 to 2426.9 m in Xianshan (the highest point is at Mt. Xianlushan); and from 66.8 to 2441 m in Badong (the highest point is at Mt. Wuyunding). According to our field work and primary statistics, the vascular plants in this region can be classified into 167 families, 818 genera and 2048 species (including a few cultivated plants) (WUHAN INSTITUTE OF BOTANY, ACADEMIA SINICA, 1976, 1979 and up to 1984). Among these, 79 species in 37 genera of 20 families are ferns, 29 species in 17 genera of 6 families are gymnosperms, 1660 species in 632 genera of 124 families are dicots and 280 species in 132 genera of 17 families are monocots.

The vertical zonal formations of vegetational in the region can be described as follows. The considerable area below 800 m has been reclaimed for agricultural vegetation, but there are some woods of *Cupressus funebris*, *Pinus massoniana*, sparse *Sapium sebiferum*, and other economical plants, such as *Citrus madurensis* and *Citrus reticulata* (cultivated species), as well as a few other evergreen plants which occur on the slopes of this zone (ZHENG ZHONG, 1983). *Cupressus funebris* grows thriftily on the limestone soil. In the zone of low mountains and river walleys between 500 and 1000 meters, there are some relic evergreen forests in which the main components are efficiently species of *Lauraceae* and *Fagaceae*. In the secondary and sparse forests on these slopes, there are also species such as *Castanopsis eyrei*, *Betula luminifera*, *Populus adenopoda*, *Pistacia chinensis*, *Liquidambar formosana*, *Castanea henryi*, *Ulmus bergmanniana*, *Carpinus fargessi*, *Corylus heterophylla* var. *sutchunensis*, *Cyclobalanopsis glauca* and *Zelkova sinica* grow on steep slopes and cliffs and *Quercus spinosa* forest can be found on mountain ridges. The zone 1000-1500 m is occupied by mixed evergreen and deciduous broad-leaved forests, mainly with a great number of deciduous species such as *Betula luminifera*, *Populus wilsonii*, *Populus adenopoda*, *Carpinus chinensis*, *Pterocarya hupehensis*, *Quercus variabilis*, *Quercus glandulifera* var. *brevipetiolata*, *Castanea seguinii*, *Juglans regia*, *Juglans cathayensis*, *Platycarya strobilacea*, *Celtis sinensis*, *Eucommia ulmoides*, *Toona sinensis*, *Cercis chinensis* and *Cornus controversa*. The evergreen tress in this zone are mainly *Cyclobalanopsis glauca*, *Cyclobalanopsis myrsinaefolia*, *Lithocarpus cleistocarpus*, *Cinnamomum wilsonii*, *Machilus ichangensis*, *Phoebe neurantha*, *Phoebe faberi*, *Lindera megaphylla*, *Daphniphyllum glaucescens* and *Photinia serrulata*. Coniferous species appearing in this zone include *Cunninghamia lanceolata*, *Cupressus funebris*, *Pinus henryi*, *Pinus armandii*, *Tsuga chinensis* and *Keteleeria davidiana*. At over 1500 m elevation the vegetation belongs to the warm-temperate [chinese terminology] deciduous broad-leaved and coniferous forests but still includes a few evergreen broad-leaved trees. The deciduous broad-leaved species in this zone are mainly *Betula luminifera*, *Quercus acutidentata*, *Fagus engleriana*, *Fagus lucida*, *Populus wilsonii*, *Populus davidiana*, *Pterocarya insignis*, *Pterocarya hupehensis*, *Juglans cathayensis*, *Acer davidii*, *Acer franchetii*, *Carpinus henryana*, *Sorbus hupehensis*, *Cornus controversa*, *Cornus macrophylla*, *Rhus verniciflua*, etc.; the evergreen trees are species of *Lauraceae*, *Rosaceae*, *Ericaceae*, *Aquifoliaceae* and *Theaceae*. Species in the coniferous forest are chiefly *Pinus armandii*, *Pinus henryi*, *Abies fargesii*, *Tsuga chinensis*, *Picea wilsonii*, *Cephalotaxus fortunei* and *Torreya fargesii* (JIN YIXING *et alii*, 1984; ZHENG ZHONG, 1983).

Based on our comprehensive investigation and analysis of the vegetation of Changjiang Sanxia Region in Western Hubei in edificators, structure, physiognomy and biotypes, the vegetation can be divided into 6 vegetation types (cultivated economical forests included) (COOPERATIVE GROUP OF SICHUAN VEGETATION, 1980; HOU HSUEHYU, 1960), 11 formation classes, 20 formation groups and 54 formations (JIN YIXING *et alii*, 1984). The classification follows: the Roman numerals (I. II. ......) indicate physiognomic vegetation types, the English capitals (A. B. ......) indicate formation groups and, the Arabic numbers (1. 2. ......) represent the individual formation.

I. Broad-leaved forests
  A. Broad leaved evergreen forests of the subtropical zone
    a. Broad-leaved evergreen forests on lower mountains
      1. *Phoebe*
      2. *Castanopsis sclerophylla*
      3. *Cynclobalanopsis glauca*
    b. Broad leaved evergreen forests of mountain slopes
      4. *Quercus engleriana*, *Querus fargesii*
      5. *Quercus spinosa*
      6. *Quercus acrodonta*.
  B. Mixed broad-leaved evergreen and deciduous forests of the subtropical zone
    c. Mixed broad-leaved evergreen and deciduous forests on mountains
      7. *Lithocarpus*, *Fagus*
      8. *Quercus fargesii*, *Platycarya strobilacea*
  C. Mixed needele-leaved and broad-leaved deciduous forests of the subtropical zone
    d. Mixed needle-leaved and broad-leaved forest on lower mountains
      9. *Pinus massoniana*, *Quercus glandulifera* var. *glandulifera*
    e. Mixed needle-leaved and broad-leaved forests on mountain slopes
      10. *Tsuga chinensis*, *Quercus acutidentata*
      11. *Abies fargesii*, *Betula utilis* var. *sinensis*
  D. Broad-leaved deciduous forests of the subtropical zone
    f. Oak forests of the mountains
      12. *Quercus acutidentata*
      13. *Quercus glandulifera* var *brevipetiolata*
      14. *Quercus variabilis*
    g. Other broad-leaved deciduous forests of the mountains
      15. *Fagus engleriana*
      16. *Castanea henryi*
      17. *Castanea seguinii*

Simple map showing the area of Chagjiang Sanxia Region in Western Hubei.



Explanation

The English capitals inside the map show the distribution of formation classes.

1 Yichang City
2 City of Yichang County
3 Nanjinguan
4 City of Zigui County
5 City of Badong County
6 City of Xingshan County
7 Mt. Yuntaihuang(alt.2079
8 Mt. Tianbaoshan(alt.2005
9 Mt. Xianlushan(alt.2426. m.)
10 Mt. Wuyunding(alt.2441m
11 Mt. Xiao Shennongjia(al 3005m)
12 Mt. Da Shennongjia (alt 3052m)

18. *Populus davidiana*
19. *Betula utilis* var. *sinensis*
20. *Platycarya strobilacea*

II. Needle leaved forests

E. Needle-leaved evergreen forests of the subtropical zone

h. Needle-leaved evergreen forests on lower mountains

21. *Pinus massoniana*
22. *Cunninghamia lanceolata*
23. *Cupressus funebris*
24. *Keteleeria davidiana*
25. *Pinus henryi*

i. Needle-leaved evergreen forests on mid-mountain slopes

26. *Abies fargesii*
27. *Pinus armandii*

III. Bamboo forests

F. Bamboo forests of the subtropi cal zone

j. Bamboo forests with large stems (D.B.H. larger than 6 cm)

28. *Phyllostachys pubescens*
29. *Phyllostachys bambusoides* f. *tanakee*
30. *Sinocalamus affinis*
31. *Phyllostachys bambusoides*

k. Bamboo forests with small stems (D.B.H. less than 6 cm)

32. *Sinarundinaria nitida*
33. *Fargeisa spathacea*
34. *Indocalamus tessellatus*

IV. Scrub and scrub mixed with herbs

G. Scrub on mountains of the sub tropical zone

l. Broad-leaved deciduous scrub

35. *Pyracantha fortuneana*, *Coriaria sinica*
36. *Cotinus coggygria* var. *pubescens*
37. *Coriaria sinica*
38. *Rosa*
39. *Quercus glandulifera* var. *brevipetiolata* (sometimes becomming small shrub)
40. *Loropetalum chinense*, *Rhododendron simsii*
41. *Vitex negundo*

H. Scrub mixed with herbs on mountains of the subtropical zone

m. Broad-leaved deciduous scrub mixed with herbs

42. *Pteridium aquilinum* var. *latiusculum*, *Lespedeza formosa*

V. Herb formations

I. Herb formations on the mountains of subtropical zone

n. Grasslands

43. *Arthraxon hispidus*, *Kummerowia stipulacea*
44. *Imperata cylindrica* var. *major*

o. Fern stands

45. *Pteridium aquilinum* var. *latiusculum*
46. *Dicranopteris dichotoma*

VI. Economic forests (cultivated vegetation)

J. Economic broad-leaved evergreen forests of the subtropical zone

p. Broad-leaved evergreen forests for fruit

47. *Citrus sinensis*, *Citrus reticulata*

q. Broad-leaved evergreen forests for oil

48. *Camellia oleifera*
49. *Trachycarpus fortunei*

K. Economic broad leaved deciduous forests of the subtropical zone

s. broad-leaved deciduous forests for oil and resin

50. *Vericia fordii*
51. *Juglans regia*
52. *Sapium sebiferum*
53. *Rhus verniciflua*

t. Broad-leaved deciduous forests for starch

54. *Castanea mollissima*

The Changjiang Sanxia is a world-famous canyon, and this region is special in its geographic position. It lies in a north-south transitional zone and represent a distribution on center of relic and endemic plants in China. The vegetation of Changjiang Sanxia Region in Western Hubei comprises about 68 species of rare plants (ZHENG ZHONG, 1984 & 1986) so it is very important and necessary to build a proper preserve in this region (JIN YIXING *et alii*, 1984), so that the vegetation can be renewed and can develop well.

Rare species in the Changjiang Sanxia Region include:

Metasequoia glyptostroboides
Davidia involucrata
Liriodendron chinense
Tetracentron sinense
Cercidiphyllum japonicum
Emmenopterys henry
Heptacodium miconioides
Manglietia patungensis
Berchemiella wilsonii
Eucommia ulmoides
Sinowilsonia henryi
Juglans regia
Ginkgo biloba
Cephalotaxus oliveri
Picea neoveitchii
Depteronia sinensis
Euptelea pleiosperma
Ormosia hosiei
Stewartia sinensis
Tapiscia sinensis
Pterostyrax psilophylla
Magnolia officinalis
Pteroceltis tatarinowii
Phoebe zhennan
Coptis chinensis
Corylus chinensis
Dysosma versipellis
Gastrodia elata
Trillium tschonoskii
Abies chensiensis
Amentotaxus argotaenia
Picea brachytyla
Tsuga forrestii
Deinanthe caerulea
Decumaria sinensis
Maytenus variabilis
Magnolia sprengeri
Chuanminshen violaceum
Psilopeganum sinensis
Gymnotheca chinensis
Astragalus henryi
Symphoricarpos sinensis
Corydalis tomentella
Sassafras tzumu
Diphylleia sinensis
Atropanthe sinensis
Citrus ichangensis
Noecinnamomum fargesii
Hepatica henryi
Lindera obtusiloba
Carrierea calycina
Gymnocladus chinensis
Chimonanthus praecox
Perrottetia racemosa
Neomartinella violaefolia
Stylophorum lasiocarpum
Hosiea sinensis
Acer griseum
Toricellia angulata
Triaenophora rupestris
Aesculus wilsonii
Iris wilsonii
Tsuga chinensis
Torreya fargesii
Davidia involucrata var. *vilmoriniana*
Myricaria germanica var. *laxiflora*

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THE VEGETATION OF THE NANSHAN MOUNTAINS OF HUNAN PROVINCE AND ITS RATIONAL UTILIZATION

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Key words: Vegetation utilization, Vegetation distribution, Hunan

INTRODUCTION

Like the south of China, the mountain areas of Hunan have a warm climate with abundant rainfall. The zonal vegetation is evergreen broad-leaved forest, consisting of *Castanopsis*, *Cyclobalanopsis*, *Lithocarpus*, *Schima* and *Machilus* (= *Persea*) as dominant constituents (QI CHENGJIN 1984). On mountains with an altitude of 1,000-2,000 m this turns into mixed evergreen and deciduous broad-leaved forest which is dominated by the above-mentioned genera plus *Fagus*, *Quercus*, *Acer*, *Betula* and *Prunus*, somewhere with conifers of *Pinus*, *Tsuga* and *Fokienia*. In addition, there are large areas of coniferous forest on the low mountains, including *Pinus massoniana* and *Cunninghamia lanceolata*. Bamboo forests also occur widely. As the human population increased, land exploitation, was intensified, resulting in the destruction of forests and the expansion of scrub and grassland. At present, there are large areas of barren mountain waiting to be utilized. How should this barren land be exploited, should it be used for stock-raising or be restored as forests? This is a widely disputed problem among agriculturists and ecologists. In this paper the local vegetation is analyzed. Nanshan may be considered an example to demonstrate what are the best way and the proper direction in the rational utilization of the south China mountain areas.

GENERAL GEOGRAPHICAL SITUATION AND NATURAL CONDITIONS

Nanshan mountain is located at 26° 14' N, 110° 50' E in Chengbu County in the south-west of Hunan Province, bordering the Guangxi Automonous Region. In the broad sense, the Nanshan mountains are considered to be a part of the Yuechengling mountains, of which the main peak in the Chengbu area has an altitude of 2,021 m. In the strick sense, Nanshan mountain is restricted to the limit of Nanshan Farm with an area of 105, 300 ha, of which 8,870 ha are managed. The main rocks are Cretaceous granite, but Ordovician metamorphic sandstone may also be found. According to the recorded data, the climate of Nanshan is as shown in Table 1. The area above 1,600 m is cool and wet, with an annual mean temperature of 11°.7 C and an annual ice-snow period of 98 days.

Mountain soil may be divided into various soil types according to different elevations: Yellow soil below 1,300 m; Yellow-brown soil 1,300-1,700 m; above 1,700 m there is mountain scrub-meadow soil (see Table 2), with bog soil in depressions.

The soil is usually thick and rich in nutrient elements, containing high percentages of organic materials more than 10% when the vegetation cover is complete.

THE VERTICAL DISTRIBUTION OF VEGETATION

In the north part of the Yuechengling mountains, which include Nanshan, the vertical distribution of vegetation can be divided into four belts as follows (QI CHENGJING *et alii*, 1982):

1. The belt of cultivated vegetation

This belt lies at an altitude of 500 m and below. Large areas of flat land as well as a part of the hilly areas are constantly exploited to grow crops. Much of the hill area is used to cultivate economic forests and orchards, involving *Camelia olifera*, *Vernicia fordii*, tea plants and oranges. Scattered *Pinus massoniana* forests and *Quercus Loropetalum* shrub forests also occur.

2. The belt of evergreen broad-leaved forest

This ranges from 500 m to 1,300 (-1,400) m in altitude, dominated by *Castanopsis syrei*, *C. carlesii*, *C. fargesii*, *C. fabri*, *Cyclobalanopsis glauca*, *Shima superba*, *S. argentea*, *Machilus rehderii* and *M. thunbergii*, with companion species such as *Cinnamomum bodinieri*, *C. wilsonii*, *Michelia platypetala*, *Manglietia fordiana*, *Parakmeria lotungensis*, *Engelhardtia roxbourghiana*, *Lithocarpus litseifolius*, *L. paniculatus*, *Phoebe sheareri*, *Ormosia xylocarpa*, *Lindera megaphylla*, *Huodendron tibeticum*, etc. The forests have suffered from large-scale destruction. *Pinus massoniana* forests, sometimes with *Liquidambar formosana*, *Betula luminifera*, *Nyssa sinensis* and *Castanea henryi*, are widely scattered.

3. The belt of mixed evergreen and deciduous broad-leaved forest.

This occurs between the altitudes of 1,300 (-1,400) and 1,700 m, where the dominant and frequent species, which form varied communities, are as follows: *Cyclobalanopsis multinervis*, *C. stewardiana*, *Fagus lucida*, *Quercus engleriana*, *Lithocarpus henryi*, *L. cliestocarpus*, *Machilus rehderii*, *Schima remoteserrata*, *Manglietia insignis*, *M. chingii*, *Betula austrosinensis*, *Tilia obscura*, *Halesia macgregorii*, *Melliodendron xylocarpum* and *Acer* ssp. On the peak of the mountain, one can occasionally discover several rare and endemic coniferous forests, involving *Cathaya argyrophylla*, *Tsuga longibracteatea* and *Pinus kwangtungensis*. Due to the destruction of former forests, there is a wide distribution of *Quercus glandulifera*, *Platycarya strobilacea*, *Rhododendron simsii* and *Clethra esquirolii* scrub and *Miscanthus-Arundinella* grassland.

4. The belt of mossy elfin forest and scrub and grassland

This belt occurs at altitude 1,700-2,000 m. The elfin forest occurs on sheltered slopes of the mountains and is

Tab. 1 — The climate record at the locality of different elevations

Altitude (m)	Temperature (C) Annual mean	January	July	Mean annual Precipitation (mm)	Mean annual relative humidity (%)	Annual fog days
447	16.9	3.8	27.1	1,126.3	77	12
1,000	14.5	2.5	23.5	1,590.8	86	141
1,640	11.7	4.3	19.1	2,023.2	88	158

Tab. 2 — General Properties of Mountain Scrub-meadow soil.

Parent rock	Altitude (m)	Depth (cm)	PH	O.M. %	C/N	N (%)	P_2O_5 (%)	K_2O (%)	C.E.C. meq 100	Base saturation (%)	Particle size(%)	
											0.001	0.01
Granite		2-8	5.5	10.50	12.16	0.50	0.26	1.57	29.06	26.84	20.7	40.2
	1,810	15-25	5.3	4.12	12.78	0.19	0.18	3.19	19.38	30.43	28.3	56.2
		40-50	5.3	1.21	13.76	0.05	0.11	2.72	10.57	40.12	30.4	57.4
Granite	1,920	2-10	5.74	5.43	13.00	0.24	0.10	1.95	18.73	40.12	7.6	22.1
		13-19	5.70	1.78	6.50	0.12	0.13	0.41	14.03	38.42	8.6	28.7

composed of *Fagus lucida*, *Cyclobalanopsis stewardiana*, *Illicium majus*, *Sorbus pratii*, *S. folgneri*, *Rhododendron* spp., *Symplocos hunanensis*, *Lindera obtusiloba*, *Stewartia sinensis*, *Magnolia sielbodii*, *Acanthopanax evodifolius*, *Ilex triflora* and *Stranvaesia davidiana* var. *undulata*. *Sinarundinaria basihirsuta*, as bamboo scrub, covers large areas on the summits of the mountains. Owing to the strong winds at high altitude and frequent burning of the mountain by farmers, large areas of grassland occur. These grassland area include *Miscanthus sinensis*, *Arundinella hirta*, *Dyeuxia scabrescens* with *Pteridium aquiliuum*, *Anaphalis margaritacea*, *Artemisia japonica*, *Astible chinensis*, *Lychnis senno*, *Swertia bimaculata*, *Eupatorium japonicum*, *Gentiana davidii*, *Juncus setchuensis*, *Carex cruciata*, *Fimbristylis diphylloides*, *Lilium brownii*, etc. In addition, the occurrence of some shrubs, such as *Rhododendron*, *Lespedeza*, *Berberis*, *Buxus* and *Buddleia* spp. is not uncommon.

THE GENERAL FEATURES AND PRINCIPAL TYPES OF VEGETATION IN THE NANSHAN FARM AREA

Nanshan Farm, set up in 1973, has a total managed area of 8,870 ha, ranging in altitude from 1,273 m to 1,946 m. The area of grassland amounts to 5,615 ha, which wrks out to be 64% of the total, while the area of forest land is 1,990 ha and the scrub area is 980 ha. Because of the unfavourable natural conditions, the land was abandoned after the destruction of the original forests. The farmers used to burn the mountain frequently, resulting in an expansion of grassland areas. In the early period since the Farm was set up, only natural grass was used as feed for cattle. However, some other types of grass such as Clover and Ryegrass, etc. were imported in 1975, and this achieved initial success.

The vascular flora in Nanshan comprises 510 species, 33 genera and 138 families. Among them, the families with more than 10 species are as follows: Poaceae (32 species), Rosaceae (31), Asteraceae (24), Liliaceae (11), Aquifoliaceae (10). Most of them belong to the flora elements of Central China and North-Central China (XIAO YUTAN *et alii* 1985, 1986). The vegetation in Nanshan may be divided into 5 vegetation types and 15 formations (XIAO YUTAN *et alii* 1985, 1986):

I. Forests

I). Deciduous broad-leaved forests

1. *Fagus lucida* forest
2. *Alnus trabeculosa* forest in depressious

II). Mixed evergreen and deciduous broad-leaved forests

3. *Cyclobalanopsis multinervia* and *Fagus lucida* forest
4. *Machilus rehderii*, *Daphniphyllum macropodum* and *Clethra esquirolii* forest
5. *Lithocarpus cleistocarpus* and *Acer pubinerve* var. *kwangtungense* forest

II. Scrub types

6. *Hydrangea paniculata* and *Weigela japonica* var. *sinica* scrub
7. *Clethra esquirolii* and *Rhododendron simsii* scrub
8. *Enkianthus quinqueflorus* and *Rhododendron chisinianum* scrub

III. Bamboo scrub

9. *Sinarundinaria basihirsuta* scrub

IV. Grasslands

10. *Miscanthus sinensis* grassland
11. *Arundinella hirta* grassland
12. *Trifolium pratense*, *T. subterrancum* and *Lolium perenne* grassland - a cultivated grassland
13. *Deyeuxia scabrescens* and *Isachne globosa* grassland - declined because of the grazing
14. *Swertia bimaculata* and *Ligularia* sp. grassland - in the area of overgrazing

V. Bog community

15. *Scirpus lushanensis*, *Juncus setchuensis* and *Sphagnum cymbifolium* community

From the viewpoint of vegetation dynamics, grassland in the area is not a stable vegetation. Today, though, large areas of grassland have arisen from original forest destruction. The basic successional pattern of the principal vegetation types is shown below

EXISTING PROBLEMS AND PROPOSED SOLUTIONS

1. The amount of nutrient elements for cattle is low in the natural grass. Large-scale farming using only natural grass can not achieve its purpose. Most of the nutrient elements are gross cellulose, with no nitrogen extract. Thus, after one to three years of grazing, the natural grassland declines rapidly, with the result that the Farm had to use cultivated grass instead of natural grass.

2. After several years of grazing, grass yields decreased rapidly.

In 1982 the average yield of fresh grass per ha was 2,100 kg.; in 1984 it was only 750kg per ha. At the same time, a change took place in the crop composition of cultivated land. In 1979, the grassland consisted of Red Clover (a good grass) 55%, White Clover 35% and Ryegrass 10% in terms of area covered. Five year later, the percentage of White Clover had risen to more than 80%, while Red Clover became scarce, and Ryegrass almost disapeared. Moreover, wild grasses and other plants,

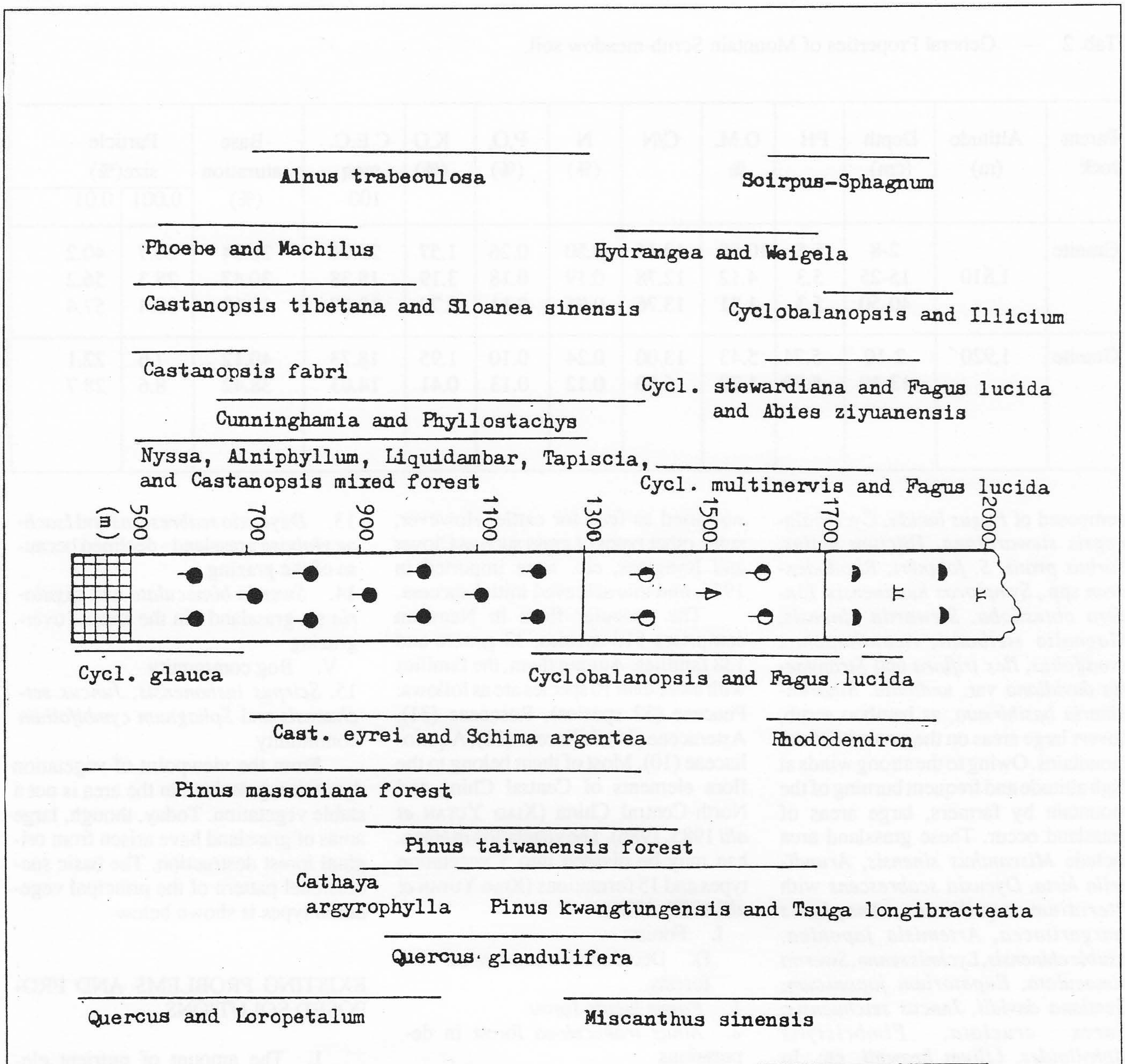

Fig. 1 — The vertical distribution of vegetation of the northern Yuechengling mountains.

such as *Arundinella hirta*, *Swertia bimaculata*, *Polygonum*, *Ligularia* and *Pteridium*, invaded the man-made grassland.

3. Soil erosion was intensified. in some areas of man-made grassland, erosion occupied 35% of the total area, sometimes up to 60% on steep slopes. So the soil fertility was also decreased. Measures should be taken to control the number of cattle, to carry out rotation grazing, to apply fertilizer and to develop forestry, and special care should be taken to protect the natural forests and water conservation forests. In general, it is better to avoid large-scale, one-species stock raising. Nanshan Farm should undertake the restoration of mountain forests as its work and arrange the raising of livestock in the proper way.

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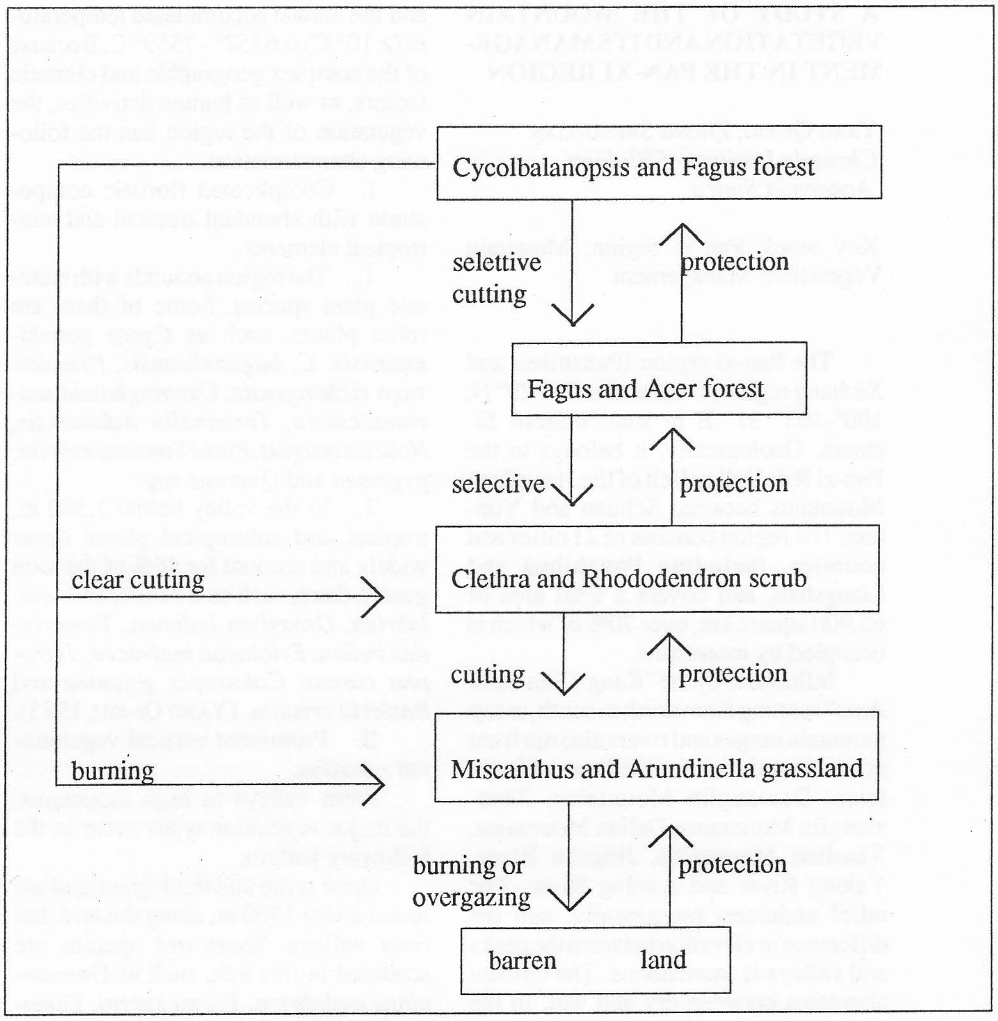

Fig. 2 — The succession pattern of the principal vegetation types in Nanshan.

Tab. 3 — The amount of nutrient elements of the natural grass in Nanshan

Month	Moisture content (%)	Gross protein (%)	Gross fat (%)	Gross cellulose (%)	No nitrogen extract (%)	Gross ash (%)
5	6.89	13.23	3.07	36.60	39.62	10.59
7	4.68	4.91	3.28	32.26	50.62	4.85
12	8.30	3.61	3.15	41.33	38.16	5.46
average	7.52	7.25	3.17	33.39	42.80	6.96

A STUDY OF THE MOUNTAIN VEGETATION AND ITS MANAGEMENT IN THE PAN-XI REGION

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Key word: Pan-xi region; Mountain Vegetation; Management

The Pan-xi region (Panzhihua and Xichang region) is located at 26°-29° N, 100°-103° 31' E in southwestern Sichuan. Geologically, it belongs to the Pan-xi Rift Valley Belt of the Hengduan Mountains between Schuan and Yunnan. The region consists of 21 cities and counties, including Panzhihua and Liangshan, and covers a total area of 65,900 square km, over 70% of which is occupied by mountains.

Influenced by the "Kang-Dian Earth Axis" running from north to south, many mountain ranges and rivers also run from north to south, such as the Daxue Mountains, Daxianglin Mountains, Xiaoxianglin Mountains, Dalian Mountains, Xiaolian Mountains, Jingsha River, Yalong River and Anning River. The relief undulates prominently, and the difference in elevation between the peaks and valleys is tremendous. The climate alternates between dry and wet. In the valleys below 1,300 m, influenced by the valley wind and foehn, subtropical vegetation can be found, where the annual mean temperature is 18°-20.3° C and the annual accumulated temperature (≥ 10° C) is 6352° - 7359° C. Because of the complex geographic and climatic factors, as well as human activities, the vegetation of the region has the following characteristics:

I. Complicated floristic composition with abundant tropical and subtropical elements.

1. The region abounds with endemic plant species. Some of them are relict plants, such as *Cycas panzhihuaensis*, *C. baguanheensis*, *Pseudotsuga xichangensis*, *Cunninghamia unicanaliculata*, *Terminalia dukouensis*, *Nouelia insignis*, *Pinus Yunnanensis* var. *pygmaea* and *Quercus* spp.

2. In the valley below 1,300 m, tropical and subtropical plants occur widely and account for 46% of the total genera there, such as *Gossampinus malabrica*, *Oroxylum indicum*, *Tamarindus indica*, *Eriolaena malvacea*, *Jatropha curcas*, *Calotropis gigantea* and *Barleria cristata* (YANG QI-XIU, 1983).

II. Prominent vertical vegetational zonation.

From valleys to high mountains, the major vegetation types occur in the following pattern:

Open scrub and thick grassland are found under 1300 m, along the arid, hot river valleys. Some tree species are scattered in this belt, such as *Gossampinus malabrica*, *Toona sureni*, *Tamarindus indica*, *Engelhardtia spicata*, *E. colebrookiana*. Bushes *Phyllanthus emblica*, *Jatropha curcas*, *Trema laevigata*, *Psidium guajava*. Grasses grow well there. The cover degree is as high as 90%. The major grasses (Gramineae) include Heteropogon contortus, *Arundinella setosa*, *Cymbopogon distans*, *Eulalia quadrinervis*, *Andropogon yunnanensis*, *Eulaliopsis binata*, etc.

Between 1,300-2,800 (3,000) m are the evergreen broad-leaved forests of *Quercus cocciferoides*, *Castanopsis delavayi*, *Cyclobalanopsis glaucoides*, *Lithocarpus variolosus*, *Cinnamomus wilsonii*, *Machilus yunnanensis*, *Schima argentea*, *Eurya* ssp. and evergreen coniferous forests mainly consisting of *Pinus yunnanensis*, *P. armandii*, *Keteleeria evelyniana*. Those occur on low and middle mountain slopes. These broad-leavedforests and coniferous forests are often mixed, becoming forests of *Pinus* plus *Quercus*.

Between 2,800 (3,000) - 3,200 m are mixed coniferous and broad-leaved forests of *Tsuga dumosa*, *T. chinensis*, *Abies fabri*, *A. forrestii*, *Acer davidii*, *A. laxiflorum*, *Betula utilis* and *B. platyphylla*.

The subalpine forests occur in the range 3,200-4,000 m, with *Picea likiangensis*, *P. brachytyla* var. *complanata*, *Abies fabri*, *A. forrestii*, *A. georgei*, *Sabina pingii*. On south-facing slopes there are sclerophyllous forests of *Quercus aquifolioides* and *Q. pannosa*.

Deciduous coniferous forests of *Larix potaninii* var. *macrocarpa* can be found 4,000-4,100 m.

At 4,100-4,500 m cover alpine scrub and meadows occur, consisting of *Rhododendron* spp., *Sabina squamata* var. *wilsonii*, *Spiraea alpina*, *Berberis* spp., *Kobresia*, *Carex*, *Festuca*, *Poa* and *Deyeuxia*.

Above 4,500 m is the subnival zone with sparse alpine plants such as *Saussurea* spp., *Rhodiola* spp., *Corydalis* spp., *Androsace tapete* and *Eriophyton wallichii*.

These vegetation types cover wide vertical belts and extensive areas, with extremely rich plant resources.

III. Higher distribution limits and wide habitat ranges.

Due to the favorable moisture and thermal conditions of the region, the upper limit of the evergreen broad-leaved forests, mainly consisting of Fagaceae, Theaceae, and Lauraceae is as high as 2,800-3,000 m. *Larix poyaninii* var. *macrocarpa* can be found in areas 4, 300 m and forms forests. Rice can be cultived in areas above 2,500 m (LIU YU-CHENG, 1982).

According to the vegetation characteristics, the general principles of vegetation management and utilization as follows:

1. It is necessary to readjust the agricultural system acoording to the local

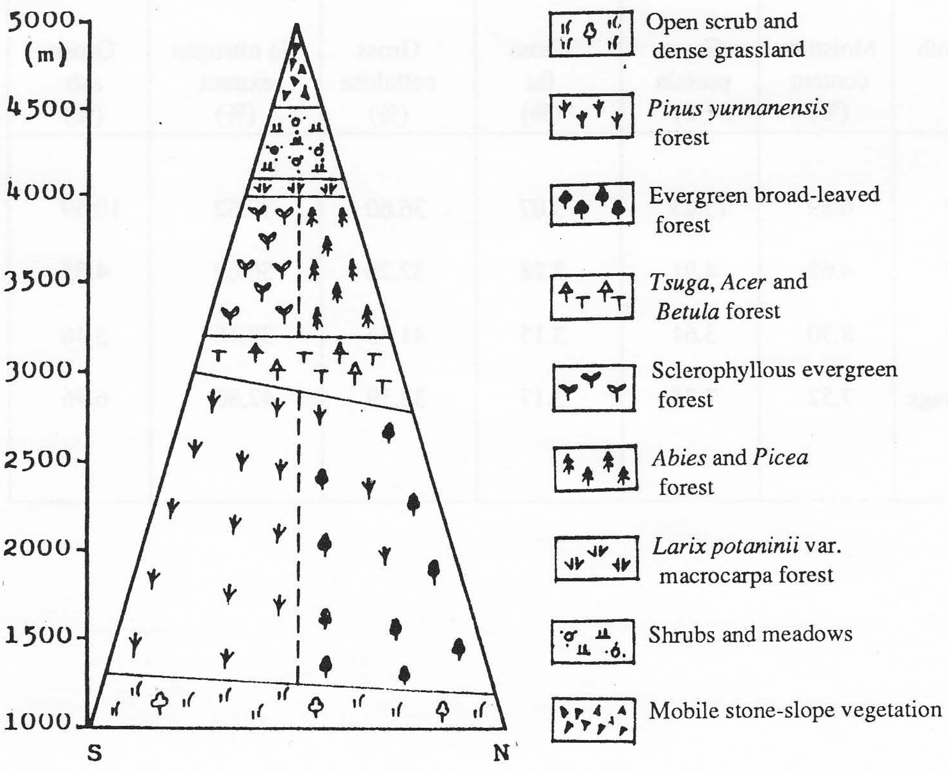

Fig. 1 — The vertical distribution of the vegetation types in Xichang, Sichuan

conditions. A series of special productive bases, such as grain, forestry, fruit, medicine, sugar, and tea plantations, should be planned and established in order to make full use of the forest area accounting for 49.14% of the total area.

2. According to the mountain vertical structure, "three-dimensional agriculture" and the multipurpose forestry processing industry should be developed. From the low valleys to the higher mountains, an arrangement of fruits and crops should be alternately harvested all year round.

3. Mountain grassland should be rational managed and improved to establish animal husbandry and its accounting for 27% of the total area (COOPERATIVE GROUP OF THE VEGETATION OF SICHUAN, 1980).

4. It is necessary to use small sites and isolated areas on the mountains to develop tropical and subtropical plants and establish small commercial crop bases.

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DISTRIBUTION AND VEGETATION TYPES OF HUANGGANGSHAN IN WUYISHAN MOUNTAINS OF FUJIAN, CHINA

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Key words: Vegetation of China, Vegetation belts, Mountain of Fujian

Huanggangshan, which is the summit of the Wuyishan mountains, is located at 27° 51' N, 117° 47' E. It is 2158 m above sea level and highest summit in southeastern China. The mountains are high and steep, streams and valleys afford irrigation. In the lofty peaks and deep gorges, environments are very different from each other, providing habitats for many vegetation types and abundant biological resorces.

NATURAL ENVIRONMENT

Huanggangshan is in the northwestern part of Fujian Province and in the Central Subtropical Climatic zone. Because the region of Huanggangshan is mountainous the terrain is high and steep. These mountains provide a natural defence for Fujian Province. These against cold airflow from the north in winter. The mountains also block the penetration of moist southeastern monsoons into the interior in summer. These mountains have the lowest air temperature, the highest rainfall and relative moisture, and heaviest fog in Fujian Province.

The main elements of climate at the summit of Huanggangshan (2158 m) are compared with corresponding values in Chong-an county (223.4 m, eastern foot of Huanggangshan) and Nan-chang city of Jiangxi Province (45.7 m lying west of Huanggangshan in figure 1 (LIN P., YE Q.H., 1983).

Fig. 1 suggests that the monthly curves of airtemperature are very similar but that climatic conditions are very different at the top and the foot of the mountains. As a result, there are quite different vegetation types. The parent rocks is mainly volcanic and rough-grain granites. Soils are red earth, yellow-red earth, yellow earth and mountain meadow soil, in regular order from the foot to the summit of Huaggangshan mountains. Because the slope is steep, alluvial materials are often found. Soil organic matter and total Nitrogen gradually increase with increasing elevation (CHAO C.P., 1981).

SURVEY METHOD

The following methods are used in the vegetation study.

(1) Quardrat method: For the tree layer (10 x 10 or 20 x 20 m²), shrub layer (2 x 2 m²) and herb layer (1 x 1 m² or 1 x 2 m²) the list quardrat method was used, or sometimes the herb layer used a denuded quadrat method.

(2) Point-centred quarter method: On some steeper slopes, the forest plot used the point-centred quarter method.

Fifty plots were studied, 11 of them in mountain top meadow vegetation, eight in mid-mountain dwarf forest, ten in needle-leaf forest, four in needle and broad-leaf mixed forest, two bamboo forest, seven in evergreen broad-leaf forest, and two in cultivated economic forests.

THE CHARACTERISTICS OF THE FLORA

Angiosperms comprise the main part of the Huanggangshan flora. In this class there are about 72 families, 180 genera, 352 species, and 10 varieties. Among these 38 families contain only one genus, making up 52.8% of the total number of families (see Table 1).

In addition, many genera contain one or few species (not over 4 species), making up 89.0% of the total number of genera (see Table 2). This includes 108 genera(60% of the total number of genera) which have only one species and 22 families that contain only one genus and only one species (30.6% of the total number of families).

So the area of Huanggangshan seems to be a marginal region for the distribution of these families and genera. On the other hand, component of the Huanggangshan flora come mainly from the Tropics and Subtropics making up 68% of the total floral component. Among these, phanerophytes with mesophyll coriaceous and herbaceous, entire and single leaves are the main type. The vertical spectrum of plant communities of Huanggangshan is con-

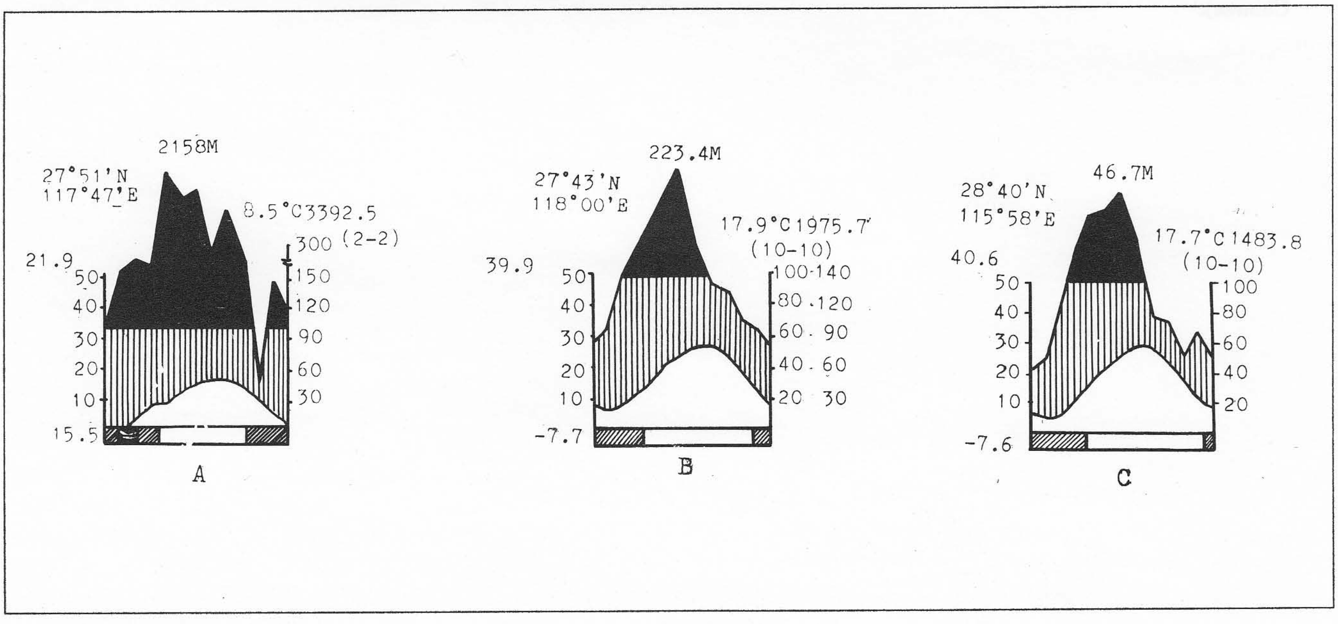

Fig. 1 — Climatic values at the summit of Huanggangshan, Chong-an county of Fujian, and Nan-chang city of Jiangxi. A. The top of Huanggangshan (2158 m above sea level) is at 27° 51' N, 117° 47' E; B. Chong-an county, at eatern foot of Huanggangshan, 223.4 m, is at 27° 43' N, 118° 00' E; C. Nan-chang city, west of Huanggangshan, 46.7 m, is at 28° 40' N, 115° 58' E (cited from "Chinese Vegetation", WU J.Y. *et alii*, 1980).

sidered to be a concentration of the vegetation of the Wuyishan Mountains, situated in the Central Subtropical Climatic of China, and a representative type of Central Subtropical mountainous vegetation, in which the biota is very rich and complex in floristic geobotany. From foot to top of the mountain the total number of pantropical species decreases and the Central Subtropical flora is replaced gradually by the Northern Subtropical flora.

VEGETATION TYPES AND ITS VERTICAL DISTRIBUTION

The region of Huanggangshan is high and broad, the relative height from Chong-an (223 m) to the summit (2158 m) of Huanggangshan is about 1900 m. The average annual temperature drops from 17.0°c to 8.7° C. The temperature difference between both stations was 9.2° c. These differ greatly from each other in relative moisture as well. The complication of geographical features in the area has formed many microhabitats for growing many vegetation types. Based on our observations, the vegetation in Huanggangshan Mountain could be divided into 7 vegetation types and 28 formations as follows:

1. Mountain-top meadow (1800-2158 m): which includes (1) Mesophyte grass meadow (see Fig. 2); (2) Grass meadow with scattered dwarf Pinus taiwanensis; (3) Transition type of meadow from bush to meadow, (4) Boffy meadow (LIN P., YE Q.H., 1985).

Table 1. — Distribution of Genera and Families of Angiospermae of Huaggangshan (LIN Y.R. et al., 1981)

Number of Genera in the Family	1	2	3	4	5	6	12	13	15
Number of Families	38	12	9	3	2	5	1	1	1
Percentage of total Families	52.8	16.6	12.5	4.2	2.8	6.9	1.4	1.4	1.4

Table 2. — Distribution of species and genera of Angiospermae of Huanggangshan.

Number of species in the genus	1	2	3	4	5	6	7	8	10	14
Number of genera	108	36	14	4	3	8	3	2	1	1
Percentage of total genera	60	20	7	2	1.7	4.4	1.7	1.1	0.5	0.5

2. Mid-mountain dwarf forest (1700-1900 m): which includes (1) *Cyclobalanopsis multinervis, Eurya nitida, Rhododendron ovatum* dwarf forest; (2) *Acer amplum, Pyrus calleryana, Styrax japonica* dwarf forest; (3) *Cornus controversa, Litsea cubeba, Fraxinus chinensis* dwarf forest; (4) *Pyrus calleryana* var. *cedanum, Symplocos anomala, Litsea cubeba* dwarf forest; (5) *Symplocos ernestii, Eurya saxicola* dwarf forest; (6) *Styrax japonica, Acer amplum, Buxus sinica* var. *parviflora* dwarf forest (see Fig. 3) (CHEN Z.R., 1983)

3. Needle-leaved forest: which includes (1) *Pinus massoniana* forest (at 200-1200 m above sea level); (2) *Pinus massoniana, Cunninghamia lanceolata* forest (200-1200 m); (3) Mixed forest of *Cunninghamia lanceolata* and *Phyllostachys pubescens* (500-1400 m); (4) *Tsuga chinensis* var. *tchekiangensis* forest (1500-1800 m) (see Fig. 4); and (5) *Pinus taiwanensis* forest (1100-1900 m) (LIN P., YE Q.H., 1984).

4. Needle and broad-leaved mixed forest: which includes (1) *Pinus taiwanensis, Cyclobalanopsis multinervis* forest; (2) *Pinus taiwanensis-Prunus campanulata* forest; (3) *Schima superba-Cunninghamia lanceolata* forest; and (4) *Pinus massoniana, Liquidambar formosana, Schima superba* forest.

5. Deciduous and evergreen broad-leaved mixed forest: which includes (1) *Styrax japonica, Betula lumifera,*

Fig. 2. — Mesophyte grass meadow in Huanggangshan top (1800-1900 m) [Dominants are *Miscanthus sinensis* and *Hemerocallis lilioasphodelus* (Yellow flower)].

Fig. 3. — The Mid-mountain dwarf forest (1800-1900 m) (Dominants: *Styrax japonica*, *Acer amplum* and *Buxus sinica* var. *parviflora* etc.).

Fig. 4. — *Tsuga chinensis* var. *chekiangensis* forest (1500-1800 m, 25 m in height, 100-150 cm in diameter breast-high), a peculiar community in Huanggangshan of Fujian.

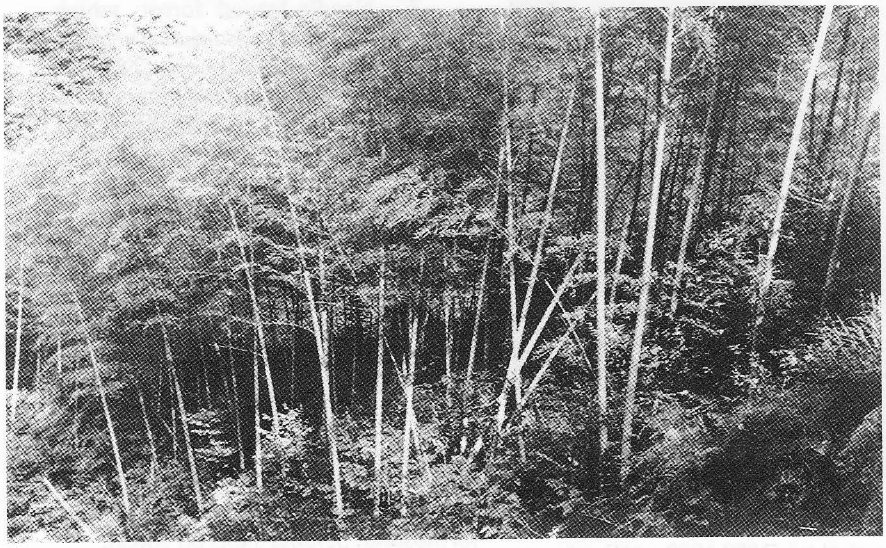

Fig. 5. — *Phyllostachys pubescens* forest (400- 1400 m). The undergrowth is *Hydrange paniculata*, *Eurya* sp., *Liriope platyphylla* etc.

Lithocarpus harlardii forest; and (2) *Quercusfabri-Cyclobalanopsis glauca* forest.

6. Bamboo forest: which includes (1) *Phyllostachys pubescens* forest (see Fig. 5); and (2) *Yushania hirticaulis* (Fig. 6).

7. Evergreen broad-leaved forest: which includes (1) *Schima superba-Cyclobalanopsis glauca* forest; (2) *Castanopsis eurei-Schima superba* forest; (3) *Castanopsis eurei-Phyllostachys pubescens* forest; (4) *Castanopsis fargesii* forest; (5) *Castanopsis tibetana* forest; and (6) *Altingia chinensis* forest, etc. (Huang S.Q. *et alii*, 1984).

In general, Huanggangshan vegetation is divided into 6 primary types and 7 secondary types which form an obvious vertical zonation (Fig. 7). Fig. 6 indicates again the relationship between climatic conditions vegetation in subtropica mountains.

There are many different habitats suitable for living beings, with varied biological characteristics. The incovenience of transportation in this rugged area of high mountains and deep valleys has kept away interference from the out side. Other forests in most places grow in their natural form in various habiatars in Wuyishan Natural Reserve (WYNR), surrounding the region on the Huanggangshan. In this Reserve many valuable or rare species of plants and animals occur. There the abundant biological resources have drawn great attention from biologists at home and abroad. this has been further confirmed by the results of our survey.

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Fig. 6. – Yushania hirticaulis thicket (height 1 m) at the summit (2100 m), an unusual community in Huanggangshan.

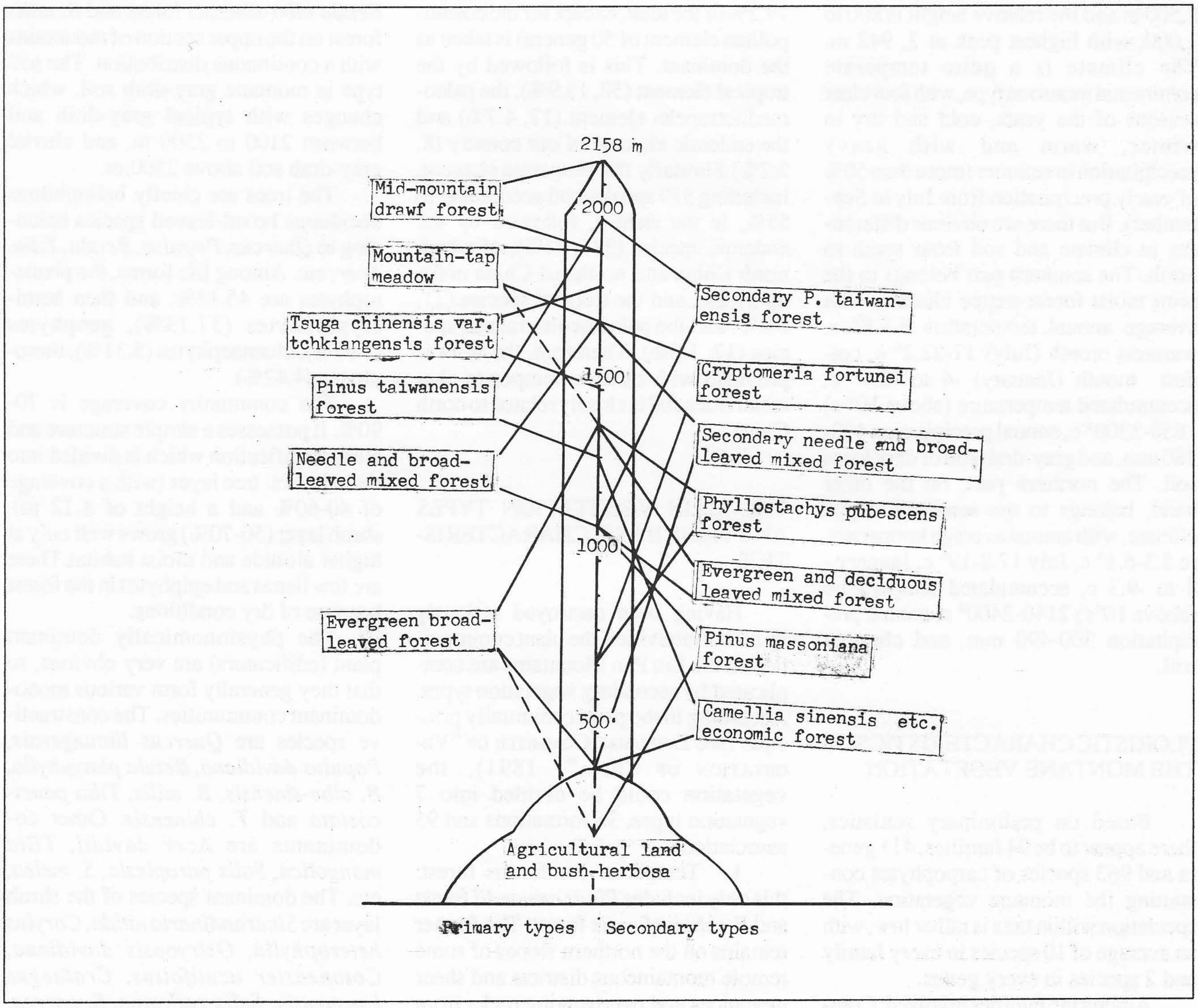

Fig. 7. — Vertical distribution of vegetational types in Huanggangshan mountains.

A STUDY OF THE MONTANE VEGETATION OF THE LIU PAN MOUNTAINS

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Key words: Liu Pan Mountains; Montane vegetation; Montane flora; Cold-temperate coniferous forest; Vertical distribution of vegetation

ECOLOGICAL FACTORS INFLUENCING THE MONTANE VEGETATION

The Liu Pan Mountains, consisting of rocky blocks running north to south and towering over the west of the loess plateau, located at 34° 30' - 36° 30' N and 105° 52' - 106° 43' E. The total area is about 6,500 km², rising gradually from north to south. The absolute elevation is 2,500 m and the relative height is 800 to 1,000, with highest peak at 2, 942 m. The climate is a quite temperate continental monsoon type, with four clear seasons of the years, cold and dry in winter, warm and with heavy precipitation in summer (more than 50% of yearly precipitation from July to September). But there are obvious differences in climate and soil from south to north. The southern part belongs to the semi moist forest-steppe climate, with average annual temperature 6-9.8° c, warmest month (July) 17-22.2° c, coldest month (January) -4 to -8.4° c, accumulated temperature (above 10° c) 1850-3300° c, annual precipitation 490-580 mm, and gray-drab soil or dark loess soil. The northern part, on the other hand, belongs to the semiarid steppe climate, with annual average temperature 5.3-6.1° c, July 17.8-19° c, January -8 to -9.3 c, accumulated temperature (above 10°c) 2140-2400° c, annual precipitation 300-490 mm, and chestnut soil.

FLORISTIC CHARACTERISTICS OF THE MONTANE VEGETATION

Based on preliminary statistics, there appear to be 94 families, 411 genera and 963 species of carpophytes constiuting the montane vegetation. The speciation within taxa is rather low, with an average of 10 species in every family and 2 species in every genus.

Among the families involved, Compositae (including 42 genera and 100 species) and Rosaceae (24/100) possess the most species, and then Gramineae (34/70), *Leguminosae* (19/60), Ranunculaceae (15/56), Labiatae (20/39), Liliaceae (18/37), Caprifoliaceae (5/35), Cyperaceae (4/30), Umbrelliferae (18/27), Saxifragaceae (9/22), Caryophyllaceae (10/21), *Polygonaceae* (4/21) Scrophulariaceae (9/20) etc. These fourteen families include 232 genra and 638 species, which make up 14.9%, 56.5% and 66.3% of the respective totals. Among the genera, *Lonicera* (including 25 species and making up 2.6% of the total) and *Carex* (23, 2.4%) possess the most species, and then *Salix* (18, 1.9%), *Evonymus* (16, 1.7%), *Prunus* (15, 1.6%), *Potentilla* (15, 1.6%), *Artemisia* (14, 1.5%), *Polygonum* (14, 1.5%), *Cotoneaster* (13, 1.4%), *Rosa* (12, 1.3%), *Acanthopanax* (11, 1.1%), *Acer* (11, 1.1%), *Rubus* (10, 1.0%) *Astragalus* (10, 1.0%), etc. These fourteen genera only account for 3.4% of the total but include 207 species accounting for 21.5% of the total.

Based on the statistics of the geobotanical elements the temperate element (including 286 genera and making up 79.2% of the total, except for the cosmopolitan element of 50 genera) is taken as the dominant. This is followed by the tropical element (50, 13.9%), the paleomediterranean element (17, 4.7%) and the endemic element of our country (8, 2.2%). Similarly the temperate element, including 519 species and accounting to 55%, is the richest, followed by the endemic species (387, 41%), of which north China and northeast China make up 51.2%, and the tropical species (21, 2.2%) and the paleomediterranean species (17, 1.8%). Therefore, the flora is provided with obvious temperate characteristics and is closely related to north China.

THE MAIN VEGETATION TYPES AND THEIR BASIC CHARACTERISTICS

Having been destroyed seriously by human activities, the plant communities on the Liu Pan Mountains are complicated by secondary vegetation types. According to the plant community principle (see Editorial Commitee of "Vegetation of China", 1891), the vegetation could be divided into 7 vegetation types, 36 formations and 95 associations.

1. Temperate coniferous forest: this only includes *Pinus armandii* forest and *P. tabulaeformis* forest. The former remains on the northern slopes of some remote montaineous districts and sheer precipices and overhanging rocks from 2000 to 2500 m with, typical gray-drab soil. Since its northern limit is situated in the Xi-lan Road, this type only occurs in the southern part of the region. *P. tabulaeformis* survives on the northern slopes of the Xu Mi Mount from 1700 to 2100 m, but its area is very small at present.

The community coverage is 80-90%, and height is 10-15 m. *Pinus tabulaeformis*' importance value is 300, so it forms the community as a single dominant. *P. armandii*'s importance value is 150-200 in the tree layer, mixed with *Tilia chinensis*, *Quercus liaotungensis*, etc. *Sinarundinaria nitida* in shrub layer predominantes absolutely with a coverage of 40-50% and a height of 1-2 m. Other co-dominants are *Corylus heterophylla*, *Smilax stans*, *Pertya discolor*, etc. Herb species are very few and the coverage is only 5-10%. But bryophytes grow well and the coverage is 40-70%.

2. Deciduous broad-leaved forest occurs on the northern slopes below 2300 m and on all slopes above 2300 m Many forest types were replaced by secondary scrub or meadow, so that most of them occur sporadically, except for *Betula albo-sinensis* forest and *B. utilis* forest on the upper section of mountains with a continuous distribution. The soil type is montane gray-drab soil, which changes with typical gray-drab soil between 2100 to 2500 m, and eluvial gray-drab soil above 2500 m.

The trees are chiefly heliophilous deciduous broad-leaved species belonging to *Quercus*, *Populus*, *Betula*, *Tilia*, *Acer*, etc. Among life forms, the phanerophytes are 45.13%, and then hemicryptophytes (37.13%), geophytes (7.97%), chamaephytes (5.31%), therophytes (4.42%).

The community coverage is 70-90%. It possesses a simple structure and clear stratification which is divided into three layers: tree layer (with a coverage of 40-60% and a height of 8-12 m), shrub layer (50-70%) grows well only at higher altitude and moist habitat. There are few lianas and epiphytes in the forest because of dry conditions.

The physionomically dominant plant (edificators) are very obvious, so that they generally form various monodominant communities. The constructive species are *Quercus liatungensis*, *Populus davidiana*, *Betula platyphylla*, *B. albo-sinensis*, *B. utilis*, *Tilia paucicostata* and *T. chinensis*. Other codominants are *Acer davidii*, *Tilia mongolica*, *Salix paraplesia*, *S. melea*, etc. The dominant species of the shrub layer are *Sinarandinaria nitida*, *Corylus heterophylla*, *Ostryopsis davidiana*, *Cotoneaster acutifolius*, *Crataegus kansuensis*, *Salix cathyana*, *S. caprea*, etc. The herb layers consists of *Brachypodium sylvaticum*, *Carex hancokiana*, *C. siderosticta*, *Epimedium brevicornum*, *Pteridium aquili-*

num var. *latiusculum*, etc.

3. Evergreen bamboo scrub: *Sinarundinaria nitida* is a main dominant of the shrub layer in the forest above 2000 m and has specific characteristics of rhizome propagation. When a forest is destroyed bamboo is suited to the changed habitat and forms a secondary scrub type.

The community coverage is 70-90%. The dominant od the scrub, with a coverage of 50-70% and a height of 1-2 m, is *Sinarundinaria nitida*. The subdominants are *Salix cathayana, Corylus heterophylla, Cotoneaster multiflorus*, etc.

4. deciduous broad-leaved scrub: Most scrub is of a secondary type which replaces the destroyed forest, except for more stable primary community types including *Salix cheilophila* scrub in ravines in moist habitat and *Hippophae rhamoides* on mointainous ridges in dry habitat. *Ostryopsis davidiana* scrub, *Corylus heretophylla* scrub, etc. occur on northern slopes below 2200 m. *Berberis circumserrata* scrub, *Rosa omeiensis* scrub, etc. are scattered on southern slopes from 2300 to 2800 m. *Salix cathayana* scrub, etc. is scattered on northern slopes above 2000 m.

The life-form components, in descending order are phanerophytes (45.13%) hemycryptophytes (37.1%), geophytes (7.97%), chamaephytes (5.31%) and therophytes (4.42%). The species saturation is only 15-20 species per square metre.

The community coverage is 70-90% and height is 1-2 m. The subdominants forming the shrub layer, with a coverage of 50-80%, are *Rosa hugonis, Crataegus kansuensis, Berberis kansuensis, Sorbaria kirilowii, Rubus pungens*, etc. The dominants in the herb layer, with a coverage of 40-70% and a height of 20-50 cm, are *Brachypodium sylvaticum, Carex sp., Artemisia gmelinii, Saussurea epilobioides, Cacalia roborowskii*, etc.

5. Steppe: The steppe vegetation on the Liu Pan Mountains develops very well and changes from the meadow steppe in the southern part to the typical steppe in the northern part. The former, with dark loess soil, occurs on southern slopes below 2300 m. The latter, with chestnut soil, occurs or all slopes below 1800 m and on southern slopes above 1800 m. The desert steppe (*Stipa gobica* steppe) only occurs on southern slopes between 1700-1800 m of the Xu Mi Mount, near the desert steppe region.

Stipa has 6 species in the steppe vegetation: *S. baicalensis, S. przewalskyi, S. grandis, S. bungeana, S. brevifolia, S. gobica*. These form various zonal steppe types. Especially, *S. baicalensis* meadow-steppe is a specific type within the eastern forest-steppe zone, belonging the Eurasian steppe region. It was reported that the steppe was limited to northeast China, but in fact this type extends in a narrow belt to the west side of the loess plateau, along the east part of the Nei Menggu plateau, and has been discovered in the southern part of the Liu Pan Mountains, in which it occurs widely on southern slopes from 1800 to 2300 m. It is important to recognize the quality of the Liu Pan Mountain steppe and to determine the boundary between forest and steppe zones in the vegetation division of the western part of the loess plateau.

The life-form components, in descending order, are hemicryptophytes (66.16%), microphanerophytes (16.54%), geophytes (6.8%), chamaephytes (6.0%); and therophytes (4.5%). The mesic-xerophytes and the xero-mesophytes make up 60.9% of the hydro-ecological types, with the exception of some typical xerophytes (25.6%) and mesophytes (13.5%).

Species all decrease gradually saturation, vegetation cover and biomass from south to north, with the increasing dryness of the climate (Table 1).

6. Meadow: Meadows are mainly secondary types which replace the destroyed forest and scrub, except for primary types occurring in ravines and floodplains, such as *Ligularia duciformis* meadow. The community cover is 80-90%, and haight is 30-50 cm. The species saturation is 18-22 species per square metre.

The main meadow types are *Brachypodium sylvaticum* meadow, *Roegneria purpurascens* meadow, *Saussurea iodostegia* meadow, *Pteridium aquilinum* var. *latiusculum* meadow and *Carex sp.* meadow, etc. The subdominants of the above communities are *Ligularia virgaurea, Elymus nutans, Leontopodium calocephalum, Saussurea glomerata, S. amara*, and so on.

7. Desert: There is only the *Ammopiptanthus mongolicus* shrub-desert, occurs sporidically on southern slopes from 1700-1800 m of Xu Mi Mountain, belonging to the northern typical-steppe zone. The biotope has dry characteristics with exposed surface and poor soil. The distribution of *Ammopiptanthus mongolicus* and of this vegetation type in region was reported only recently. It is of very important scientific value to study the origin, development and evolution of the flora and vegetation of the region.

The community characteristics are species, low biomass and simple structure, with a coverage of few 30-40% and a height of 20-50 cm.

THE QUESTION OF THE MONTANE COLD-TEMPERATURE CONIFEROUS FOREST

In this paper, the following attests to the existence of cold-temperate coniferous forest on the Liu Pan Mountains in the past.

1. From buried ancient trees which were dug out from underground, such as *Picea, Abies* and *Larix*; *Picea* constitutes the major portion and is found chiefly in the southern, remote part of the region. According to C-14 dating, they were buried 7130±80 to 8900±120 years ago. They must have been big trees, 20 metre high, so they had not been carried in from outside.

2. Based on pollen analysis of quadrats No.1 and No.2, the pollen of *Picea* and *Abies* has been identified. The result is identical with ancient trees.

3. Generally speaking, spruce and fir require definite water-heat conditions as follows (LI WEN-HUA and ZHOU PEI-CUN, 1981): average temperature 10° c to 15° c in the warmest month and above 600 mm annual precipitation. Based on the horizontal distribution pattern of spruce and fir in the surrounding areas, such as the He Lan Mountains on the north, *Picea crassifolia* forest

Table 1. — Simple comparison of the three subtypes of steppe

vegetation subtype typical formation	meadow steppe *Stipa baicalensis* steppe	typical steppe *Stipa grandis* steppe	desert steppe *Stipa gobica* steppe
coverage (%)	70-80	50-60	20-30
average biomass (fresh) (Jin/Mu)	500-600	400-500	< 150
all the registered species	95	84	55
average species per square metre (species/m²)	15-18	12-15	8-10

occurred on the northern slopes from 2200 to 3100 m; in the Xin Long Mountains on the west, *Picea wilsonii* forest and *P. crassifolia* forest occurred on the northern slopes from 2200 to 3100 m; on Mount Tai bai to the south, forest types consisting of *Abies* and *Larix* occurred on the northern slopes from 2600 to 3350 m. A cold-temperate coniferous forest must have existed once also on the Liu Pan Mountains owing to the high altitude (about 2800 m) and appropriate ecological conditions.

4. The forests existing on the upper section of the region are *Populus davidiana* forest, *Betula platyphylla forest* and *B. albo-sinensis* forest etc. By analysing the succession tendency and regeneration process of the spruce-fir forest on the northern mountains of our country, especially in the above areas, it is seen that aspen and birch are often pioneers after the coniferous forest was destroyed and rapidly from secondary communities. They still preserve the typical ground plants existing in the montane cold-temperate coniferous forest, such as *Maianthemum bifolium, Pedicularis muscicola, Sinarundinaria nitida*, etc.

According to the above discussion it is obvious that the montane cold-temperate coniferous forest consisting of spruce and fir must have existed on the Liu Pan Mountains and had been destroyed by human activities in the past. By mathematical modeling and ecological analysing, it is determined that the species making up the spuce-fir forest are *Picea wilsonii* and *P. crassifolia* and that the lower limit of the type is 2300 m.

THE VERTICAL DISTRIBUTION OF MONTANE VEGETATION

In dividing the vertical belt of vegetation so as to really show the regularity of geographical distribution we not only consider the typicla climatic climax but also the characteristics of every community and their combinations.

because the horizontal chages of the ecological factors are very obvoius, the horizontal zones of vegetation change gradually from forest-steppe to typical steppe. The spectra of vertical belts are corrispondingly different.

(1) The forest-steppe belt: the upper limit is about 2300 m. *Quercus liaotungensis* forest is a main type on the northern slopes. The steppe types consist of *Stipa baicalensis* steppe, *S. przewalskyi* steppe and *Bothriochloa ischaemum* steppe on the southern slopes.

(2) The montane cold temperate coniferous forest-deciduous broad-leaved forest belt: this occurs from 2300 to 2943 m. According to the above discussion, the vegetation type on the northern slope was the cold-temperate coniferous forest which consisted of *Picea wilsonii, P. crassifolia*, etc. before destruction by humans. But there are *Populus davidiana* forest, *Betula platyphylla* forest, *B. albo-sinensis* forest and *B. utilis* forest on the same slopes nowdays. Besides *Pinus armandii* forest and *P. tabulaeformis* forest, the deciduous broad-leaved forest chiefly consisting of *Quercus liaotungensis* occurs on the southern slopes.

2. Vertical vegetation distribution in the north

(1) The typical steppe belt: The upper limit is about 1800 m. *Stipa grandis* steppe is not only a main type on the northern slopes, but also occurs on the upper parts of southern slopes as well as *Stipa bungeana* steppe on the lower parts of the same slopes.

(2) The montane forest-steppe belt: The lower limit is about 1800 m. *Quercus liaotungensis* forest is a typical type. *Stipa grandis* steppe ia a main community on the southern slopes.

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CHARACTERISTICS OF THE VEGETATION IN MOUNTAINOUS AREAS AND THEIR VERTICAL DISTRIBUTION IN YUNNAN PROVINCE

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Key words: Yunnan, Vegetation, Vertical distribution

Yunnan Province is situated near the southwestern border of China and is known for its complexity and diversity of physical geographical environments and many plant species. The whole province occupies an area of about 394,000 km², mountainous areas taking up 94%.

The topography of Yunnan is high in the north and low in the south, the altitude decreasing with latitude. Due the deep cutting of the rivers, the topography changes intricately creating extreme diversity of habitats. The climate of the mountainous plateau is under the influence of tropical monsoons, and therefore tropical and subtropical evergreen forests have developed

GENERAL CHARACTERISTICS OF YUNNAN'S MOUNTAINOUS AREAS

The tropical region of Yunnan belongs to the northern most part of the tropical zone, both in distribution of vegetation and in geographic position. But in the subtropical region, the distribution area of evergreen broad-leaved forest is wide and the types are abundant.

It is indispensable to analyse the character of the vertical vegetation zonation and its main types, when studying the distribution regularity of the vegetation of Yunnan. The complexity and diversity of the vegetation of Yunnan is due to the mountainous areas.

The mountains of Yunnan are undulating and stretch very far. The elevation of the mountains decreases with the latitude from north to south. Alpine areas with elevation exceeding 5,000 m, are concentrated in NW Yunnan; most of the other regions are covered by mountains with elevation not exceeding 3,200 m. Generally, the relative height of the mountains is lower around basins but higher on the sides of river valleys. The main vegetation type forming the vertical zonation, though, are always found whithin a certain range of elevation.

VERTICAL DISTRIBUTION OF VEGETATION IN YUNNAN

1. In the tropical zone of Yunnan (south of 23° 30' N, basin elevation below 900 m, in SW Yunnan rising to 25°N, basin elevation 960 m), there are two kinds of vertical vegetation zonation:

A. The wet sequence occurs in SE Yunnan, which is the distributional region of the humid rainforest.

Below an altitude of 300-500 m, tropical humid rainforest: mainly *Dipterocarpus tonkinensis*, *Hopea mollissima*, *Crypteronia paniculata* Comm.

300-700 m, tropical seasonal rainforest mainly *Terminalia myriocarpa*, *Pometia tomentosa* Comm.

700-1,300 m montane rainforests mainly *Madhuca pasquieri*, *Altingia yunnanensis* Comm.

1,300-1,750 monsoon evergreen broad-leaved forests mainly *Castanopsis hystrix*, *Manglietalia fordiana* Comm.

1,700-2,900 m moss evergreen broad-leaved forests mainly *Rhodoleia parvipetala*, *Machilus* spp., *Lithocarpus* spp. Comm.

2,700-2,900 m, moss evergreen coppice on the mountain topo composed of the species of *Rhododendron*, *Vaccinium*, *Lyonia* and *Gaultheria*, etc.

B. A different sequence of vertical vegetation belts occurs in the region west of Mt. Ailaoshan. The climate of this region is on the dry side, and only a few of the mountains go beyond the altitude of 2,000 m. Therefore, the vertical vegetation sequence is rather simple:

Below an altitude of 800-900 m, tropical seasonal rainforests mainly *Antiaris toxicarta*, *Pouteria grandifolia*, *Canarium album* Comm.

800-1,000 m montane rainforests mainly *Semecarpus reticulata*, *Phoebe nanmu*, *Dysoxylon spicatum* Comm.

Above 1,000-1,100 m montane monsoon evergreen broad-leaved forests *Castanopsis indica*, *Schima wallichii* Comm.

2. In the subtropical zone of Yunnan the vertical vegetation zonation can be divided into two parts:

A. In the southern part of the subtropical zone the vertical sequence of vegetation is:

1,200-1,800 m, monsoon evergreen broad-leaved forests *Castanopsis*, *Lithocarpus* forest and *Pinus kesiya* var. *langbianensis* forest.

1,800-2,500 m, humid evergreen broad-leaved forests *Lithocarpus forest*.

2,400-2,800 m, mossy evergreen forest and *Tsuga dumosa* forest.

2,800-3,000 m, mossy evergreen eltin forest

Above 3,000 m, *Abies delavayi* forest.

B. The vertical sequence in the northernpart of the subtropical zone is:

1,600-1,900-2,500 m, semi-humid evergreen broad-forests *Castanopsis*, *Cyclobalanopsis* forest.

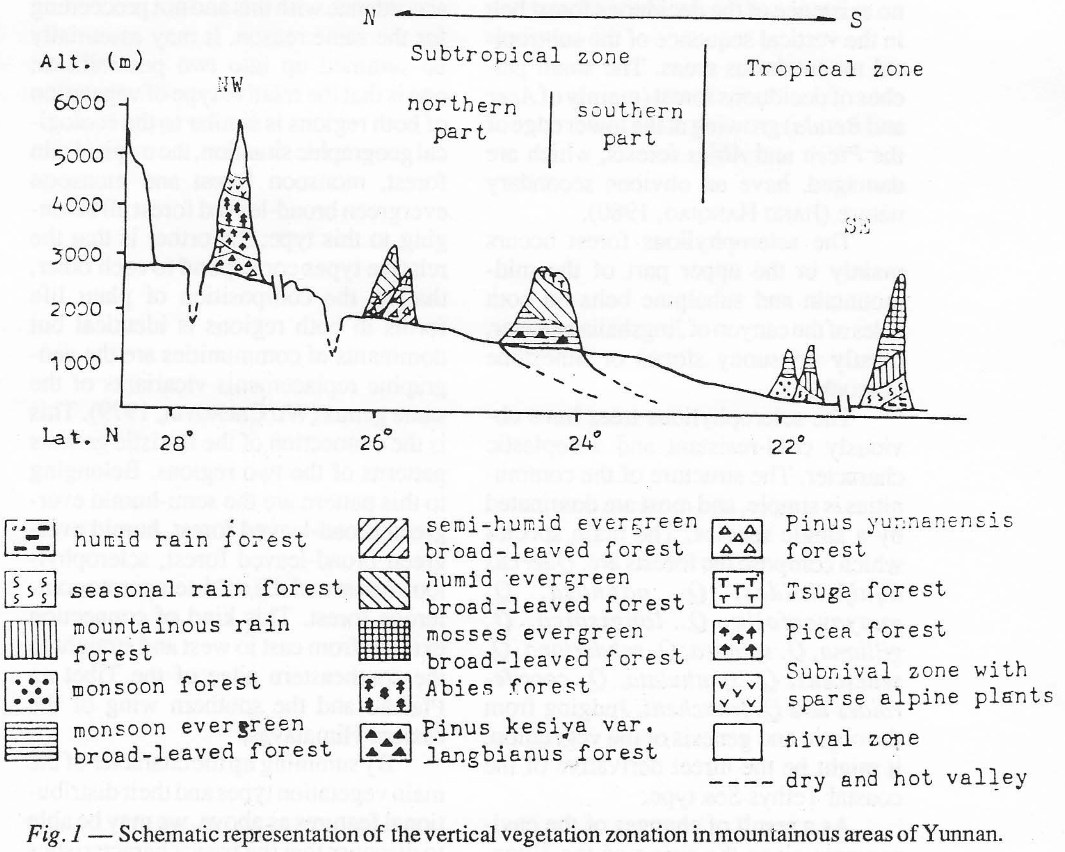

Fig. 1 — Schematic representation of the vertical vegetation zonation in mountainous areas of Yunnan.

2,500-2,900 m, humid evergreen broad-leaved forests dominated by *Lithocarpus*, but species differ in different mountains.

2,900-3,200 m, *Tsuga dumosa* forest and coniferous mixed forest.

3,100-4,100 m, mainly *Picea likiangensis* forest and *Abies georgei* forest.

4,100-4,700 m, alpine thicket and alpine meadow.

In this series there are also cross distributions of three types, namely the *Pinus densata* forest (3,000-3,400 m), *Larix potaninii* var. *macrocarpa* forest (3,600-4,200 m) and sclerophyllous forest (dominated by *Quercus* spp.) in the mid-mountain and subalpine belts.

It can been seen from the above that, in the tropical zone of Yunnan, the representative type in the mountains is the montane rainforest, and in the subtropical zone, the humid evergreen broad-leaved forest. In the southern part of the subtropical zone, the humid evergreen broad-leaved forest occurs in mountainous regions with an elevation of 2,400-2,800 m; in the northern part of subtropical zone, it occurs at 2,900-3,200 m. From south to north, the elevation of this distribution increases, and this is related to the elevation of the base level of the horizontal zone. But, the subtropical zone being regarded as a natural region, the vertical sequence on mountain vegetation is fundamentally identical with the umid evergreen broad-leaved forest upwards.

It should be pointed out that there is no existence of the deciduous forest belt in the vertical sequence of the subtropical mountainous areas. The small patches of deciduous forest (mainly of *Acer* and *Betula*) growing at the lower edge of the *Picea* and *Abies* forests, which are damaged, have an obvious secondary nature (Jiang Hanqiao, 1980).

The sclerophyllous forest occurs mainly in the upper part of the mid-mountain and subalpine belts on both sides of the canyon of Jingshaiiang River, mostly on sunny slopes or limestone bedrock.

The sclerophyllous trees have obviously cold-resistant and xeroplastic character. The structure of the communities is simple, and most are dominated by a single species. The main species which compose the forests are: *Quercus aquifolioides*, *Q. pannosa*, *Q. guayavaefolia*, *Q. longispica*, *Q. gilliana*, *Q. spinosa*, *Q. rehderiana*, *Q. senescens*, *Q. spathulata*, *Q. cocciferoides* and *Q. franchetii*. Judging from the origin and genesis of the vegetation, it might be the direct derivative of the coastal Tethys Sea type.

As a result of changes of the environment since the rising of the Himalayas (Vegetation of China, 1980), differentiations and new adaptation have been produced.

The *Pinus yunnanensis* forest is closely connected in distribution with the semi-humid evergreen broad-leaved forest.

The Yunnan Plateau is the distribution center of *P. yunnanensis* (Wu Chengyih, 1979), but this species has great capacity of ecological adaptation in its distribution areas, which can be found at an altitude of 800-3,200 m. Research conducted in recent years shows that *P. yunnanensis* is a species with multiple forms, which indicates that differentiation of the species is going on under conditions of diversified habitats in mountainous areas.

BASIC CHARACTERISTICS OF VEGETATION IN YUNNAN

According to studies of relations between the nature of the main vegetation types of Yunnan and that of the surrounding regions, a demarcation from northwest to southeast can be made along a line from Mt. Yunling, Mt. Cangshan to the Ailaoshan Mountain Range. East of this line, the main vegetation types are related to those of eastern regions of China; west of this line, the vegetation is more like that of eastern Nepal (see M. Ohsawa, 1983) and the upper-Burmese region, where the elevation is lower.

The connection between Yunnan and its neighbouring regions is not in accordance with this and not proceeding for the same reason. It may essentially be summed up into two possibilities: one is that the relative type of vegetation of both regions is similar to the ecological geographic situation, the tropical rain forest, monsoon forest and monsoon evergreen broad-leaved forest all belonging to this type; the orther is that the relative types correspond to each other, that is, the composition of plant life forms in both regions is identical but dominants of communities are the geographic replacements vicariants of the same genus (Wu Chengyih, 1979). This is the connection of the floristic genesis patterns of the two regions. Belonging to this pattern are the semi-humid evergreen broad-leaved forest, humid evergreen broad-leaved forest, sclerophyllous forest and the cold-temperate coniferous forest. This kind of connection extends from east to west and straight to the southeastern edge of the Tibet an Plateau and the southern wing of the eastern Himalayas.

By summing up the character of the main vegetation types and their distributional features as above, we may be able to discover that the basic characteristics of the vegetation in Yunnan, in terms of vegetation geography, lie in its transitional nature. That is the vegetation of Yunnan represents the joining and transition from East Asia to South Asia, and from the Tibetan Plateau to South-mid Peninsula, as a consequence of spatial change of the tropical monsoon and the mountainous of old vegetation types and relics but also a unique ground for the transition of vegetation types (Jiang Hanqiao, 1985). It is the vegetation types and plant species are rich and varied in Yunnan.

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THE NATURAL VEGETATION TYPES OF YUNNAN, CHINA

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Key words: Vegetation of China, Yunnan, Vegetation belts

PHYSICAL ENVIRONMENT

Geographic position

Yunnan is situated in the southwestern part of China, at about 21° 09' - 29° 15' N (north latitude) and 97° 39' - 106°12' E (east longitude). It extends about 885 km from east to west and 910 km from south to north. Yunnan is bordered by Sichuan to the north, Guizhou and Guangxi to the east, Xizang (Tibet) at the northwest corner, Burma to the west and southwest, and Laos and Vietnam to the south and southeast. The boundary of Yunnan is over 3,000 km long. The total area of Yunnan is about 394,000 km², just smaller than France, bigger than England or Italy, and close to Poland or Spain. Yunnan is the eighth largest of the 29 Provinces of China (Fig. 1)

Landforms

Yunnan is a mountainous province. Of the total area, 85% is mountains, 10% is plateau with many hills, and only 6% is basin or river valley. Kunming is located in the largest plateau basin. The land surface of Yunnan, higher in the northwest and lower in the southeast, may be divided into three levels or "steps". The first one, about 2,500-3,000 m in the northwest part, includes the Yulong snow mountain (5,590 m), Haba snow mountain (5,390 m), Beimang snow mountain (5,130 m), and their foothills (2,500-3,000 m). The second step, about 1,300-2,200 m in the middle-east, represents the main territory of the Yunnan Plateau, including Kunming City. The third step, about 500-900 m in the south, has lower mountains, hills and basins, including the famous tropical region Xishuangbanna. The highest point in the whole province is the summit of Meili snow mountain in the northwest (6740 m), and the lowest point is in the Hekou river valley along the southeast boundary (74 m), a difference from north to south of 6,666 m. Large river systems spread throughout the province, for example the Jinsa river (a part of the Yangtze river), Langcang river (Mekong river), Nu river (Salween river), Nampang river (Pearl river) and so on. There are also many limestone hills and Karst landforms in the east and southeast of Yunnan, a typical example of which is the well known "Limestone Forest" about 150 km east of Kunming City.

Climate

The climate of Yunnan in quite varied from north to south. Even on a high mountain in one region, the climate changes regularly from upper to lower levels. In general, the climate types correspond to the elevation above sea level, for example a temperate montane climate at 2,300-3,900 m; a cold montane climate above 3,900 m; a subtropical climate from 2,300 m to 900 m; and a tropical climate below 900 m. The main region of Yunnan is situated between 900 m and 2,300 m, so the main climate type is subtropical and is called "subtropical monsoon plateau climate". Its yearly mean air temperature ranges between 15° and 20° C, with yearly precipitation from 1,000 to 1,500 mm. Below 900 m, in southern Yunnan, the climate is called "tropical montane monsoon climate", with yearly mean air temperature 20°-24° C and yearly precipitation 1,500-1,800 mm. The Yunnan climates are also divided into a rainy season from July to October and a dry season from December to May, with 80% of the precipitation concentrated in the rainy season. Kunming City is located in the middle part of Yunnan, with a climate between the subtropical and temperate types. It is not hot in summer, not cold in winter, very warm all year, and has been called "four seasons like spring" or "Spring City" (Fig. 2).

A GENERAL OUTLINE OF NATURAL VEGETATION

The vegetation of Yunnan has been deeply influenced by various types of landforms and climate. Landforms bring about different types of meso- and micro-climate, and the latter directly influence the vegetation. On the other hand, the current situation of Yunnan vegetation was affected by the development of the flora and the distribution of the existing plants. They were also affected by human economic activity and the development of agriculture.

As for the natural vegetation, because the bioclimatic belts change in sequence from south to north or from low to high altitude (correspondingly), the vegetation of Yunnan shows the following major classes: tropical, subtropical, temperate and microthermal (cold). Of these, the largest area is covered by the subtropical vegetation. These general vegetation classes and their respective regions and formations can be described as follows.

Tropical vegetation: mainly the tropical rainforest and monsoon forest, occurring in the southern region near the Tropic of Cancer, below alt. 900 m, including Xishuangbanna in the south, Hekou in the southeast, and Yinjiang in the southwest. The major part of the vegetation in these regions had been destroyed, resulting in secondary forests, but there are still a few virgin forests to be protected, including some types of tropical rainforest near the Yunnan Institute of Tropical Botany (Academia Sinica).

(1) The tropical rainforest of Yunnan is closely connected with the vegetation types of Southeast Asia, representing their northernmost form. One of its characteristics is the presence of some species of Dipterocarpaceae, such as *Dipterocarpus* (3 sp.), *Hopea* (2 sp.), *Parashorea chinensis* (so called "look-up-to-the-sky tree"), which have been preserved at a large area of virgin forest in Xishuangbanna. This forest has a canopy 40-50 m high, individuals of 70 m, and is very rich in its floristic component. There are also many other tropical plant families in the rainforest, such as Myristicaceae, Sapotaceae, Annonaceae, Guttiferae, Combretaceae, Samydaceae, etc. The ecological features are very distinct, such as buttress roots, aerial roots, stranglers, cauliflory, etc.

(2) The second tropical forest type is the monsoon forest, mainly occurring along the dry hot valleys or canyons in the southern part of Yunnan. Virgin forests are very rare because of human agricultural activity, after which the regrowth is slower than that of other types of tropical forest. The main ecological feature is the presence of many tree species which drop their leaves in the dry season, always appearing in the upper layer (not over 30 m high) and having flowers of beautiful colours. The main tree species (including their plant families) are Bombacaceae (*Bombax malabaricum*), Sonneratiaceae (*Duabanga grandiflora*), Bignoniaceae (*Sterospermum tetragonum, Oroxylum indicum*), Mimosaceae (*Albizia chinensis, Acacia* spp.), Lythraceae (*Lagerstroemia intermedia*), etc.

Subtropical vegetation: widely distributed in the middle and southern mountains of Yunnan.

(1) Subtropical evergreen broad-leaved forest: now this only has a limited area, due to human influence. Its main features are that the upper layer of this forest consists of many tree species of the families Fagaceae, Lauraceae, Theaceae, and Magnoliaceae; their leaves are mostly of medium size,

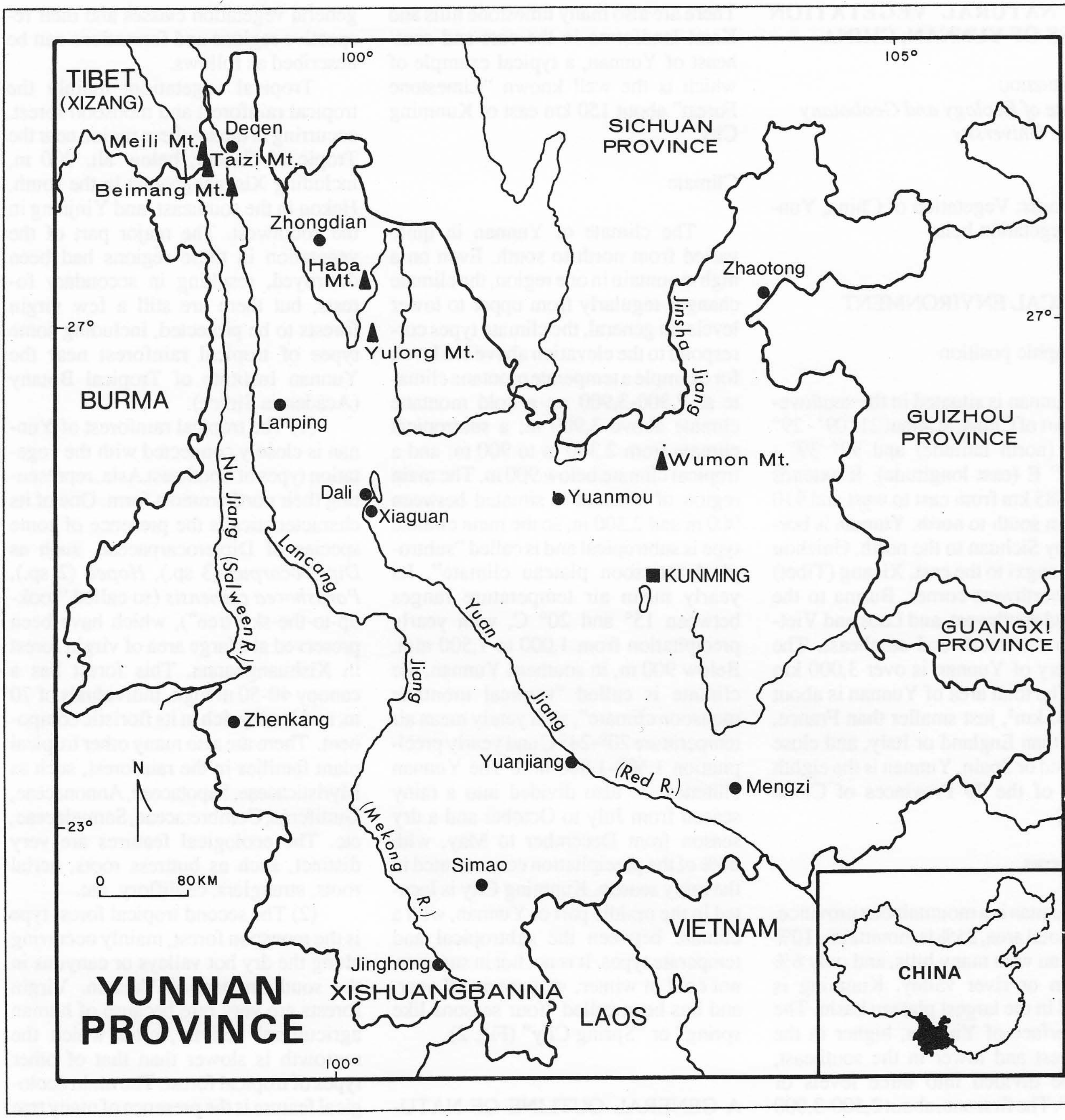


Fig. 1 — Geografic position of Yunnan.

coriaceous, elliptic and glabrous; and the upper trees are about 20 m high, with thick bark, no buttresses, and no cauliflory. The four families cited above have many important genera, such as *Castanopsis*, *Lithocarpus*, *Cyclobalanopsis*, *Schima*, *Ternstroemia*, *Camellia*, *Machilus* (*Persea*), *Litsea*, *Lindera*, *Cinnamomum*, *Magnolia*, *Michelia*, *Manglietia*, etc. Others are Araliaceae (*Schefflera*), Aquifoliaceae (*Ilex*), Hamamelidaceae (*Altingia*, *Exbucklandia*), etc. The floristic component of this forest differs very widely, for this vegetation type originally had a wide distribution. The general pattern seems to be more temperate deciduous components in the northern and higher regions and more tropical floristic components in southern and lower regions.

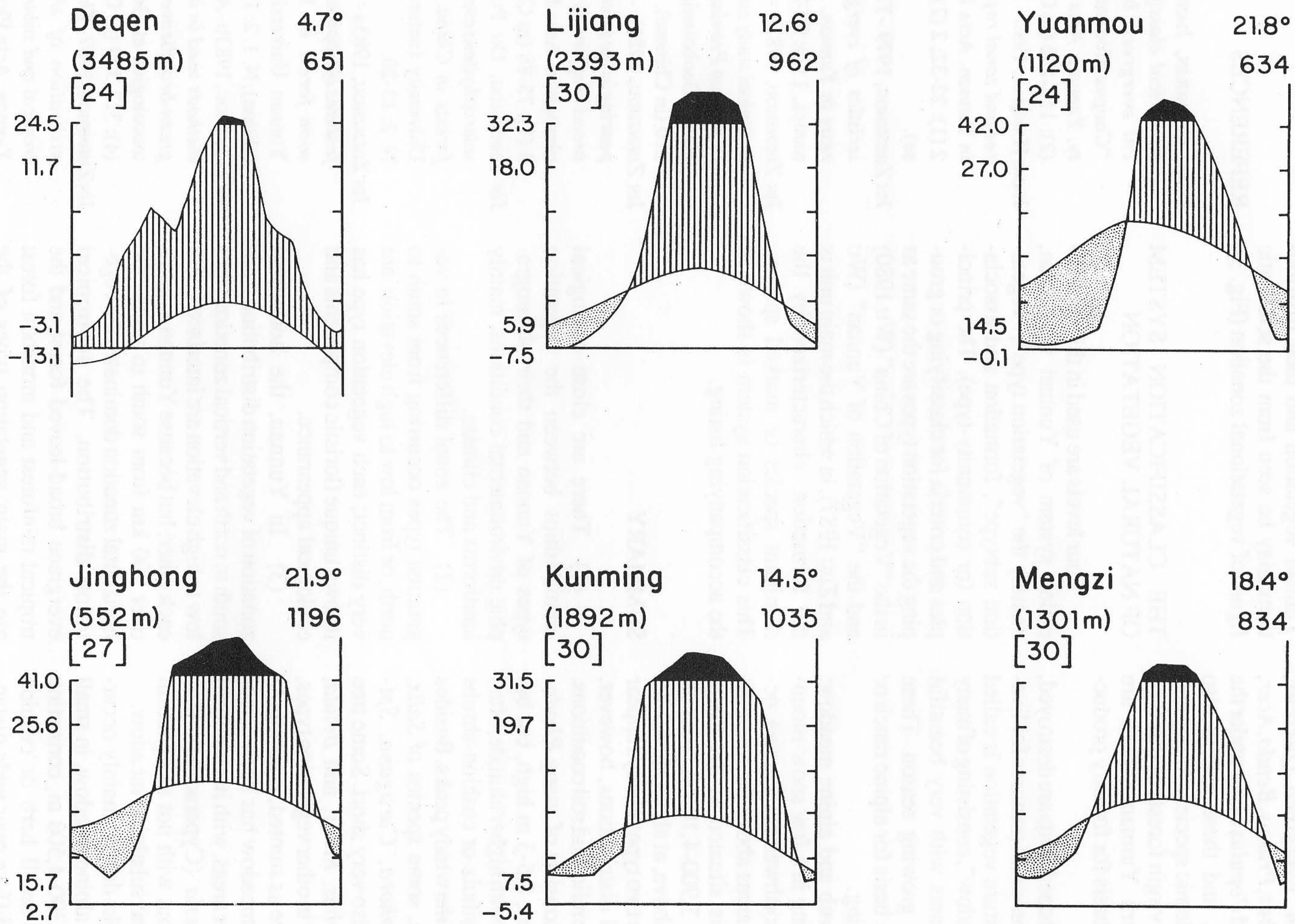
(2) Subtropical evergreen coniferous forest: this has many sub-types, is widely distributed, and occupies a very large area, mostly secondary forests, (i.e., successional to the evergreen broad-leaved forests that had been destroyed before). The main type is Yunnan pine forest, consisting of *Pinus yunnanensis*, has its largest area in the middle, northern, western, and eastern parts of Yunnan. The next type is Simao pine forest, consisting of *Pinus kesiya* var. *longbianensis*, mainly occurring in the south. Both coniferous forest types are monodominant forests. In addition to them, there are many forests which have only small areas in all parts of Yunnan. In their upper layer there occur as dominants some species endemic to China or Yunnan, including *Keteleeria evelyniana*, *Cunninghamia lanceolata*, *Pinus armandi*, *Cupressus duclouxiana*, *Taiwania flousiana*, *Calocedrus macrolepis*, etc.

Montane coniferous and broad-leaved mixed forest: mainly the transitional or intermediate type between evergreen broad-leaved forest and the higher-situated subalpine coniferous forest. These forests occur around 2,300-2,800 m and have temperate ecological features, for example a *Tsuga dumosa* mixed forest.

Subalpine coniferous forest and meadow: having many smaller types, widely distributed at alt. 2,800-3,900 m of northwestern Yunnan, and belonging to the cold-temperate climate.

(1) Subalpine coniferous forest: mainly *Abies* forest, *Picea* forest, *Larix* forest, and at the lower limits a *Pinus densata* forest. These forests that have a

Fig. 2 — Climate diagram of 6 typical areas for 6 climate types in Yunnan (WALTER, 1979; METEOROLOGICAL BUREAU OF YUNNAN, 1984).



Legend:

Jinhong	:	Tropical climate	Kunming	:	Subtropical climate (warm-temperate one)
Yuanmou	:	Dry-hot valley climate	Lijiang	:	Mountainous climate (temperate-cool one)
Mengzi	:	Subtropical climate (warm-hot one)	Deqen	:	Subtropical climate (cold temperate one)

temperate or cold-temperate nature may be considered as of common origin to those of Europe and North America. But in Yunnan, there are many endemic species as dominants in the upper forest layer, e.g. *Abies georgei*, *A. georgei* var. *smithii*, *A. forrestii*, *A. delavayi*, *A. ferreana*, *A. nukiangensis*, *Picea likiangensis*, *P. brachytyla* var. *complonata*, *Larix potaninii* var. *macrocarpa*, *L. speciosa*, etc. Evergreen *Rhododendron*, evergreen *Quercus*, deciduous *Sorbus*, *Prunus*, *Betula*, *Acer*, *Tilia*, *Salix*, and *Populus* occur under the forest canopy, and these genera also have many endemic species. At present, there are large virgin forests of this type in northwestern Yunnan. These are becoming the basis for forestry production of China.

(2) After these forests are destroyed, there often occur small pastures for livestock. The pasture vegetation is called "subalpine meadow", consisting of many mesophytic plants with very beautiful flowers in the growing season. These established the basis for alpine ranch or livestock farming.

Alpine scrub and alpine meadow: mainly occurring in a few snow-mountain ranges in northwestern Yunnan, occupying small areas above the tree line. Alpine scrub is situated in the lower part, about alt. 3,900-4,100 m, with alpine meadow above, at about alt. 4,100-4,300 m. These two types always appear with interlaced distributions, however, according to the relief and soil conditions. Alpine scrub consists of many *Rhododendron* species, 0.5-3 m high, but becoming shorter with higher altitude, often forming krummholz or cushion-shrubs of 0.1-0.3 m on the windy peaks. Besides *Rhododendron*, some species of *Salix*, *Sabina*, *Dasiphora*, *Caragana*, *Spiraea*, etc. are also very short. Some tree species of *Sorbus*, *Ribes*, and *Betula*, which are taller in other vegetation types, also appear here as stunted, krummholz forms. Alpine meadow has been discovered in smaller areas, with its dominant species, *Kobresia* (Cyperaceae), plus other species but with not as beautiful flowers as in the subalpine meadow.

Alpine cold-desert: mainly occurring above the alpine meadow, in small areas of alt. 4,300-4,500 m, consisting of very short, small herb or cushion plants, which diffuse over wide distances and do not grow in communities. They always occur dispersed in gravel areas or alpine talus. These plants, such as *Saussurea*, *Cremanthodium*, *Meconopsis*, *Corydalis*, *Sedum*, and *Saxifraga*, are cold and drought-resistant, have hairy leaves, are cushion-like, and have strong root systems to adapt to the worse environment at high altitude. In alt. 4,500-5,000 m only a few lichens occur scattered on the rock surfaces, with no vascular plants. This vegetation also belongs to the alpine cold-desert. Above 5,000 m no plants can grow, and near the peak of the snow mountains there always occur mountain glaciers belonging to the ice-snow belt, including the glaciers of Yulong, Haba, Beimang, Taizi, and Meili snow mountains.

To sum up, the major types of Yunnan vegetation and their distributions may be seen from the schematic figure of vegetational zonation (Fig. 3).

THE CLASSIFICATION SYSTEM OF NATURAL VEGETATION

Four levels are used in this classification system of Yunnan vegetation, namely the "vegetation type", "vegetation subtype", formation and association (or community-type). The principles and criteria for classifying or grouping the vegetation types are the same as in the "Vegetation of China" (Wu 1980) and the "Vegetation of Yunnan" (Wu and Zhu 1987), in which the main unit is the formation, characterized by the dominant species or marked species. This classification system is shown in the accompanying listing.

SUMMARY

(1) There are close ecological relationships between the vegetation types of Yunnan and their physiographic environmental conditions, mainly landforms and climate.

(2) The zonal differences in vegetation types occurring from south to north, or from low to high elevation, are very distinct; each vegetation type has its own unique floristic components and ecological appearance.

(3) In Yunnan, the horizontal zonation of vegetation distribution from south to north and vertical zonation from low to high elevation are interlaced with each other; but because Yunnan extends over 900 km from south to north, the horizontal zonation dominates the vegetation distribution. The subtropical evergreen broad-leaved forest and the tropical rainforest and monsoon forest are the main vegetation types of the horizontal zonation. The horizontal boundary between subtropical and tropical vegetation is located at about the Tropic of Cancer.

(4) According to the classification system of Yunnan vegetation, nine vegetation types, 32 vegetation subtypes, 134 formations, 210 associations have been identified.

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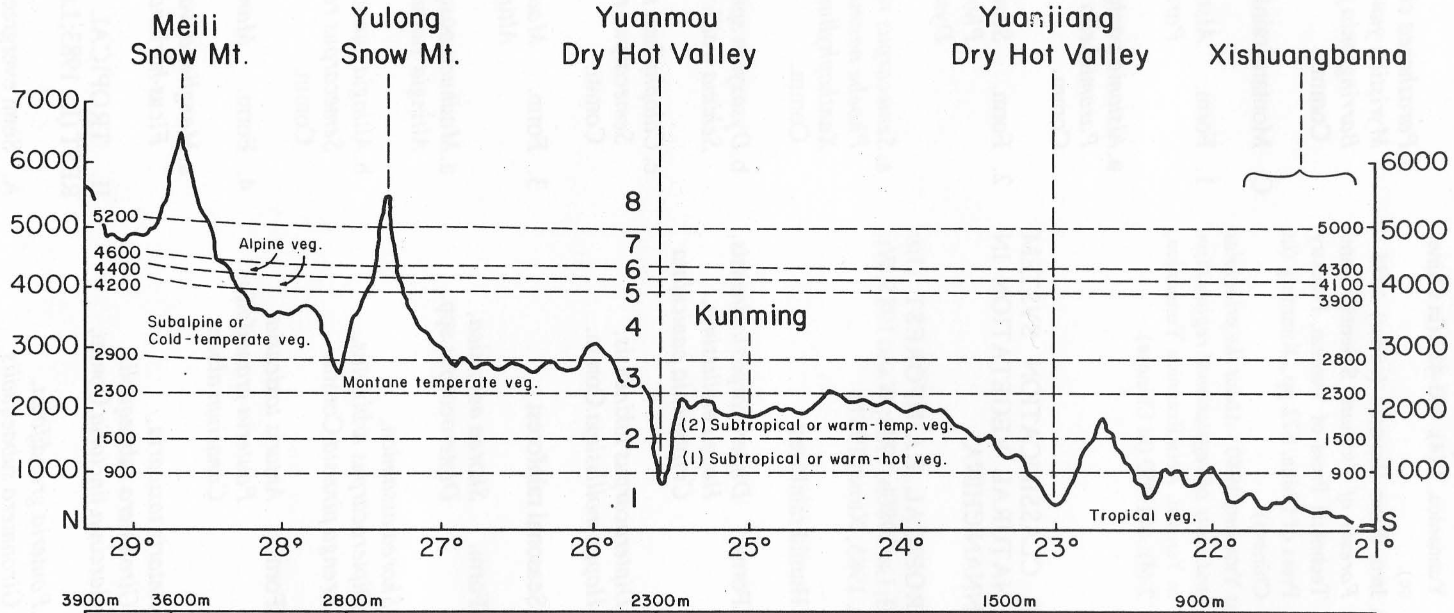
Fig. 3 — The distribution of the main vegetation types in Yunnan.



Cold temperate climate		Temperate-cool climate	Subtropical climate		Tropical climate
4 Subalpine forest		2 Evergreen broad-leaved forest: 3 Humid montane	2 Evergreen broad-leaved forest: 2(2) Semihumid	2 Evergreen broad-leaved forest: 2(1) Monsoon	1 Tropical forest
Abies-Picea-Larix	*Tsuga*	*Lithocarpus-Acer*	*Castanopsis delavayi-Lithocarpus*	*Castanopsis-Schima wallichii*	*Pometia-Antiaris*
Betula-Acer	*Pinus densata*	*Pinus armandi*	*Pinus yunnanensis*	*Pinus kesiya* var. *langbianensis*	*Macaranga-Mallotus*
Gray-brn. forest soil	Red-brn. Soil	Brn.-red soil	Red soil	Lateritic soil	Laterite

Legend

1. Tropical rainforest and monsoon forest (≤900 m)
2. Subtropical evergreen broad-leaved forest and subtropical evergreen coniferous forest (900 - 2,200 m)
3. Montane coniferous and broad-leaved mixed forest (2,200 - 2,800 m)
4. Subalpine coniferous forest and meadow (2,800 - 3,900 m)
5. Alpine scrub *Rhododendron* scrub (3,900 - 4,100 m)
6. Alpine meadow *Kobresia* meadow (4,100 - 4,300 m)
7. Alpine cold-desert (4,300 - 5,000 m)
8. Permanent ice-snow belt (≥5,000 m)

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THE CLASSIFICATION SYSTEM OF NATURAL VEGETATION IN YUNNAN CHINA

1. TROPICAL RAINFOREST (JIN 1983; LIU 1980b, 1983; WANG 1985; WU B-X. 1985, XIONG 1981)

A. Humid rainforest

1. Form. *Dipterocarpus tokinensis, Hopea mollissima, Crypteronia paniculata*

a. *Dipterocarpus tokinensis, Hopea mollissima* Comm.

B. Seasonal rainforest

1. Form. *Shorea assamica, Dipterocarpus* spp.

a. *Shorea assamica, Dipterocarpus urbinatus, Arenga pinnata* Comm.

2. Form. *Antaris toxicaria, Pouteria grandifolia, Canarium album*

a. *Antaris toxicaria, Gironniera subaequalis, Garcinia tinctoria* Comm.

b. *Pouteria grandifolia, Gironniera subaequalis Xanthophyllum siamense* Comm.

3. Form. *Terminalia myriocarpa, Pometia tomentosa*

a. *Pometia tomentosa, Knema furfuracea, Carcinia cowa* Comm.

b. *Terminalia myriocarpa Epiprenus silhelianus, Mitrephora wangii* Comm.

c. *Pometia tomentosa, Tetrameles nudiflora, Epiprenus silheliarus* Comm.

4. Form. *Carashorea chinensis*

a. *Parashorea chinensis, Myristica yunnanensis, Barringtonia fuscicarpa* Comm.

C. Montane rainforest

1. Form. *Alstonia pachycarpa, Paramichelia baillonii*

a. *Alstonia pachycarpa, Paramichelia baillonii* Comm.

2. Form. *Semecarpus reticulata Phoebe nanmu, Dysoxylon spicatum*

a. *Semecarpus reticulata, Phoebe nanmu, Xanthophyllum siamense* Comm.

b. *Dysoxylon spicatum, Schima wallichii* Comm.

c. *Calophyllum smilesianum, Semecarpus reticulata* Comm.

3. Form. *Madhuca pasquierii, Altingia yunflanensis*

a. *Madhuca pasquierii, Altingia yunnanensis* Comm.

b. *Altingia yunnanensis, Semecarpus reticulata* Comm.

4. Form. *Manglietia wangii*

a. *Manglietia wangii, Ficus harlandii* Comm.

II. TROPICAL MONSOON FOREST (JIN 1983; LIU 1983; XIONG 1981)

A. Semi evergreen monsoon forest

1. Form. *Ficus altissima, Chukrasia tabularis*

var. *velutina*
a. *Ficus altissima, Chukrasia tabularis* var. *velutina* Comm.

b. *Chukrasia tabularis Saraca chinensis* Comm.

2. Form. *Mesua ferrea*

a. *Mesua ferrea Mangifera sylvatica* Comm.

3. Form. *Cassia siamea*

a. *Cassia simea* Comm.

B. Deciduous monsoon forest

1. Form. *Bombax malabaricum, Albizia chinensis*

a. *Albizia chinensis, Lysidice rhodostegia* Comm.

b. *Bombax malabaricum, Albizia chinensis* Comm.

c. *Albizia kalkora, Michelia exelsa* Comm.

2. Form. *Terminalia myriocarpa, Erythrina stricta*

a. *Terminalia myriocarpa, Erythrina stricta* Comm.

3. Form. *Crotium serratum, Castanopsis hystrix*

a. *Crotium serratum, Castanopsis hystrix* Comm.

4. Form. *Pterocarya tonkinensis*

a. *Pterocarya tokinensis* Comm.

5. Form. *Tectona grandis*

a. *Tectona grandis, Bombax malabaricum* Comm.

C. Limestone monsoon forest

1. Form. *Tetrameles nudifloria, Garuga floribunda, Ulmus tokinensis*

a. *Garuga floribunda, Cleistanthus saichikii* Comm.

b. *Tetrameles nudiflora, Nephelium chryseum* var. *lapengii* Comm.

c. *Pistacia weinmannifolia Cleisthanthus saichikii* Comm.

III. EVERGREEN BROAD-LEAVED FOREST (Jin 1979, 1983; Dang 1982; Ceng 1984)

A. Monsoonal evergreen broad- leaved forest

1. Form. *Castanopsis hystrix, Castanopsis indica*

a. *Castanopsis hystrix, Schima villosa* Comm.

b. *Castanopsis hystrix, Lithocarpus microspermus, Schima wallichii* Comm.

c. *Castanopsis hystrix, Castanopsis indica* Comm.

2. Form. *Castanopsis fleuryi, Lithocarpus truncatus*

a. *Castanopsis fleuryi, Lithocarpus truncatus* Comm.

3. Form. *Castanopsis fabrii*

a. *Castanopsis fabrii, Castanopsis calathiformis, Lithocarpus truncatus* Comm.

4. Form. *Machilus kurzii, Castanopsis fargesii*

a. *Machilus kurzii, Castanopsis fargesii, Schefflera diversifolialata* Comm.

5. Form. *Quercus utilis*

a. *Quercus utilis, Podocarpus brevifolius* Comm.

6. Form. *Cyclobalanopsis blakei*

a. *Manglietia duclouxii, Cyclobalanopsis blakei, Podocarpus imbricatus* Comm.

b. *Cyclobalanopsis blakei, Michelia fulgens, Illicium majus* Comm.

B. Semihumid evergreen broad- leaved forest

1. Form. *Cyclobalanopsis glaucoides*

a. *Cyclobalanopsis glaucoides Lithocarpus dealbatus, Keteleeria evelyniana* Comm.

b. *Cyclobalanopsis glaucoides, Pistacia weinmannifolia* Comm.

c. *Cyclobalanopsis glaucoides, Castanopsis delavayi* Comm.

d. *Cyclobalanopsis glaucoides Clatycarya strobilacea* Comm.

e. *Cyclobalanopsis glaucoides Celtis yunnanensis, Magnolia delavayi* Comm.

2. Form. *Cyclobalanopsis delavayi*

a. *Cyclobalanopsis delavayi, Rhododendron spinuliferum* Comm.

b. *Cyclobalanopsis delavayi, Lithocarpus confinis* Comm.

3. Form. *Castanopsis orthacantha*

a. *Castanopsis orthacantha, Cyclobalanopsis glaucoides* Comm.

b. *Castanopsis orthacantha, Lithocarpus dealbatus* Comm.

c. *Castanopsis orthacantha, Lithocarpus craibianus* Comm.

d. *Castanopsis orthacantha, Schima argentea* Comm.

4. Form. *Castanopsis delavayi*

a. *Castanopsis delavayi, Keteleeria evelyniana*, Comm.

C. Mountainous humid evergreen broad-leaved forest.

1. Form. *Lithocarpus echinoporus*

a. *Lithocarpus echinophorus Manglietia insignis, Lindera latifolia* Comm.

b. *Schima argentea, Lithocarpus hancei, Lithocarpus echinophorus* Comm.

2. Form. *Lithocarpus echinotholus*

a. *Lithocarpus echinotholus, Cyclobalanopsis glaucoides, Schima noronhae* Comm.

b. *Manglietia delavayi, Acer sikkimense* var. *serrulatum, Lithocarpus echinotholus* Comm.

3. Form. *Lithocarpus xylocarpus*

a. *Lithocarpus xylocarpus, Lithocarpus chintungensis, Castanopsis wattii* Comm.

4. Form. *Lithocarpus pachyphylloides*

a. *Lithocarpus pachyphylloides* Comm.

5. Form. *Lithocarpus naidarum*

a. *Lithocarpus naidarum*, *Acanthopanax evodiaefolius* var. *pseudoevodiaefolius* *Fagus longipetiolata* Comm.

6. Form. *Lithocarpus craibianus*

a. *Lithocarpus craibianus*, *Illicium yunnanense* Comm.

7. Form. *Cyclobalanopsis glauca*

a. *Cyclobalanopsis glauca*, *Lithocarpus hancei*, *Adinandra megaphylla* Comm.

b. *Cyclobalanopsis glauca*, *Lithocarpus variolosa*, *Schima argentea* Comm.

8. Form. *Taiwania flousiana*, *Cyclobalanopsis glauca*

a. *Taiwania flousiana*, *Huodendron tibeticum*, *Cyclobalanopsis glauca* Comm.

9. Form. *Lithocarpus variolosa*

a. *Lithocarpus variolosa*, *Castanopsis orthacantha* Comm.

10. Form. *Lithocarpus cleistocarpus*

a. *Lithocarpus cleistocarpus*, *Sycopsis triplinervis*, *Tsuga tchekiangensis* Comm.

11. Form. *Castanopsis platycantha*

a. *Castanopsis platycantha*, *Schima crenata*, *Eurya brevistyla* Comm.

b. *Castanopsis platyacantha*, *Fagus engleriana*, *Litsea chunii* Comm.

c. *Castanopsis platycantha*, *Lithocarpus cleistocarpus*, *Sycopsis triplinervis* Comm.

D. Montane mossy evergreen broad-leaved forest

1. Form. *Rhodoleia parvipetala*, *Machilus* spp., *Lithocarpus* spp.

a. *Rhodoleia parvipetala*, *Manglietia forrestii*, *Camellia rosaeflora* Comm.

b. *Alseodaphne mollis*, *Lithocarpus* sp., *Camellia wenshanensis* Comm.

c. *Machilus shweliensis*, *Lithocarpus pachylepsis*, *Manglietia forrestii* Comm.

d. *Sloanea dasycarpa*, *Rhodoleia parvipetala*, *Rehderodendron fengii* Comm.

E. Mountaintop mossy shrub-forest ("Elfin Woodland")

1. Form. *Rhododendron* spp., *Vaccinium* spp., *Illiciun* spp.

a. *Rhododendron excellens*, *Gaultheria forrestii*, *Vaccinium* sp. Comm.

b. *Illicium major*, *Pieris formosa*, *Clethra lancilimba* Comm.

c. *Rhododendron faconeri*, *Eurya tsaii*, *Lyotria ovalifolia* Comm.

d. *Vaccinium bracteatum*, *Ternstromeia gymnanthera*, *Myrsine semiserrata* Comm.

2. Form. *Lithocarpus pachyphylloides*, *Rhododendron* spp., *Vaccinium* spp.

a. *Lithocarpus pachyphylloides*, *Rhododendron irroratum* Comm.

IV. SCLEROCHYLLOUS EVERGREEN BROAD-LEAVED FOREST (Jin 1981a, 1981b)

A. Cold-temperate mountainous sclerophyllous evergreen broad-leaved forest

1. Form. *Quercus pannosa*

a. *Quercus pannosa*, *Sorbus pallescens* Comm.

b. *Quercus pannosa*, *Sorbus rufopilosa* Comm.

2. Form. *Quercus guayavaefolia*

a. *Quercus guayavaefolia*, *Quercus longispica* Comm.*tetrago*

b. *Quercus guayavaefolia*, *Osmanthus delavayi* Comm.

3. Form. *Quercus aquifolioides*

a. *Quercus aquifolioides* Comm.

B. Dry-hot river valley sclerophyllous evergreen broad-leaved forest

1. Form. *Quercus cocciferoides*

a. *Quercus cocciferoides*, *Pistacia weinmannifolia* Comm.

2. Form. *Quercus franchetii*

a. *Quercus franchetii*, *Engelhardtia colebrookiana* Comm.

3. Form. *Quercus rehderiana*

a. *Quercus rehderiana*, *Cyclobalanopsis glaucoides* Comm.

V. DECIDUOUS BROAD-LEAVED FOREST (Xue 1985)

1. Form. *Quercus dentata* var. *oxyloba*

a. *Quercus dentata* var. *oxyloba*, *Pteridium aquilinum* var. *latiusculum* Comm.

2. Form. *Quercus acutissima*, *Quercus variabilis*

a. *Quercus acutissima*, *Quercus variabilis*, *Phyracantha fortuneana* Comm.

3. Form. *Alnus nepalensis*

a. *Alnus nepalensis*, *Pteridium aquilinum* var. *latiusculum* Comm.

b. *Alnus nepalensis*, *Rhus chinensis* Comm.

c. *Alnus nepalensis*, *Gaultheria trichophylla* Comm.

4. Form. *Acer* spp., *Betula* spp.

a. *Acer* spp. *Betula albo-sinensi* *Sinarundinaria* sp. Comm.

5. Form. *Populus szechuanica*, *Betula platyphylla* var. *szechunanica*, *Carex* sp. Comm.

6. Form. *Populus bonatii*

a. *Populus bonatii*,
Rhododendron decorum Comm.

7. Form. *Liquidambar formosana*

a. *Liquidambar formosana*,
Mallotus philippinensis Comm.

8. Form. *Catalpa fargesii* f. duclouxii

a. *Catalpa fargesii* var. duclouxii,
Crataegus scabrifolia,
Polygala arillata Comm.

VI. WARM CONIFEROUS FOREST (Li 1984, Qiu 1982)

A. Warm-hot coniferous fast

1. Form. *Pinus keya* var. *langbianensis*

a. *Pinus kesiya* var. *langbianensis*,
Schima wallichii,
Wendlandia paniculata Comm.

b. *Pinus kesiya* var. *langbianensis*,
Schima wallichii,
Engelhardtia colebrookiana Comm.

c. *Pinus kesiya* var. *langbianensis*,
Schima wallichii,
Vaccinium sprengelii Comm.

d. *Pinus kesiya* var. *langbianensis*,
Schima wallichii,
Castanopsis hystrix Comm.

2. Form. *Calocedrus macrolepis*

a. *Calocedrus macrolepis*,
Elaeocarpus sp.,
Gordonia axillaris Comm.

B. Warm-temperate coniferous forest

1. Form. *Pinus yunnanensis*

a. *Pinus yunnanensis*,
Cyclobalanopsis delavayi,
Alnus nepalensis Comm.

b. *Pinus yunnanensis*,
Cyclobalanopsis delavayi,
Keteleeria evelyniana Comm.

c. *Pinus yunnanensis*,
Alnus nepalensis,
Quercus aliena Comm.

d. *Pinus yunnanensis*,
Quercus griffithii,
Quercus variabilis Comm.

e. *Pinus yunnanensis*,
Quercus guayavaefolia,
Quercus pannosa Comm.

f. *Pinus yunnanensis*,
Quercus monimotricha Comm.

g. *Pinus yunnanensis*,
Quercus senescens Comm.

h. *Pinus yunnanensis*,
Schima wallichii,
Keteleeria evelyniana Comm.

2. Form. *Pinus armandi*

a. *Pinus armandi*,
Myrsine africana,
Rhododendron ssp. Comm.

b. *Pinus armandi*,
Berberis dictyophylla Comm.

c. *Pinus armandi*,
Parochetus communis Comm.

3. Form. *Keteleeria evelyniana*

a. *Keteleeria evelyniana*,
Castanopsis delavayi Comm.

4. Form. *Cupressus duclouxiana*

a *Cupressus duclouxiana*,
Juniperus formosana Comm.

5. Form. *Taiwania flousiana*

a. *Taiwania flousiana*,
Lindera communis Comm.

6. Form. *Cunninghamia lanceolata*

a. *Cunninghamia lanceolata*,
Schima wallichii,
Oxyspora paniculata Comm.

b. *Cunninghamia lanceolata*,
Alnus nepalensis,
Stachyurus himalaicus Comm.

c. *Cunninghamia lanceolata*,
Castanopsis platycantha,
Phyllostachys sp. Comm.

VII. TEMPERATE CONIFEROUS FOREST (Liu 1980a, 1984, 1985; Jin 1981c; Ming, 1982)

A. Temperate-cool coniferous forest

1. Form. *Tsuga dumosa*

a. *Tsuga dumosa*,
Sinarundinaria nitida Comm.

b. *Tsuga dumosa*,
Lindera sp. Comm.

c. *Tsuga dumosa*,
Schima noronhae,
Pleioblastus sp. Comm.

2. Form. *Pinus densata*

a. *Pinus densata*,
Quercus monimotricha Comm.

b. *Pinus densata*,
Rhododendron spp. Comm.

3. Form. *Sabina recurva*

a. *Sabina recurva*,
Rhododendron spp. Comm.

4. Form. *Sabina wallichiana*

a. *Sabina wallichiana*,
Quercus aquifolioides Comm.

B. Temperate-cold coniferous forest

1. Form. *Picea likiangensis*

a. *Picea likiangensis*,
Sinarundinaria sp. Comm.

b. *Picea likiangensis*,
Rhododendron spp. Comm.

2. Form. *Abies georgei*

a. *Abies georgei*,
Rhododendron spp. Comm.

b. *Abies georgei*, *Carex* spp. Comm.

c. *Abies georgei*,
Sinarundinaria chungii Comm.

d. *Abies georgei*,
Sinarundinaria nitida Comm.

e. *Abies georgei*,
Abies forrestii,
Rhododendron siderophyllum Comm.

3. Form. *Abies georgei* var. *smithii*

a. *Abies georgei* var. smithii,
Sinarundinaria fangiana Comm.

4. Form. *Abies delavayi*

a. *Abies delavayi*,
Rhododendron spp. Comm.

5. Form. *Abies nukiangensis*

a. *Abies nukiangensis*,
Larix speciosa Comm.

6. Form. *Picea brachytyla* var. *complanata*

a. *Picea brachytyla*

var. *complanata*,
Abies ferreana Comm.

7. Form. *Larix potaninii* var. *macrocarpa*

a. *Larix potaninii* var. macrocarpa, *Sinarundinaria nitida* Comm.

8. Form. *Larix speciosa*

a. *Larix speciosa*, *Sinarundinaria* spp. Comm.

VIII. BAMBOO SHRUB-FOREST

A. Bamboo liana-shrub

B. Bamboo shrub

C. Bamboo forest

1. Form. *Dendrocalamus strictus*

a. *Dendrocalamus strictus* Comm.

b. *Dendrocalamus strictus*, *Ficus altissima* Comm.

2. Form. *Bambusa sinospinosa*

a. *Bambusa sinospinosa* Comm.

3. Form. *Lingnania chungii*

a. *Lingnania chungii* Comm.

IX. SHRUB-GRASSLAND (JIN 1986; XU 1985; WIN B-X. 1982)

A. Dry-hot shrub-grassland

1. Farm. Middle grassland containing *Bombax malabarica*, *Woodfordia fruticosa*

a. *Heteropogon contortus* Comm. containing *Bombax malabarica*, *Woodfordia fruticosa*

2. Form. Mid. grassland containing *Quercus franchetti*, *Dodonaeaviscosa*

a. *Heteropogon contortus* Comm. containing *Quercus franchetti*, *Dodonaea viscosa*

B. Hot shrub-grassland

1. Form. Tall grassland containing *Cratoxylon cochinchi nensis*, *Aporusa villosa*

a. *Neyraudia reynaudiana*, *Themeda gigantea* var. *villosa*, *Thysanolaena maxima* Comm.

b. *Eupatorium odoratum* Comm.

2. Form. Mid. grassland containing *Bauhinia variegata*

a. *Microstegium gratum* Comm. containing *Bauhinia variegata*

3. Form. Tall grassland containing *Sterospermum tetragonum*, *Oroxylum indicum*

a. *Themeda gigantea* var. *caudata* Comm. containing *Sterospermum tetragonum*, *Kydia calycina*

4. Form. Mid. grassland containing *Schima wallichii*, *Ficus altissima*

a. *Themeda triandra* var. *japonica* Comm. containing *Schima wallichii*, *Wendlandia scabra*

5. Form. Mid. grassland containing *Liquidambar formosana*, *Quercus variabilis*

a. *Dicranopteris ampla* Comm. containing *Liquidambar formosana*, *Quercus variabilis*

C. Warm-hot shrub-grassland

1. Form. Mid. grassland containing *Castanopsis hystrix*, *Schima wallichii*

a. *Arundinella bengalensis* Comm. containing *Castanopsis indica*, *Schima wallichii*

2. Form. Tall grassland containing *Pinus kesiya* var. *langianensis*, *Castanopsis fleuryi*

a. *Themeda gigantea* var. *caudata* Comm. containing *Pinus kesiya* var. *langbianensis*, *Phyllanthus emblica*

D. Warm-temperate shrub-grassland

1. Form. Mid. grassland containing *Pinus yunnanensis*, *Lyonia ovalifolia*

a. *Eulalia pallens*, *Arundinella setosa* Comm. containing *Pinus yunnanensis*

2. Form. Low grassland containing *Pinus yunnanensis*, *Quercus monimotricha*

a. *Arundinella hookeri*, *Cotentilla fulgens* Comm. containing *Pinus yunnanensis*

3. Form. Low grassland containing *Pinus armandi*, *Tsuga dumosa*

a. *Eragrostis mairei*, *Arundinella hookeri* Comm. containing *Pinus armandi*

X. SCRUB (Ming 1982; Liu 1984, 1985)

A. Cold-temperate scrub

1. Form. *Rhododendron cephalanthum*

a. *Rhododendron cephalanthum*, *Salix calyculata* Comm.

b. *Rhododendron cephalanthum*, *Rhododendron adenogynum*, *Salix vaccinioides* Comm.

2. Form. *Rhododendron adenogynum*

a. *Rhododendron adenogynum*, *Sorbus wilsoniana* Comm.

3. Form. *Rhododendron nailleanum*

a. *Rhododendron trailleanum*, *Dasiphora glabra* var. *rhodocalyx* Comm.

4. Form. *Rhododendron balfourianum*

a. *Rhododendron balfourianum*, *Rhododendron lacteum* Comm.

5. Form. *Rhododendron heliolepis*

a. *Rhododendron heliolepis*, *Betula delavayi* Comm.

6. Form. *Rhododendron hippophaeoides*

a. *Rhododendron hippophaeoides*, *Rosa omeiensis* Comm.

b. *Rhododendron hippophaeoides*, *Sinarundinaria fangiana*, *Lyonia villosa* Comm.

7. Form. *Rhododendron brevistylum*

a. *Rhododendron brevistylum*,

Rhododendron trichocladum, Diapensia purpurea Comm.

8. Form. *Rhododendron racemosum*

a. *Rhododendron racemosum, Cotoneaster microphyllus* Comm.

9. Form. *Rhododendron siderophyllum, Sinarundinaria fangiana* Comm.

10. Form. *Salix calyculata*

a. *Salix calyculata* Comm.

11. Form. *Salix vaccinioides*

a. *Salix vaccinioides* Comm.

12. Form. *Salix lindleyana* var. *microphylla*

a. *Salix lindleyana* var. *microphylla, Rhododendron adenogynum*

13. Form. *Caragana jubata*

a. *Caragana jubata, Salix vaccinioides, Dasiphora arbuscula* Comm.

14. Form. *Caragana franchetiana*

a. *Caragana franchetiana, Prinsepia utilis* Comm.

15. Form. *Sabina pingii* var. *wilsonii*

a. *Sabina pingii* var. *wilsonii*

16. Form. *Sabina squamata*

a. *Sabina squamata, Quercus pannosa* Comm.

17. Form. *Quercus monimotricha*

a. *Quercus monimotricha, Lespedeza forrestii* Comm.

18. Form. *Hippophoae rhamnoides*

a. *Hippophoae rhamnoides, Cyracantha crenulata* Comm.

19. Form. *Myricaria germanica*

a. *Myricaria germanica, Coriaria nepalensis* Comm.

B. Warm limestone scrub

1. Form. *Myrsine africana*

a. *Myrsine africana, Berberis wilsonae* Comm.

b. *Ligustrum sempervirens, Myrsine africana* Comm.

2. Form. *Rosa mairei*

a. *Rosa mairei, Bauhinia faberi, Quercus rehderiana* Comm.

3. Form. *Zanthoxylum planispinum*

a. *Zanthoxylum planispinum, Rosa* spp., *Rhamnus leptophyllus* Comm.

4. Form. *Breynia rostrata*

a. *Breynia rostrata, Indigofera pseudotinctoria, Mallotus barbatus* Comm.

C. Dry-hot river-valley scrub

1. Form. *Sophora viciifolia*

a. *Sophora viciifolia, Bauhinia faberi* var. *microphylla* Comm.

b. *Sophora viciifolia, Cyracantha fortuneana* Comm.

2. Form. *Cotinus nana*

a. *Cotinus nana, Desmodium tilaefolium* f. *rhabdocladum, Caryopteris forrestii* Comm.

3. Form. *Desmodium yunnanense*

a. *Desmodium yunnanense, Fraxinum pistaciifolia, Viburnum utile* Comm.

4. Form. *Vitex negundo* var. *laxipaniculata*

a. *Vitex negundo* var. *laxipaniculata, Terminalia franchettii* Comm.

5. Form. *Opuntia monacantha*

a. *Opuntia monacantha, Euphorbia royleana* Comm.

D. Hot floodplain scrub

a. *Homonoia riparia, Litsea lancifolia* Comm.

XI. SUBALPINE OR ALPINE MEADOW (LIU 1984, 1985)

A. Cold-temperate meadow (subalpine meadow)

1. Form. *Festuca ovina*

a. *Festuca ovina, Anaphalis bicolor, Roscoea alpina* Comm.

b. *Calamagrotis arundinacea* var. *ligulata, Arundinella hookeri, Festuca ovina* Comm.

c. *Achnatherum chingii, Festuca ovina* Comm.

d. *Festuca vierhapperi, Festuca ovina* Comm.

2. Form. *Sinarundinaria fangiana*

a. *Sinarundinaria fangiana, Deyeuxia scabrescens, Helictotrichon polyneurum* Comm.

3. Form. *Sinarundinaria* sp.

a. *Sinarundinaria* sp., *Festuca ovina, Calamagrostis arundinacea* var. *ligulata* Comm.

4. Form. *Iris bulleyana, Ligularia* spp.

a. *Iris bulleyana, Ligularia tsangshangensis* Comm.

b. *Veratrilla baillonii, Iris bulleyana* Comm.

5. Form. *Veratrum yunnanense*

a. *Veratrum yunnanense, Anaphalis nepalensis*

6. Form. *Rheum emodii, Euphorbia erythrocoma*

a. *Rheum emodii, Euphorbia erythrocoma, Rumex nepalensis* Comm.

7. Form. *Cirsium forrestii, Ligularia vellerea*

a. *Cirsium forrestii, Ligularia vellerea, Strobilanthes versicolor* Comm.

B. Moor meadow (subalpine moor meadow)

1. Form. *Blysmus sinocompressus*

a. *Blysmum sinocompressus*,
Phlomis atropurpurea Comm.

b. *Blysmus sinocompressus*,
Crimula sikkimenensis Comm.

2. Form. *Sanguisorba filiformis*

a *Sanguisorba filiformis*,
Juncus spp. Comm.

b. *Sanguisorba filiformis*,
Kobresia spp. Comm.

c. *Sanguisorba filiformis*,
Phlomis atropurpurea,
Blysmus sinocompressus Comm.

C. Cold meadow (alpine meadow)

1. Form. *Kobresia tunicata*

a. *Kobresia tunicata*,
Kobresia stiebritziana Comm.

2. Form. *Cotentilla stenophylla*, *Kobresia spp.*

a. *Potentilla dumosa*,
Potentilla stenophylla,
Kobresia sp. Comm.

b. *Potentilla stenophylla*,
Veratrilla baillonii,
Kobresia sp. Comm.

D. Talus scattered herb meadow (talus meadow)

1. Form. *Saussurea leucoma*, *Saussurea eriocephala*

a. *Saussurea leucoma*,
Saussurea graminifolia,
Cremanthodium campanulatum Comm.

b. *Saussurea eriocephala*,
Saussurea likiangensis,
Meconopsis lancifolia Comm.

2. Form. *Cremanthodium smithianum*

a. *Cremanthodium smithianum*,
Soroseris umbrella,
Fritillaria delavayi Comm.

b. *Cremanthodium smithianum*,
Chamaesium viridiflorum Comm.

3. Form. *Cremanthodium hookeri*

a. *Cremanthodium hookeri*,
Draba oreodoxa Comm.

THE MAIN TYPES OF VEGETATION AND THEIR DISTRIBUTION IN TIBET

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Key words: Types of vegetation, Horizontal distribution, Vertical distribution

Tibet, one of the autonomous regions of China, is situated on the southwestern frontier of China, and the southwestern part of Qinghai-Tibet plateau. It straddles 9°30' of latitude (from 27° to 36°30'N) and 20°30' of longitude (78°30'to 99°E). The region is more than 1.2 million km^2 in area.

For a long time the vegetation of Tibet has been studied by many scientists, for example, HANDEL-MAZZETI, H. (1920); WARD, F. K. (1935); TENG, S.C. (1948); TSOONG, P.C. (1954); SCHWEINFURTH, U. (1957), and ZHANG JINGWEI and WANG JINTING (1966). Many other botanists have collected specimens and studied phytogeography and flora in Tibet.

PHYSICAL CONDITIONS OF TIBET

Topography

The Tibetan plateau is higher in the northwest and lower to the southeast, with an average altitude of 4200-5000 m. In the southeast, several rivers have cut deep valleys, forming a distinctive topography with an altitudinal range of 1500 to 2000 metres. In the northwest, the topography comprises a more uniform plateau surface with an altitudinal range of only 200 to 500 metres. The Gangdise mountain range is a major watershed between catchments draining north and south. Thus the whole plateau may be divided into three regions, namely: the valley of southern Tibet; the three river gorge region, and the plateau of northern Tibet.

Climate

This is chiefly influenced by westerly wind and the southwestern monsoon. Precipitation is closely related to the start of the monsoon, and 80 to 90 percent of precipitation occurs from June to October. The mean annual precipitation decreases gradually from 4000mm at the southern side of the Himalayas to only 20-50mm in the northwestern part of Tibet (Fig. 1).

On the Tibetan plateau, the mean annual temperature is less than 100C, and in some parts of northern Tibet is lower than 0 0C. There is a high level of solar radiation on the Tibetan plateau. The daily range of temperature is about 20 0C, but the yearly difference is not great, fluctuating between 160 and 260C. Vertical variation of the climate is very distinct.

Corresponding to these factors, various vegetation types have developed in each major region of Tibet.

THE MAIN VEGETATION TYPES IN TIBET

About seven main types of vegetation can be described. They are as follows:

a) Forests

1) Tropical mountain rain forest
Lower montane tropical evergreen rain forest: Mêdog, below 600m altitude. The main constituents are *Dipterocarpus tarbinatus*, *Terameles nudiflora*, *Artocarpus chaplasha* etc. Lower montane tropical semi-evergreen rain forest: Mêdog, Zayu, 600-1000 m. The main constituents are *Terminaria myriocarpa*, *Altingia excelsa*, *Dysoxylon gobara*, *Talauma hodgsonii* etc.

2) Montane evergreen broad-leaved forest: Southern side of the Himalayas, 1000 (1100)-1800 (2400) m. The main constituents are *Castanopsis hystrix*, *Cyclobalanopsis indica* etc.

3) Montane fog forest: Mêdog, 1800-2200 2400) m. The main constituents are *Cyclobalanopsis lamellosa*, *Lithocarpus xizhangensis*, etc.

4) Sclerophyllus evergreen broad-leaved forest: There are two main types in Tibet; *Quercus aquifolioides* communities occupy the southeastern part of Tibet (south of about 30°N) at 2300-4300 m; and *Quercus semicarpifolia* communities occupy the southern side of the central Himalayas at 2000-4100 m.

5) Montane coniferous forest: Southeastern Tibet, the *Tsuga dumosa* community is distributed chiefly on the southern side of the Himalayas between 2200 and 3200m; *Pinus yunnanensis* is found at Zayu, 2400- 2700m, *Pinus densata* in southeastern Tibet 30°N 2500-3700m, and *Pinus graffithii* is found chiefly to the south of the Himalayas, at 2000-3000m.

6) Deciduous broad-leaved forest: *Betula platyphylla* and *Populus davidiana* communities are the main types, and are secondary forests in Tibet. In addition, *Alnus nepalensis* and *Salix spp.* communities are found in southeastern Tibet.

7) Subalpine evergreen coniferous forest: This is a most important type of forest in Tibet. The main communities are as follows: *Picea likiangensis* var. *balfouriana* in the three river gorge region 3200-4200 m; *Picea likiangensis* var. *lintzeensis* at Mainling, Nyingchi, and Bomi 3200-4300 m; *Abies spectabilis* on the southern slopes of the middle Himalayas at 3600-4200 m; *Abies gorgei* var. *smithii* at Zayu and Bomi at 3400-4200m; *Sabina tibetica* at the three river gorge region at 3400-4600 m etc.

8) Subalpine deciduous coniferous forest: This is usually distributed about tree-line in the southern part of southeastern Tibet. The communities are *Larix graffithii*, *L. potaninii* var. *macrocarpa*, *L. spiceosa* etc.

b) Shrubs

1) Alpine shrubs: There are three types of alpine shrublands, which are generally distributed above treeline in mountainous areas.

(a) Leather leaved shrubs: *Rhododendron anthopogon*, *R. cephalatum*, *R. nivale*, *R. thrichostomum* etc.

(b) Deciduous leaved shrubs: *Caragana jubata*, *C. versicolor*, *Potentilla fruticosa*, *Salix* spp., etc.

(c) Needle-leaved shrubs, such as *Sabina pingii* var. *wilsonii* etc.

2) Subalpine shrubs: The dry-warm valley shrubs. In the middlecourse of Yarlung Zangbo between 3500 and 4200 m *Sophora moorcroftiana* communities exist. In the Jinsha, Lancang, and Nu river gorge, 2300 to 3400 m, the main community is *Sophora viciifolia*. The river flood-shoal shrubs: between 3800 and 4000 m there are *Hippophae rhamnoides* and *Myricaria elegans*. Subalpine deciduous secondary shrubs; in the southeastern part of Tibet, 3400-3800 m,are *Berberis umbellata*, *Cotoneaster multiflorus*, *Rosa sericea*, *R. omeiensis*, *Spiraea mollifolia* etc.

c) Meadows

1) Alpine meadows: In northeast and southeast Tibet, at 4200 to 4800 m, are *Kobesia pygmaea*, *Polygonum shaerostachyum*, *P. viviparum*, etc.

2) Interzonal meadow: Near the plateau lake shore, and flood plain beaches, there are *Carex moorcroftii*, *Kobresia littledalei*, and *Polygonum sibiricum* communities.

d) Steppes

1) High-cold steppe: In northern Tibet (Qangtang) 4600(4400)-5100 m, there are *Stipa purpurea*, *Carex moorcroftii*, *Artemisia minor*, *A. wellbyi*, and *Stipa subsessiflora* var. *basi-*

plumosa communities. These are also found on northern slopes of the middle Himalaya.

2) Subalpine steppe: In the mountains on both sides of Central Yarlung Zangbo 3800-4400(4600) m, there are *Aristida triseta* and *Orinus thoroldii* communities.

e) Deserts

1) High-cold desert: In the northern part of Ngari and northwestern part of Qangtang 4600-5200m, a Ceratoides compacta community is distributed. The dominant species is a cushion shrub.

2) Montane desert: In the western part of Ngari 4200-4600 m, is *Caeratoides latens*, *Christolea crassifolia*, *Ajania fruticosa* etc.

f) Alpine scattered vegetation

1) Flowstone slope scattered vegetation: Below the nival zone of every belt spectrum, there are communities of *Saussurea tridactyla*, *S. gnophaioides*, *Arenaria musciformis* and *Cremanthodium plantagineum* etc.

2) Cushion vegetation. On gentle arid slopes with whetstone in the Himalayan rain shadow region above 3900m, cushion plants are developed. The dominant species are *Arenaria musciformis*, *Androsace tapete*, etc.

g) Aquatic vegetation

In static and slow flowing water are *Hippuris vulgaris*, *Myriophyllum verticillatum*, *Potamogeton pectinatus* etc.

III. CHARACTERISTICS OF VEGETATIONAL DISTRIBUTION IN TIBET

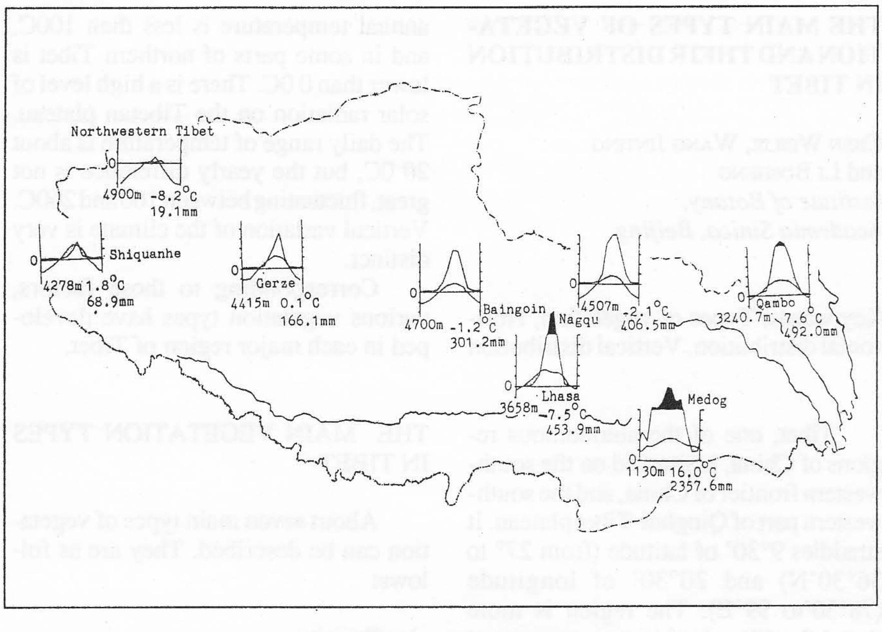

Fig. 1 — Climatic diagrams of eight weather stations of Tibet.

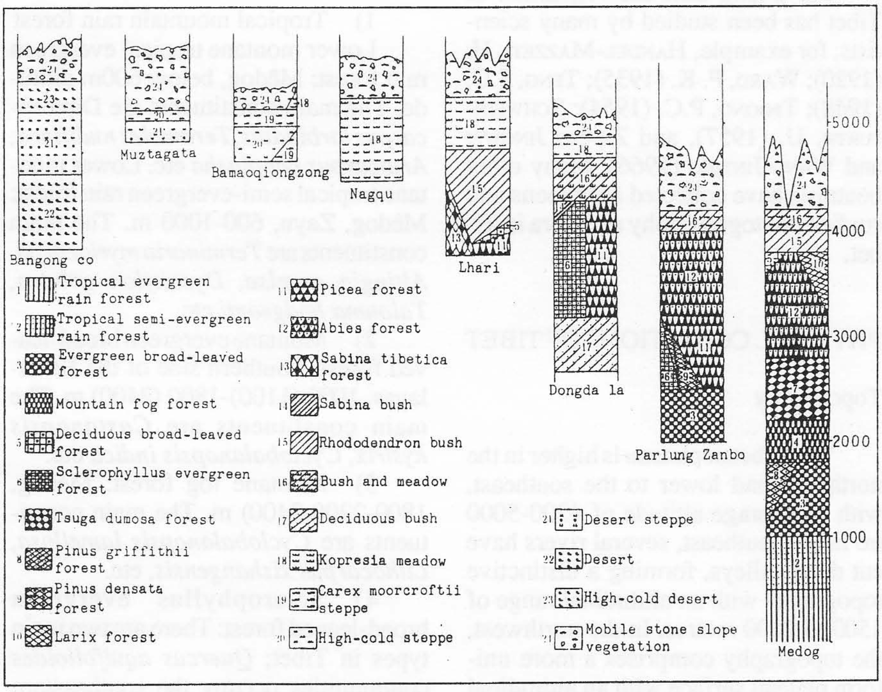

Fig. 2 — The vertical distribution of the vegetation types in Tibet.

Vegetational distribution in Tibet is very complex. It consists of close combinations of vertical and horizontal zonation.(Fig. 2) At the southern frontier mountains of the Tibetan plateau, the main characters of the vegetational belts are as follows:

Tropical rain forest forms the basic belt. Above it exists a belt of montane fog forest (1800-2400m), and then a belt of *Tsuga dumosa* and *Quercus semicarpifolia*, both of which are absent in the temperate zone. There is no deciduous broad-leaved forest belt. The amplitude of each belt is very wide, usually more than 1000 m.

There are well developed alpine shrublands and alpine meadow between the tree line and the snow line, but none of the tundra which exists on the temperate zone mountains. All these characteristics indicate that the vegetation of the southeastern Tibetan plateau is tropical and subtropical mountain vegetation.

There are some local variations in the belts, caused by the effects of local topographical and edaphic factors in the Himalayas. For example, at the Mêdog region of the southeastern Tibet a well developed evergreen broad-leaved forest exists, but there is no *Picea* forest nor the sclerophyllous evergreen braodleaved forest within the subalpine coniferous belt. The *Tsuga dumosa* forest directly adjoins the *Abies* forest belt, which has a wide vertical amplitude. All of these characteristics suggest a very moist local climate.

In the more arid local regions, such as at Zayu in the southeastern, and at Yadong and Gyirong in the southwestern parts of Tibet, there are coniferous forests (*Pinus yunnanensis*, *P. roxburghii* etc) and well developed sclerophyllous evergreen broadleaved forests (*Quercus semicarpifolia*, *Q. aquifolioides* etc) form a mixed forest belt with *Tsuga*.

In the valley of three rivers, because of the warm dry environment, the thorn bush *Sophora viciifolia* grows on drier sites. In the northern region of the hairpin bend of Yarlung Zangbo river the rather moist climate induced by the monsoon blowing up along the river has created an evergreen broad-leaved forest dominated by *Quercus tungmainensis*. All of these characters show how complex is the distribution of the mountain vegetation and how distinct is its local difference in the southeastern part of Tibet.

Different environmental conditions on the Tibetan plateau (particularly the decrease in moisture from southeast to northwest) creates a zonal distribution of meadow, steppe and desert plants accordingly.

The meadow vegetation zone characterised by low and uniform *Kobresia pygmaea* begins to appear in the upper region of the Nu river, (in the northeastern part of Tibet) where there is no forest vegetation.

Further towards the northwest the climate becomes gradually dry and cold, and the *Kobresia* meadow is succeeded by xerophytic *Stipa purpurea* steppe. Such a steppe vegetation also appears in the "rain shadow" region in the southern part of Tibet, but in the more northern part of Tibet, Qangtang, it becomes broader and more extensive. Its sparsely scattered grass cover, simple structure of stratum, and the synusia of cushion plants are characteristics in which it differs from the general steppe of the temperate zone.

At lower altitudes (3000-3800 m) in the steppe zone, (for example, in the valley of the middle course of the Yarlung Zangbo river) there are bushes and steppes with some subtropical floristic components, such as some species of the genera *Arundinella*, *Celatostigma*, *Danthonia*, *Orinus*, *Onosma*, and so on.

From Qangtang toward the northwest, the desert components among the steppe vegetation increase gradually. Especially in the northwestern part of the Ngari region, the most arid part of the Tibetan plateau, an extremely arid desert type of vegetation exists. This is characterised by *Ceratoides latens*, while in the neighbouring Kunlun mountains the high-cold desert is typified by the cushion forming plant *Ceratoides compacta*.

On the details of vegetational division of the vegetation in Tibet, there is no unanimous conclusion yet. Three important summaries have been published:

(a) Vegetation of Plateau zonation (CHANG, 1981)

(b) Three vegetational regions (HOU, 1982)

(c) Plateau vegetation of subtropical zone (ZHANG 1980)

Based on environmental conditions and the characteristics of vegetation in Tibet, in fact, there are two major divisions: humid regions, and arid regions. They belong respectively to southeast Asia and central Eurasia. Both have belts of mountain vegetation with horizontal transitional zones.

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ON THE VEGETATION ZONALITY OF QINGHAI-XIZANG PLATEAU

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Key words: Vegetation zonality, Qinghai-Xizang (Tibet) Plateau

The Qinghai-Xizang Plateau and its fringe of mountain ranges is the largest mountainous system in Asia. It has a remarkable influence on the climate, physical geography and the vertical and horizontal vegetation zonation of east Asia.

The general elevation of more than 4,000 m of the Plateau is a major factor in the zonation of the vegetation. The massiveness of the Plateau, extending 14° in latitude and 25° in longitude, is a further major factor in the distribution of vegetation. The range is from forest to alpine meadow and scrub, high-cold steppe, and high-cold desert.

The zonality of the vegetation and opinions regarding its development have been discussed by CHIAN (1960), HOU (1957), HUANG (1959) and SCHWEINFURTH (1957). The traditional concept has been termed "regionalization" while more recently the concept of "extrazonal" has evolved. The characteristic latitudinal zonation is broken by the altitudinal massiveness of the plateau and therefore the vegetation zones are expressed differently (Fig. 1).

A converse view point is that the altitudinal belts are connected with the latitudinal or regional zonation. This concept stresses that the vegetation zonation results from a combined altitudinal-latitudinal influence.

A newer concept has been proposed by CHANG (1981), the "high plateau zonation" theory. Chang has stressed that the fringe mountain ranges provide the vertical belts while the high elevation of the plateau provides the horizontal or latitudinal zonation.

Another concept has been called the "latitudinal zones through the plateau" which emphasizes that the latitudinal zonation is fundamental and that the vertical zones are secondary. The plateau vegetation is considered to be the "upper steps" from the neighbouring mountain ranges and that this produces the different latitudinal zones (ZHANG, 1981).

Against these views, I would like to propose my opinions. The vegetation of the fringe mountains is considered as the vertical belt of the neighbouring horizontal zones found on the Plateau and that this provides the connection for the vertical-horizontal zones of the Plateau.

Many researchers have studied the striking pattern of the vertical vegetation belts on the fringe mountains. However, few researchers have attempted to correlate the vertical and horizontal zones. Even in the theory of "three dimensional zonation", there is no discussion of this problem. The vertical dimension is limited to the fringe mountain ranges (TROLL, 1972).

Based upon the studies of the mountain vegetation on the north and south slopes of Mt. Chomolungma (Mt. Everest) (Fig. 2) and the mountains of western Sichuan and northern Yunnan (Figs. 3 and 4), I believe that although the vertical belts are somewhat different on each mountain massif there are also similarities. Although these mountains are located within the tropics and subtropics, the upper zones of subalpine coniferous forests, alpine meadow scrub and the nival have remarkably common characters. Thus it is possible to arrange the vegetation zones from south to north, from lower to higher elevations into a ladder-like belt within these tropical and subtropical latitudinal zones. The bottom zone or vegetation belt can be shown within the general pattern of latitudinal zonation (Figs. 3 and 4).

From this point of view, it is possible to combine the vegetation zones of the fringe mountain ranges as a part of the horizontal zones of vegetation found on the Plateau (SHU, 1960, 1964; ZHANG and SHU, 1973).

THE RELATION BETWEEN THE FRINGE MOUNTAIN BELTS AND THE HORIZONTAL ZONES WITHIN THE PLATEAU

Physiographically, a distinct boundary exists between the Plateau and its fringe of mountain ranges. However, the pattern of vegetation is not the same; it is a combination of the vertical-horizontal rather than one or the other.

The vertical belts are distinctly expressed in the fringing mountains while on the Plateau the vegetation belts are arranged south to north with increasing aridity, or distance from the annual monsoon. Thus there is a zonation from forests in the south through meadow and steppe vegetation to deserts in the north. Here the horizontal rather than vertical zones or belts predominate. Based upon this view, there is no sharp boundary in the pattern of vegetation from the fringing mountains to the high plateau, but only a gradient. Since the Xizang Plateau is not cut by deep valleys, it is difficult to understand what is the basic cause of the zones.

There is a broad zone occupied by alpine meadow and scrub and steppe at the south and southeastern part of the Plateau. Steppe vegetation is found west of Lhasa towards Dingri, Rikaze and the Tsongpo Valley, influenced by the rainshadow of the Himalaya. The alpine meadow and scrub forms a broad belt from Lhasa towards the east and north to Nagqu, Changdu, northern Yunnan, western Sichuan and southwestern Qinghai (ZHANG and WANG, 1966). This alpine meadow and scrub belt is not only the upper zone of vegetation in the tropical and subtropical mountains, but also dominates in the transition zone from the fringe mountains towards the inner plateau. Towards the northwest, with increasing aridity, the alpine meadow and alpine scrub change to the high-cold steppe and the high-cold desert zones. Thus the alpine scrub is the transitional zone from the mountains to the Plateau.

The high-cold steppe extends from the Plateau towards the northeast along the southern side of Xekexili and the northern side of Mt. Bayankala to the valley of the Yellow River and the lands surrounding Kokonor Lake (Qinghai Lake). The cold steppe extends to the temperate steppe zone extending from southwest Ordous of Inner Mongolia and Lanchou (see Fig. 5) (HOU, 1983). The high-cold desert zone connects with the desert zone of Inner Mongolia and Xinjiang at the boundary of the western Kunlun Mt. and Altin Mt. and the western Gilan Mt. Desert vegetation occurs from the base to the top of the mountains and southward to the Tsaidam Basin.

Looking at the general zonation of vegetation on the Plateau it is connected with comparable vegetation zones in the whole of China. China is influenced by the monsoons, including the fringe mountains of the Plateau. The latitudinal zonation in China extends from tropical monsoon, subtropical evergreen, broadleaved, and boreal coniferous forests, etc. To the northwest, including the inner plateau, and extending into central Asia, the climate is arid. The vegetation changes from forest to steppe and finally to desert. Here longitudinal rather than latitudinal controls become central, a patterning similar to that found on the Plateau.

Finally, I would like to summarize my opinions as follows:

1. The traditional view of vegetation on the Plateau is that of regionalization but I propose the view of vertical-horizontal zonation, the connection of vertical and horizontal zones.

2. The vegetation of the plateau fringe mountains belongs to the concept

of vertical belts. This concept includes the latitudinal or horizontal zones including tropical monsoon, subtropical evergreen, broad leaved temperate forests, etc. Secondly, the upper zones in the mountains are the ones that connect the fringe mountains to the zones of vegetation across the Plateau.

3. The formation of the zonal transition from forests to the cold steppe and cold desert of the inner plateau are caused by the transition from the vertical to the horizontal zonality rather than separate zonal patterns.

4. The fringe mountains of the Plateau with their forests and the high-cold steppe and high-cold desert of the Plateau are connected through their horizontal zones and the plateau vegetation is not separate from that found in central Asia. Thus the vegetation zones of the Plateau cannot be considered as separate types of vegetation

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A PRELIMINARY STUDY ON ALPINE VEGETATION IN THE QINGHAI-XIZANG (TIBET) PLATEAU

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Key words: Qinghai-Xizang Plateau, Alpine vegetation, Vertical spectrum, Alpine cushion vegetation

The Qinghai-Xizang (Tibet) Plateau, 2,400,000 km² in area, is the largest, highest and the youngest plateau in the world. Several large mountain ranges, such as the Himalayan, the Hengduan, and the Kunlun stretch along the margin and the interior of the plateau. Within this severe climate, there are many kinds of alpine vegetation that have developed in these ranges (EDITING COMMITTEE OF CHINA VEGETATION, 1980; EDITING COMMITTEE OF SICHUAN VEGETATION, 1980; HOU, 1982; INTEGRATED SURVEY TEAM OF SINKIANG & INSTITUTE OF BOTANY, 1978).

THE MAIN TYPES OF ALPINE VEGETATION

"High mountain" as a scientific term has many different viewpoints all over the world (BILLINGS, 1979). The mountain vertical belt above the forest line is named the alpine belt, and the vegetation is called alpine vegetation in this paper. There are different types of alpine vegetation in the Qinghai-Xizang Plateau, such as 1) alpine scrub. It is chiefly distributed on the southeast mountains of the Plateau, the evergreen leaved-leathery scrubs dominated by *Rhododendron* spp. grow luxuriantly on shady slopes with evergreen needle-leaved scrub dominated by *Sabina pingii* var. *wilsonii* on sunny slopes. In addition, the deciduous broad-leaved scrub including species of *Salix*, *Dasiphora*, *Caragana*, etc. is widely distributed. 2) High-cold meadows occur over a vast area in the southeast part of the Plateau, the most typical community is dominated by *Kobresia* spp., and forb meadows are composed of species of *Polygonum*, *Spenceria*, *Leontopodium*, *Anaphalis*, *Anemone*, *Pedicularis*, etc. 3) High-cold steppe is found on the Chiangtan Plateau and its adjacent regions the East Kunlun Plateau and the river source area of the Changjiang (Yangtze River). Grasslands dominated by *Stipa purpurea* are the most typical (WANG *et alii*, 1982), along with steppes consisting of *Carex moorcroftii* and *Artemisia* spp. 4) High-cold deserts are mainly distributed in the northwest part of the plateau. The community consisting of *Ceratoides compacta* is representative. 5) Alpine cushion vegetation occurs locally in the alpine belt of various parts of the Plateau, but frequently in the central and the southern part (LI *et alii*, 1985). The main dominants are *Androsace tapete*, *Arenaria bryophylla*, *Thylacospermum caespitosum*. 6) Sparse vegetation occurs on alpine scree and rock stripe slopes. These are found widely in the subnival belt of the Plateau. Common species belong to the genera *Saussurea*, *Rhodiola*, *Phyllophyton*, *Melandrium*, *Christolea*, *Corydalis*, *Waldheimia* and *Carex*.

THE DISTRIBUTION PATTERN OF THE ALPINE VEGETATION

Within the alpine belt, alpine scrub - high cold meadow - high cold steppe- high cold desert occur in order from southeast to the northwest. Though this change is certainly influenced by the altitude, it chiefly demonstrates the horizontal variation influenced by the route of the monsoons toward the interior of the plateau. The principal environmental factors resulting in this change are solar radiation, temperature, and precipitation caused by variation in terrain and altitude (ZHENG *et alii*, 1979), but the decisive factor is precipitation under the influence of the monsoon. As shown in Fig. 1, the annual mean temperature drops gradually from southeast to northwest on the Plateau. Variation in the mean annual temperature and that of the warmest month at 4000 m is not marked. On the contrary, rainfall shows greater variation.

The vertical pattern of alpine communities is very different from one area to another (Fig. 2). The alpine belts of the southeast region of the Plateau and its margin (Fig. 2-A.B.C.D.E.), are dominated by alpine scrub. The distributional pattern of alpine scrub and high-cold meadow is controlled by sunny vs. shady slopes rather than by elevation. In some areas these communities form an alpine scrub-meadow belt. Scree slopes with few plants and the nival belt without plants occupy the higher elevations. Below the alpine belt there are various types of forests.

On the mountains of northeast Xizang and southern Qinghai Province (Fig. 2- F.G.H.), high-cold meadows predominate over alpine scrub. These communities not only appear on the shady and sunny slopes respectively, but also have a vertical differentiation with the scrub at lower elevations. High-cold meadow communities occur on many mountains with *Kobresia* meadows predominating over forb meadows. Alpine cushion vegetation is widely distributed.

The Chiangtang Plateau is a semi-arid inland. Here the vertical pattern of communities changes. The high-cold steppe is a main type in the alpine belt (Fig. 2-I.J.); the alpine scrub seldom occurs, and high-cold meadows are found occasionally. At higher elevations there are scree slopes with few plants. In the northwest region of the Qinghai-Xizang Plateau, typical vegetation consists of high-cold desert or the high-cold steppe desert, with high-cold steppe and scree slopes with sparse plants above (Fig. 2-K.).

DISCUSSION AND CONCLUSION

1. The diversity of alpine vegetation.

As mentioned above, the Qinghai-Xizang Plateau is the richest floristically and the most extensive region of alpine vegetation in China. The main reasons are the unique physiographic setting and the environmental diversity of the plateau. The plateau lies within the subtropical and the warm-temperate latitudinal zones, and includes humid, semi-humid, semi-arid, and arid climates. These characteristics result in the great diversity of plant communities. There is mesophilous vegetation - the alpine scrub and the high-cold meadow, the xerophilous vegetation - high cold-steppe and the high-cold desert. The Qinghai Xizang Plateau forms a floristic and geographic region (WU, 1979; EDITING COMMITTEE OF CHINA VEGETATION, 1980). In other words, it is a mountain plateau containing several zones or biomes (WALTER, 1979) with alpine vegetation types predominating.

2. The vertical belt types of the alpine vegetation.

The alpine vegetation belt of the Plateau is a part of the mountain vertical belt spectrum. As mentioned before, the montane vegetational zones of the southeast plateau are composed of mesophilous communities such as forests, scrubs and meadows. It is obvious that these zones or belts are affected by an oceanic humid climate, corresponding to humid and semi-humid climates. The alpine belt of the northeast Xizang and the south Qinghai Province, is the same or similar to the upper part of the montane vertical spectra of the above mentioned region. It also belongs to the humid type. On the Chiangtang Plateau and adjacent regions, such at the East Kunlun Plateau and the river source area of the Changjiang (Yangtze River), the alpine belt is dominated by xerophytic high-cold steppes. The alpine belt of the northwestern part of the QinghaiXizang Plateau consists of high-cold desert adapted to an arid climate. At higher elevations the high-cold steppe is adapted to a semi-arid climate. The mesophilous alpine scrub does not occur in these regions, and the high-cold meadow vegetation occurs as a limited type in some mountains.

3. The ecologic-geographic characteristics of the alpine cushion vegetation.

The alpine cushion vegetation occurs in different regions. It is sparse in the humid and the arid regions, but is frequent in the semi-humid and the semi-arid regions. It is more abundant in the transitional area of the semi-humid and semi-arid regions. This indicates that the ecological character of alpine cushion vegetation is similar to the meadow and the steppe vegetation. The alpine cushion vegetation is not a zonal type for it does not occupy a specific place in the horizontal vegetation zone of the Qinghai-Xizang Plateau. The vertical distribution of alpine cushion vegetation is relatively wide, as a plant community but it does not form an independent belt.

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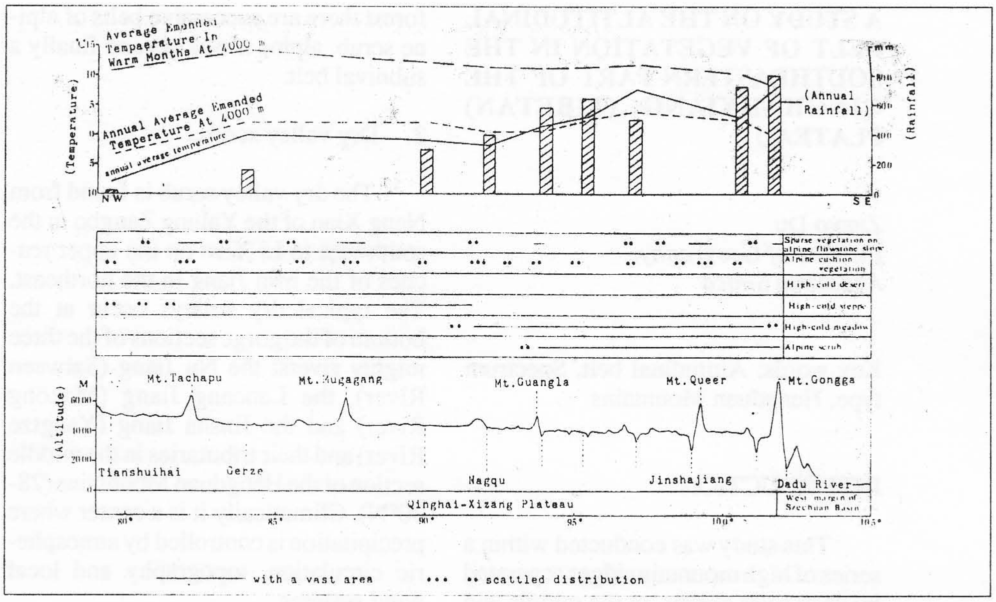

Fig. 1 — Horinzontal vegetation distribution from SE to NW in relation with temperature and rainfall in the Qinghai-Xizang Plateau.

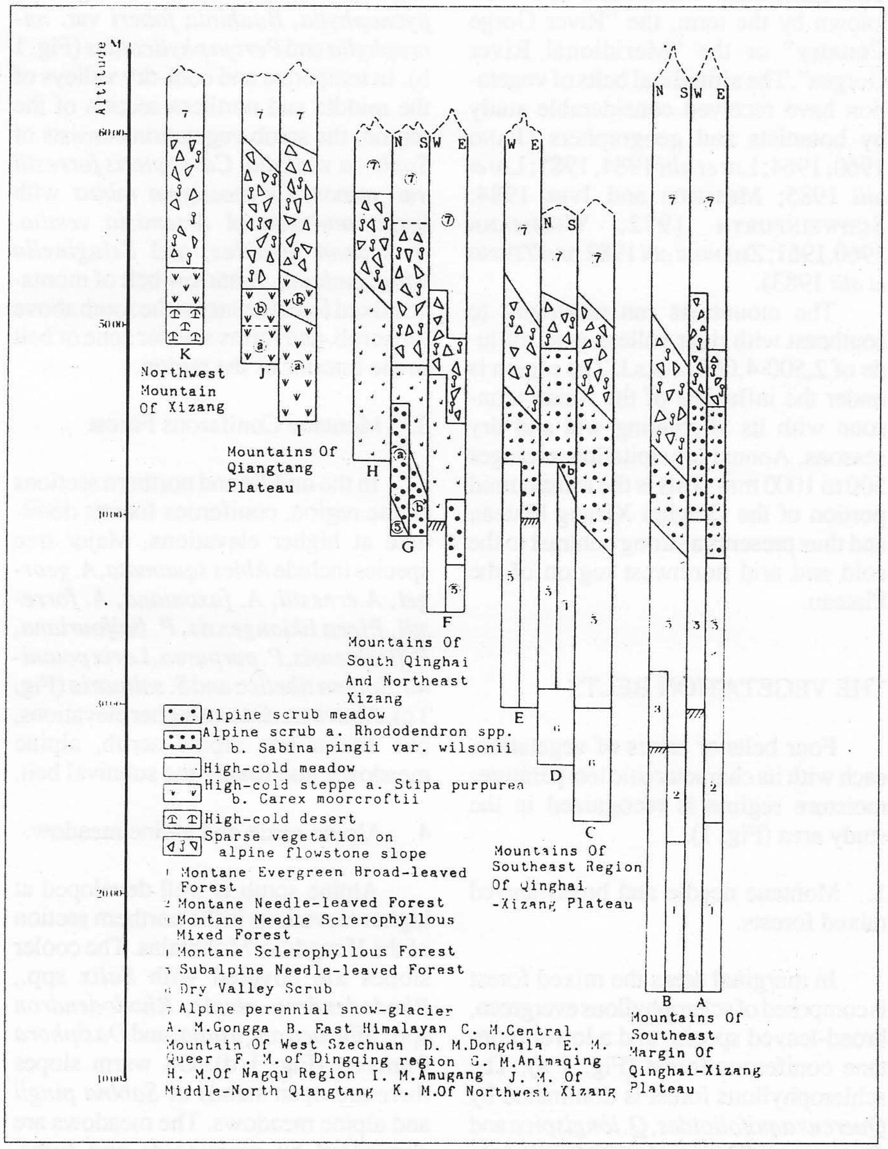

Fig. 2 — Vertical distribution of alpine vegetation of Qinghai-Xizang Plateau.

A STUDY ON THE ALTITUDINAL BELT OF VEGETATION IN THE SOUTHEASTERN PART OF THE QINGHAI-XIANG (TIBETAN) PLATEAU

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Key words: Altitudinal belt, Spectrum type, Hengduan Mountains

INTRODUCTION

This study was conducted within a series of high mountain ridges separated by deep river gorges, in the middle and northern sections of the Hengduan Mountains in the Nyingchibomi District. The Hengduan Mountains are well known by the term, the "River Gorge Country" or the "Meridional River Gorges". The altitudinal belts of vegetation have received considerable study by botanists and geographers (JIANG 1960, 1964; LIU *et alii* 1984, 1985; LIU *et alii* 1985; MESSERLI and IVES 1984; SCHWEINFURTH 1972, WISSMANN 1960,1961; ZHANG *et alii* 1982 and ZHONG *et alii* 1983).

The mountains run northwest to southeast with river valleys at an altitude of 2,500-4,000 m a.s.l. The region is under the influence of the Asian monsoon with its alternating wet and dry seasons. Annual precipitation averages 500 to 1000 mm. This is the most humid portion of the Qinghai Xizang Plateau and thus presents a strong contrast to the cold and arid northwest region of the Plateau.

THE VEGETATION BELTS

Four belts or zones of vegetation, each with its characteristic temperature-moisture regime is recognized in the study area (Fig. 1).

1. Montane needle and broad-leaved mixed forests.

In marginal areas the mixed forest is composed of sclerophyllous evergreen, broad-leaved species and a lower montane coniferous forest (Fig. 1 a). The schlerophyllous forest is dominated by *Quercus aquifolioides*, *Q. longispica* and *Q. pannosa*. The coniferous forest consists of *Pinus densata*, *Tsuga dumosa* and *T. chinensis*. In places there are secondary (successional) forests dominated by *Betula platyphylla* and *Alnus nepalensis*. Above the upper coniferous forest there are successive belts of alpine scrub, alpine meadows and finally a subnival belt.

2. Dry valley scrub.

The dry valley scrub is found from Nang Xian of the Yalung Zangbo in the southwest to Li Xian on the upper reaches of the Min Jiang in the northeast. The typical dry valleys occur at the bottom of the gorge sections of the three mighty rivers; the Nu Jiang (Salween River), the Lancang Jiang (Mekong River) and the Jinsha Jiang (Yangtze River) and their tributaries in the middle section of the Hengduan Mountains (28-30°N). Climatically it is a center where precipitation is controlled by atmospheric circulation, topography and local wind systems.

In the warm valleys of marginal lands, the major species include *Vitex negundo* var. *microphylla*, *Sageretia pycnophylla*, *Bauhinia faberi* var. *microphylla* and *Pertya phylicoides* (Fig. 1 b). In temperate and cool-dry valleys of the middle and northern section of the region, the scrub vegetation consists of *Sophora vicifolia*, *Caryopteris forrestii* var. *minor*, *Ceratostigma minus* with lesser amounts of *Artemisia vestita*, *Arthraxon hispidus*, and *Selaginella sanguinolenta*. A narrow belt of montane mixed forest occurs in the south above the scrub, and forms a wider zone or belt in the interior of the region.

3. Montane Coniferous Forest

In the middle and northern sections of the region, coniferous forests dominate at higher elevations. Major tree species include *Abies squamata*, *A. georgei*, *A. ernestii*, *A. faxoniana*, *A. forrestii*, *Picea likiangensis*, *P. balfouriana*, *P. linzhiensis*, *P. purpurea*, *Larix potaninii*, *Sabina tibetica* and *S. saltuaria* (Fig. 1 c). Above treeline, at higher elevations, one encounters alpine scrub, alpine meadows, and finally the subnival belt.

4. Alpine scrub and alpine meadow.

Alpine scrub is well developed at higher elevations in the northern section of the Hengduan Mountains. The cooler slopes are covered with *Salix* spp., *Rhododendron nivale*, *Rhododendron* spp., *Sibiraea angustata*, and *Dasiphora fruticosa* (Fig. 1 d). On warm slopes there are open stands of *Sabina pingii* and alpine meadows. The meadows are dominated by graminoids and forbs, including *Kobresia pygmaea*, *K. setchwanensis* and other species of *Kobresia*, *Polygonum macrophylla*, *P. viviparum*, *Festuca ovina*, *Anaphalis flavescens* and *Spenceria ramalana*.

REGIONAL VARIATION IN THE ALTITUDINAL ZONES OF VEGETATION

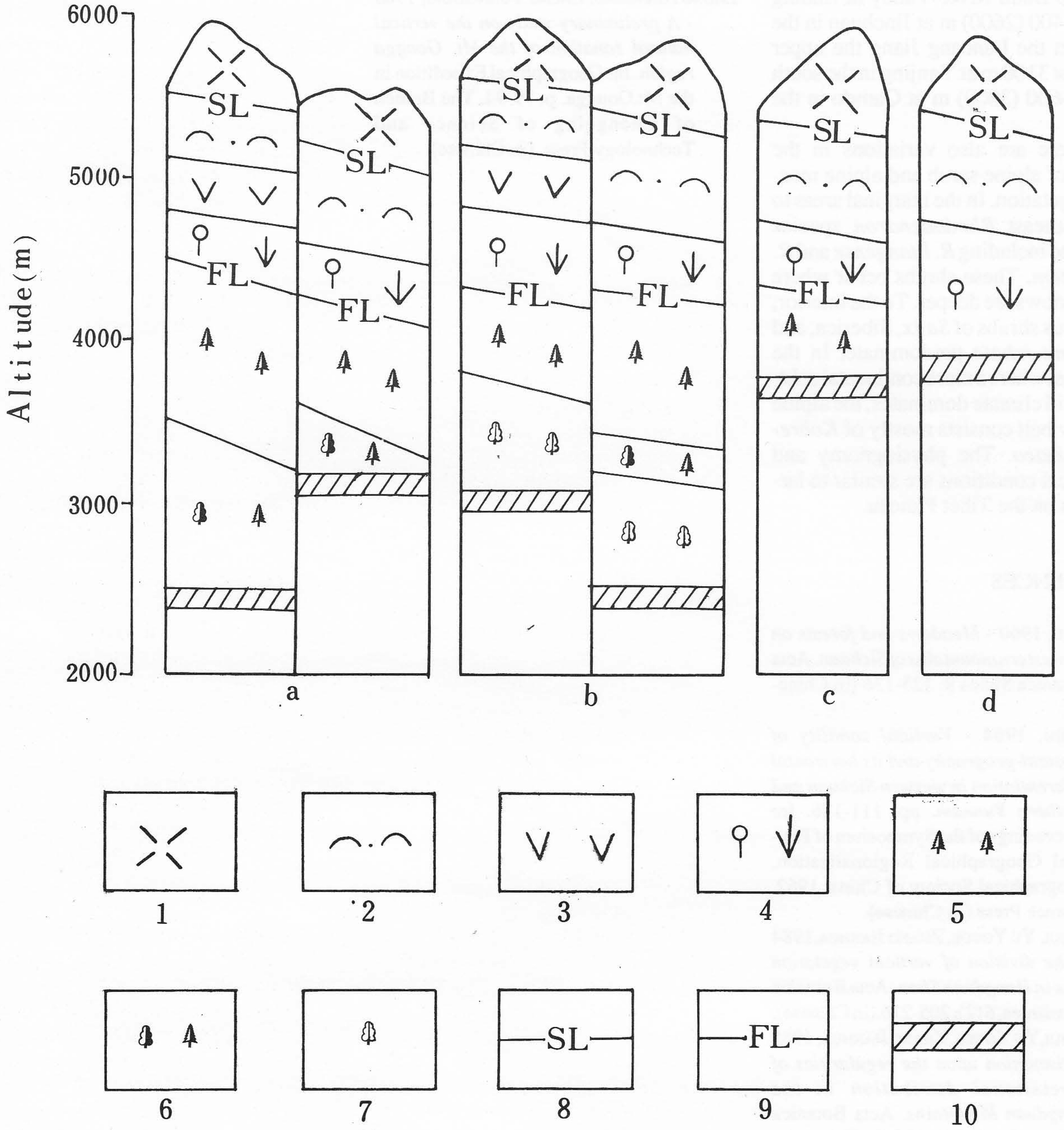
From the margin to the interior of the region the number of altitudinal belts decreases and species richness also decreases. In the southern section of the Daxue Shan near Jiulong the montane needle and broad-leaved mixed forest belt consists of five zones. In the Mt. Qiaoer Shan district, near Manigango the montane coniferous forest consists of only three or four zones.

The forest types that occur in the montane needle leaf and broad-leaf mixed forest belt are quite different throughout the region. The hygrophilous forests of *Tsuga dumosa* and *T. chinensis* dominate in the southeastern marginal lands. Towards the interior, where precipitation is less favorable, forests of *Pinus densata* dominate. The montane schlerophyllus evergreen broad-leaf forests consist mostly of *Quercus aquifolioides* and *Q. longispica*. These forests predominate in the altitudinal range of 2500-4000 m. In some places a variation of the scrub type, dominated by species of *Quercus* reaches an elevation of 4200-4500 m.

In most of the region the upper montane coniferous forest is dominated by species of *Abies* and *Picea*. Near the margin of the region this belt is 800-1000 m in width with *Picea balfouriana* on north-facing slopes and open forests of *Sabina* on south-facing slopes. This coniferous forest belt decreases to 400-500 m in width to the northwest, occurring in discontinuous patches. Further northwest the belt narrows and gradually disappears.

The upper limit of these forests varies in elevation in relation to the geographic location. Along the eastern margin the upper limit is found at 3700-3800 m, even less than 3,500 on the eastern slopes of the Qionglai Shan and the Jiajin Shan. The upper forest limit reaches 4200-4300 m inland, in the middle section of the Hengduan Mountains, and drops to 4000-4200 m in the northern section. In eastern Tibet the forest limit is at 4,400 on shady, cool slopes and at 4600 m on sunny slopes, dominated by *Picia balfouriana* and *Sabina tibetica* respectively. Compared with other regions, these are the highest elevation forests in the world (WISSMANN 1960, 1961) at these latitudes (30-31° N).

The scrub belt in dry valleys varies in elevation by 300-800 m, depending upon the precipitation regime. The upper limit of the scrub belt can be considered the lower limit of the montane forest belt. In the middle section the upper limit of the scrub is found at 1,600 on the



1. nival belt;
2. subnival belt;
3. alpine meadow belt;
4. alpine scrub and meadow belt;
5. montane coniferous forest belt;
6. montane mixed needle- and broad-leaved forest belt;
7. dry valley scrubs belt;
8. snowiine;
9. upper forest limit;
10. piedmont belt

a. type of the base-belt of montane needle- and broad-leaved mixed forest;
b. type of the base-belt of dry valley scrubs;
c. type of the base-belt of montane coniferous forest;
d. type of the base-belt of alpine scrubs and meadows.

Fig. 1 — Spectrum-types of the altitudinal belt of vegetation in the southeastern part of Qinghai-Xizang (Tibetan) Plateau.

eastern margin and 3,100 m in the interior of the region. From south to north the upper limit of scrub occurs at 1,600 m in the Dadu River Valley at Luding and at 2400 (2600) m at Jinchuan in the north. In the Lancang Jiang the upper limit is at 3100 m at Yanjing in the south and at 3600 (3800) m at Qamdo in the north.

There are also variations in the pattern of alpine scrub and alpine meadow vegetation. In the marginal areas to the southeast *Rhododendron* species dominate including *R. litangense* and *R. fastigiatum*. These shrubs occur where winter snows are deeper. To the interior, deciduous shrubs of *Salix*, Siberica, and *Caragana jubata* predominate. In the northwest where a more continental cold-subhumid climate dominates, the alpine meadow belt consists mostly of *Kobresia pygmaea*. The physiognomy and ecological conditions are similar to large areas on the Tibet Plateau.

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THE ALTITUDINAL BELTS OF VEGETATION ON THE NORTHERN SLOPES OF THE MIDDLE PART OF THE KUNLUN MOUNTAIN RANGE AND THEIR UTILIZATION IN ANIMAL HAUSBANDRY.

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Key words: Vegetation belts, Kunlun Mountain, Vegetation of China.

INTRODUCTION

The Kunlun Mountain Range, stretching along the southern border of Tarim Basin for more than 900 km, is not only one of the largest mountain systems in Central Asia, but also one of the driest mountain regions in the world. Owing to the fact that it is located deep in the hinterland of the large land mass-Eurasia, far remote from the sea and blocked by range upon range of other surrounding high mountains, the moisture-laden air from the sea can hardly penetrate this region. Moreover, the situation is compounded by the drying effect of the extremely arid Taklamakan Desert. Every aspect of its vegetation is influenced by this very arid climate.

The middle part of the Kunlun Range reaches an average elevation of 6000 m, with a main ridge of 7500 m. The southern slope of the Range is connected with the North Tibetan Plateau. The mountains are moderately or shallowly dissected compared with the northern slope where the mountains are lofty and deeply dissected with ravines and valleys.

The vegetation of the Kunlun Mountain Range was not investigated until the 1950's. During 1957-1959, the geobotanical section of the Xinjiang Integrated Investigation Team climbed it at several spots. A paper entitled "The characteristic features of the vegetation of northern slope of Kunlun Mountain Range, with special reference on the relationship between its formation and aridification" was published by LI SHIYING (1960). In this paper Li, for the first time, discussed comprehensively the characteristics and types of altitudinal belts of vegetation on the northern slope of Kunlun. However, some of his theses need to be supplemented and modified.

VEGETATION ON THE NORTHERN SLOPE OF THE MID-KUNLUN RANGE

In his paper, Li pointed out important characteristics of the vegetation on the northern slope of the Mid-Kunlun: 1) incompleteness of the spectrum of altitudinal belts; 2) absence of a forest belt; and 3) severe aridification of the vegetation. Desert vegetation ascends from the inclined plain north of the mountains to 3000 m a.s.l..

Geographically the Kunlun Mountain Range is situated at approximately 36° N. The climate of its basic belt is characterized by warm temperate, yet its vegetation is quite different from that of mountains in eastern China. Its sequential spectrum of altitudinal belts is greatly simplified and it is incomplete. The degree of simplification increases from west to east as aridity increases. In its western part, on Jingetao Mountain and along the upper reaches of Gaizhi He and Yarkan He (Heshlafu), forests of *Picea schrenkiana* can be found at an elevation of 2800-3600 m. But to the east there are no forests. The northern slopes of the middle and eastern parts of Kunlun are completely devoid of a forest belt.

According to Li, "The altitudinal belts of vegetation on the northern slope of Kunlun are not only devoid of complete forest belt like that on the northern slopes of the Tian Shan, southern slopes of Altay Shan and Saur Shan, but it also lacks subalpine meadows (or meadow-steppe) and forest-meadows, which these other ranges posses.

The typical Central Asian mountain steppe, composed of *Festuca* and *Stipa*, is also poorly developed here". Zhang Xinshi also though that "On Kunlun Mountain Range... mountain forest belt and meadow belt completely disappeared... the typical spectrum is: desert-steppe-subalpine meadow steppe-alpine belt of heath and cushion plant" (ZHANG XINSHI, 1963). However, according to our investigation, on the northern slopes of Mid-Kunlun at an elevation of 3370-3600 m, at least within the territory of Qira County, the community dominated by *Kobresia*, *Carex*, *Leontopodium ochroleucum*, *Polygonum viviparum*, *Primula*, *Gentiana*, *Oxytropis* etc. should be listed as subalpine meadow, though there still is a large proportion of the mesoxerophytic "high-cold" - steppe grass silver fescue (*Festuca olgae*) occurring on south-facing slopes. Therefore we consider it mainly a belt of subalpine meadow, but not "meadow-steppe".

It is necessary to point out that the northern slopes of Mid-Kunlun are not only devoid of a forest altitudinal belt, but are also devoid of a shrub belt. From foothills of the mountain to the alpine talus belt, no tract of shrubland can be seen, at least along the route we passed. A few xerophytic shrubs, such as *Caragana camilli-schneideri* and *Berberis kashgarica*, may be distributed on the mountain-steppe belt at about 3000 m a.s.l., yet the former species occurs in other communities, and the latter appears only along stream banks in the bottom of gullies and ravines. The lack of shrub belts is also a characteristic feature of the vegetation of Mid-Kunlun.

Contrary to Li's affirmation, the mountain steppe, composed of *Festuca* and *Stipa*, is very well developed. From 2850 to 3000 m large tracts of communities consisting of *Artemisia parvula*, *Stipa purpurea*, *Festuca ovina* subsp. *sphagnoicola* and *Aster alpinus* with scattered *Caragana camilli-schneideri*, can be found, though they are desert-like to a certain degree.

Desert ascends to 2850 m with mountain steppe occurring in the normal range of subalpine meadows. On south-facing slopes there are fragments of silver fescue communities but no forest or shrub belt is present. All of these indicate a xerophytic vegetation.

The xerophytic vegetation on the northern slopes of the Kunlun Mountain Range is the result of an extremely arid climate and the increased continentality of this great mountain massif. The whole Kunlun Mountain Range is located along the southern border of the extremely-arid deserts of China, with very scarce precipitation, rather high average annual temperature and very high rates of evaporation. For example, Qira, situated at the northern rim of the piedmont diluvial-alluvial fan of the Mid-Kunlun Range, has an annual precipitation of only 34.0 mm with high annual variability. At the same time, the average annual temperature is 11.9° C, and the annual accumulated degree days above 10° C reaches 4727° C. Evaporation is exceedingly large, equaling 2570.6 mm, nearly 77.4 times the precipitation. The average absolute humidity is only 6.3 mb, while relative humidity is usually not more than 41% (Fig. 1). It is well-known that within a certain range of altitude, precipitation increases with altitude. On the northern slope of Mid-Kunlun the same situation holds, so that in Nurlangan at 2320 m (still within the mountain desert belt), annual precipitation increases to 127.5 mm and mean annual temperature decreases to 6.7° C. Thus the effectiveness of precipitation with respect to plant life increases. Nevertheless, precipitation of the Kunlun Mountain district is not comparable

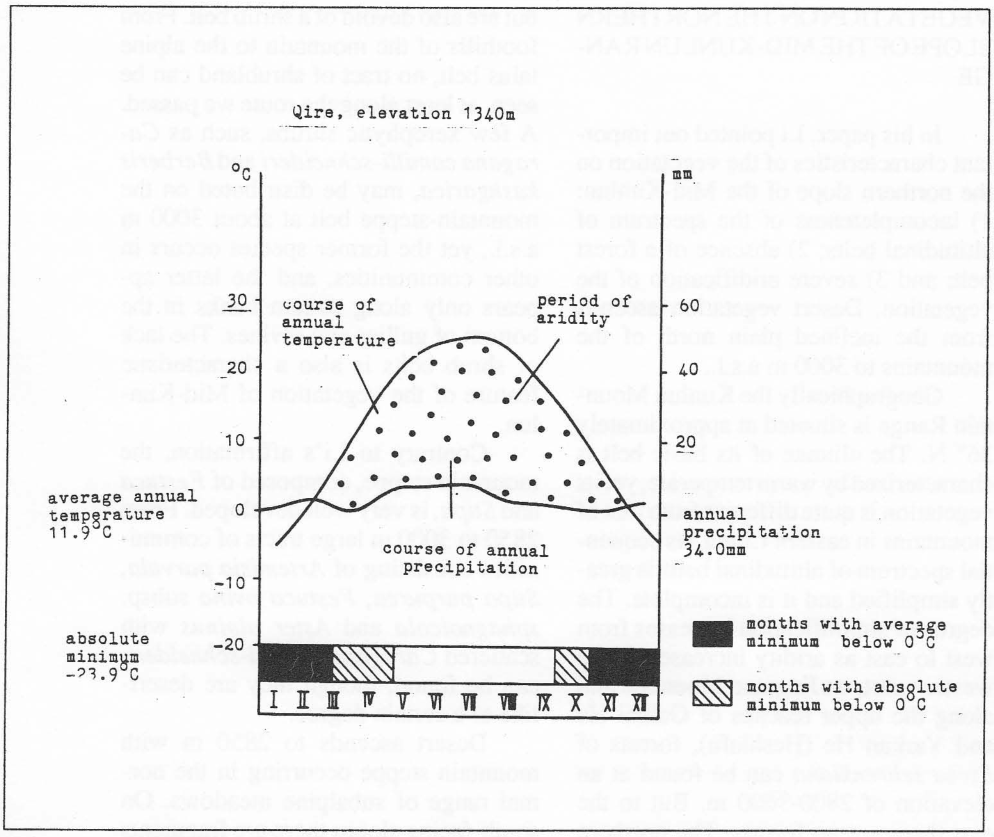

Fig. 1 – The climatogram (after Gausen-Walter).

with that of other mountains of the same latitude. According to the Office of Agroclimatic Regionalization of Hotan Prefecture, precipitation of the northern slope of Mid-Kunlun, including high and medium high mountains, is about 150-200 mm (we conjecture, that in the subalpine belt, it may exceed 300 mm). It is the scarcity of precipitation data in combination with the increased continentality that limits the growth and distribution of woody plants. Therefore, except for some local non-plakor habitats, only communities consisting of xerophytic and superxerophytic perennials and dwarf shrubs prevail. The desert altitudinal belt ascends to 2700 m, with the mountain-steppe desert-like.

ALTITUDINAL BELTS ON THE NORTHERN SLOPE OF THE MID-KUNLUN RANGE

In discussing the division of altitudinal belts of vegetation, we should first determine the criteria by which we judge. The altitudinal vegetation belts form a complex spatial combination of plakoral and non-plakoral communities. This combination corresponds to definite hydrological and thermal regimes, and to certain relief-soil traits. The altitudinal belts should be based upon the types of communities found on plakors. With mountains how can we identify the plakor types? Here, we agree with Ladeigina, that mountain plakor vegetation should be understood as the plant communities in gently inclined, level, or undulating slopes with a deep ground water table, the vegetation and soil of which reflect the typical traits of this altitudinal belt (Ladeigina, 1977). In accordance with this principle, we identified the following sequential vegetational belts:

1. Plain gravelly desert (1400-2200 m) distributed on an inclined sandy gravelly plain (Gobi) with the ground water table generally below 30 m. In this belt, from 1400 to 1600 m is the vast bare Gobi Desert, devoid of vegetation. Many places grow not even grass. Only in some local spots where the sand layer lies near the surface, is there a sparse cover (<5%) of *Zygophyllum fabago*, *Calligonum roborovskii*, *Reaumuria soongorica*, *Salsola* sp. and others.

From 1600-1800 m *Reaumurieta soongorica* predominantes, one of the extremely-arid desert communities. It is characterized by its low coverage (6%) and low richness in species (3 spp/100 m² The whole community is composed of less than 10 species) and biomass is small (100 kg/ha, among them, 1/4-1/3 are withered branches). Other species include *Calligonum roborovskii*, *Tamarix ramosissima*, *Scorzonera divaricata*, *Inula salsoloides*, and others. The last three usually occur on overturned soil along the road side. The soil is a brown desert soil developed from gypsum.

From 1800-2000 m the community changes into *Ephedra przewalskii*, with slightly increased coverage (approximately 12% and a greater biomass (700 kg/ha), yet the richness in species is still low (5 spp/100 m²). Other species include *Reaumuria soongorica*, *Calligonum roborovskii*, *Tamarix ramosissima*, etc. Soils are also an extremely-arid gypsiferous brown desert soil.

2. Mountain desert (2100-2700 m) covers the low mountains and hills. The soil is a loess-derived mountain gray-brown desert soil with light loamy texture. The total coverage of the community varies from 6% to 15%. Richness in species is low, usually 4-5 species are common. Biomass is similar to the previous community (800 kg/ha). Associated species include *Sympegmeta regelii*, *Sophora alopecuroides*, *Scorzonera divaricata*, *Achnatherum splendens*, *Salsola* sp., *Oxytropis* sp. etc. The edificator *Artemisia parvula* is only a small shrub (7-20 cm), but is evenly distributed. The community forms a uniquely dismal picture all over the dissected loess mountains and hills.

Based on records in the literature (Li Shiying, 1960), *Sympegmeta regelii* is also widely distributed, particularly in Inner Kunlun. The lower limit of its distribution is 1800-2600 m, while the upper limit is 2100-2900 m. Associated species are *Orostachys spinosa*, *Halogeton glomeratus*, *Echinopsilon sedoides*, etc. The total coverage varies from 15 to 18%. We did not see it along our route of investigation.

3. Mountain steppe desert (2700-2850 m) occupies the mountain brown soil, which is developed on eolian and slope wash deposits. The dominant is still *Artemisia parvula* with other steppe species. *Stipa roborovskii* is the representative of turf grasses. Herbs-Roborovsk needlegrass-Kunlun sagebrush community occurs on the slope of gullies and ravines at 2700 m. In addition to the dominants such as *Artemisia parvula*, *Caragana camilli-schneideri*, and *Stipa roborovskii*, there are also *Allium satoliczkii*, *Potentilla bifurca*, *Aster alpinus*, *Oxytropis* sp., *Euphorbia tibetica* etc. The total coverage reaches 40%, the height of herbage is 15-25 cm, and biomass is about 1250 kb/ha. In ravine bottoms the shrub *Berberis kashgarica* and the cushion plant *Androsace squarrosa* predominate. The occurrence of *Androsace* may be explained by temperature inversions which enable alpine plants to penetrate to this altitude. On slopes where the ground water table is high, stretches of feather grass

(*Achnatherum splendens*) can be seen.

4. Mountain steppe (2850-3000 m) occurs in the middle part of Kunlun, at 2900-3100 m where there are several flat or undulating mountain tops, covered with relatively thick soils. Each covers an area of several square kilometers. The local inhabitants call them "Ker", such as Fumatuker, Kuaibaiker, Pirmaker, Kuosikabasiker, etc. They are raised sections of the Tarim platform, separated from the latter along an east-west rift. Distributed on these "Ker" or slopes there are mountain desert-like steppe with *Stipa purpurea*, *Festuca ovina* subsp. *sphagnicola*, *Poa litevinowia*, and *Artemisia parvula* as dominants and a variety of herbs. The height of herbage is 20-40 cm and the total coverage is 25-60%. Biomass reaches 1800-3400 kg/ha. *Achnatherum splendens* often dominates locally, especially in depressions with a relatively high ground water level. *Aster alpinus*, *Oxytropis chilophylla*, *Allium satoliczkii*, *A. oreoprasum*, *Euphorbia tibetica*, *Androsace squarrosa*, *Potentilla* sp. and *Astragalus* sp. are common herbs. The Kunlun sagebrush appears in large numbers indicating the xerophytic nature of these communities. This belt contains the most important summer-autumn pastures for livestock breeding in Qira County.

5. Mountain "high-cold" steppe: This is mainly the Silver fescue (*Festuca olgae*) community. It occurs extensively in the upper part of the medium-high mountains and the lower part of the high mountains of Mid-Kunlun. It is a characteristic feature of the northern slope of Mid-Kunlun. Silver fescue, is the edificator of the community, and grows with abundant herbs, such as *Allium*, *Astragalus*, *Oxytropis*, *Leontopodium ochroleucum*, *Potentilla*, *Geranium collinum*, *Poa*, *Euphorbia tibetica*, *Taraxacum*, and others. Occasionally, moss synusia can be found under the herbage. Here the Kunlun sagebrush gradually disappears and many herb species are mesophytic. All of these indicate the relatively cold and moist nature of the habitat. So we list them as mountain "high-cold" steppe. It has a total coverage of 60-90%, with herbage height of 35-50 cm and biomass of 2000-3800 kg/ha. The density of Silver fescue is about 6/m². Soils are a light chestnut brown.

6. Subalpine meadows (3370-3600 m) are found on north, north-east and north-west aspects of the mountains. They generally occupy areas with steep slopes and thin soils (subalpine meadow soil). Herbage is short and low-lying, with a height of 7-15 cm. Plant cover varies from 20 to 75%, yet the biomass may reach 2100 kg/ha. It consists mainly of mesophytic *Cypraceae* and herbs. *Kobresia stenocarpa* and *Polygonum viviparum* are usually the dominants. Other graminoids include *Poa calliopsis*, *Kobresia filifolia*, *Carex musatina*, and *C. serotina*. They grow together with *Androsace squarrosa*, *Parnassia laxmanni*, *Potentilla* spp. *Saxifraga oppositifolia*, *Gentiana karelinii*, *Oxytropis* sp. and others. The floristic and ecological composition make these subalpine meadows, not "subalpine steppe" or "meadow-steppe", although some Silver fescue communities occur on south-facing aspects.

7. The alpine cushion plant belt (3600-4000 m) is characterized by bare and rocky ground. Moist, dark alpine cold desert soils of sandy loam may occasionally be found among boulders with a few sparsely scattered prostrate cushion plants such as *Androsace squarrosa*, *Rhodiola coccinea*, *Polygonum viviparum*, *Oxytropis* sp., and *Leontopodium alpinum* are also present. Lichens can be found on boulder surfaces.

8. Extensive alpine talus deposits of glacial till and debris originating from physical weathering are found above 4000 m. Cushion plants of *Androsace squarrosa* and others occur sparsely between rock blocks along with *Rhodiola* and lichens. *Polygonum viviparum* can also exist on small pockets of soil. Glaciers and permanent snowfields are found above 5,000 m.

ALTITUDINAL BELTS OF VEGETATION AND ANIMAL HUSBANDRY

The northern slopes of the Kunlun Range provide grazing lands for counties along the southern border of the Tarim Basin. For example, Qira County has about 200,000 domestic animals grazing on these lands. Owing to the fact there is no tall grasses that can be cut for hay, these slope pastures are utilized for grazing. There are winter-spring pastures at higher elevations and summer-autumn pastures below. Location of pastures varies in strict accordance with the altitudinal belts of vegetation. The mountain-steppe of 2850-3370 m and subalpine meadow of 3370-3600 m are selected as summer-autumn pastures. Here the summer climate is cool (favorable to the health of cattle), fodder grasses are plentiful and in good quality. Moreover, drinking water for cattle is also available. The desert and mountain steppe-desert of 2100-2850 m are selected as the winter-spring pastures. The plain desert and the outerringing shrub-woodlands (*Populeta diversifoliae*), Reeds (*Phragmites communis*) community and salinized meadows in depressions are all used as winter-spring pastures as well. The period of utilization is similar everywhere: winterspring pastures are used from the end of October to the beginning of May; summer-autumn pastures are used from the beginning of May to early November. Cattle from communes of the mountain district live through the winter below 2500 m in the hilly terrain while those of communes on the plains live in nearby village pastures. In short, the winter-spring pastures are used for about 195 days, while summer-autumn pastures are used for about 170 days. The winter-spring pastures cover a much larger area than that of the summer-autumn pastures. For example, the area of available pastures in Qira County amounts to 3,750,000 ha, of which 66,000 ha are summer-autumn pasture, accounting for 17.6%; 309,000 ha are winter-spring pastures, accounting for 82.4%. Yet the quality of the former is better than that of the latter.

Though this is a vast and thinly populated area, a series of problems have developed in the utilization of these natural pastures. The foremost is overgrazing which leads to severe degradation of pastures. At the summer- autumn pastures near Ya Mem, a village of Qira County, the forage grasses were severely grazed and in many places their height was reduced to less than 10 cm. The amount of nutritious and palatable forage grasses decreased, and at the same time, weeds and poisonous grasses and herbs (i.e., *Oxytropis* sp.) became more abundant. The basic problem is that the number of cattle grows quickly and the area of pastures becomes insufficient. This is especially true for the winter-spring pastures of the mountain communes. Herders have to move cattle from the winter-spring pastures upslope, so that a portion of summer-autumn pasture is used earlier. In addition to this, most of the fuel used by mountain district inhabitants depends upon chopping and digging the dwarf semi-shrubs (*Artemisia parvula*, *Ceratoides latens*, *Calligonum* spp.) found on these pastures, thus further increasing the destruction of vegetation.

At present it is impossible to carry on pasture improvement on a large scale, so controlling the number of cattle, rationally utilizing pastures and enhancing pasture preservation are important measures to prevent further degradation.

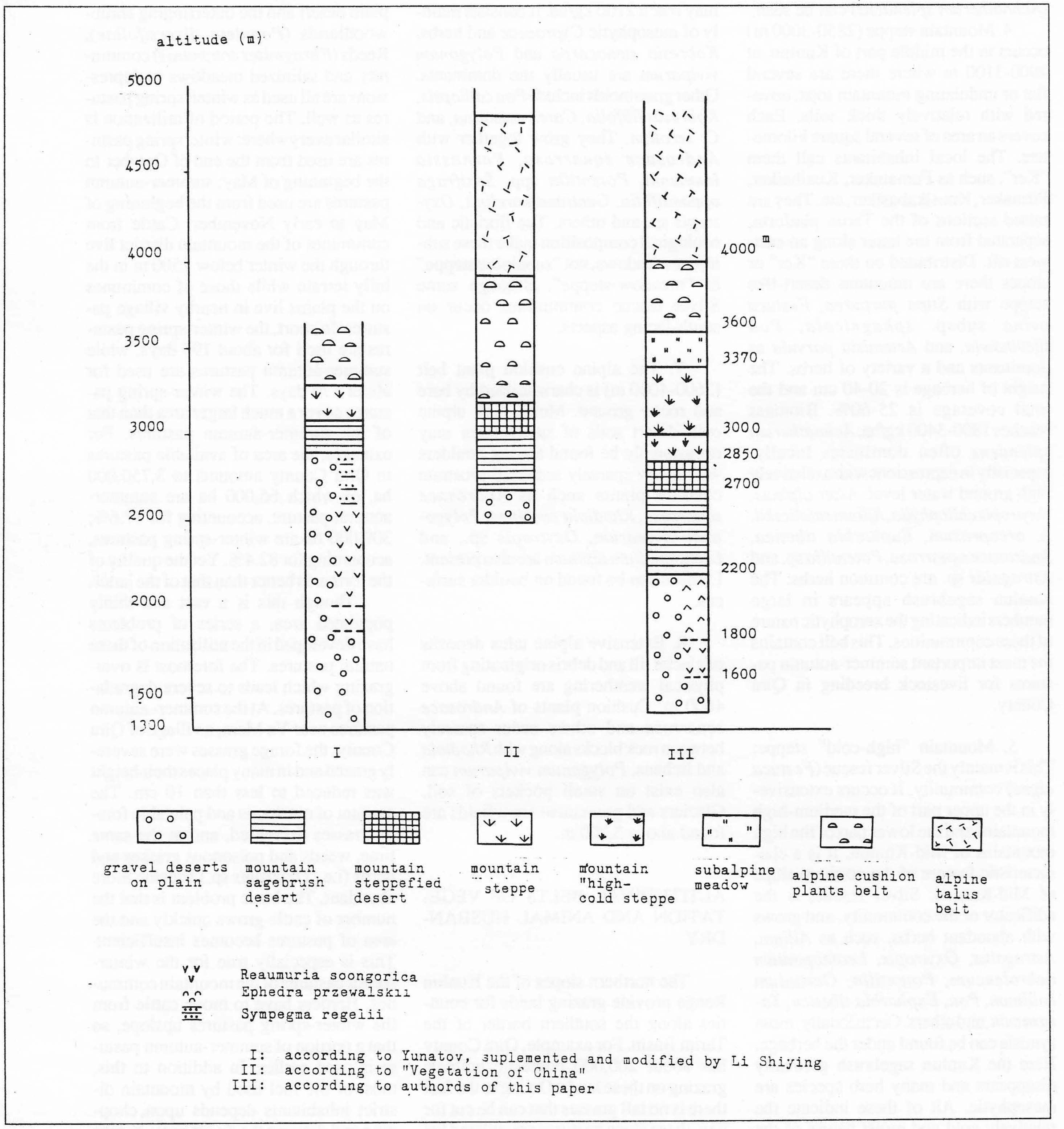

Fig. 2 — The structure of the altitudinal belts of vegetation on northern slope of Mid-Kunlun.

CONCLUSIONS

After investigating the altitudinal belts of vegetation on the northern slopes of the Mid-Kunlun Range, we have arrived at the following four conclusions:

1. From 3370 m to 3600 m there are subalpine meadows, but on south-facing aspects there are fragments of communities dominated by Silver fescue.

2. From 2850 m to 3600 m there are mountain steppe communities, and from 3000 m to 3370 m a kind of "high-cold" steppe where *Festuca olgae* predominates.

3. Because of the extremely-arid climate and enhanced continentality of the Kunlun Mountain System, the sequential spectrum of altitudinal belts of vegetation has been quite simplified. Both the forest belt and shrub belt have disappeared. The desert belt ascends to 2700 m.

4. The northern slope of Mid-Kunlun is the base of animal husbandry for local counties. A two season method of utilization (summer-autumn pastures and winter-spring pastures) has been adopted, with pastures strictly arranged according to altitudinal belts of vegetation. Due to overgrazing, most of the pastures have become severely degra-

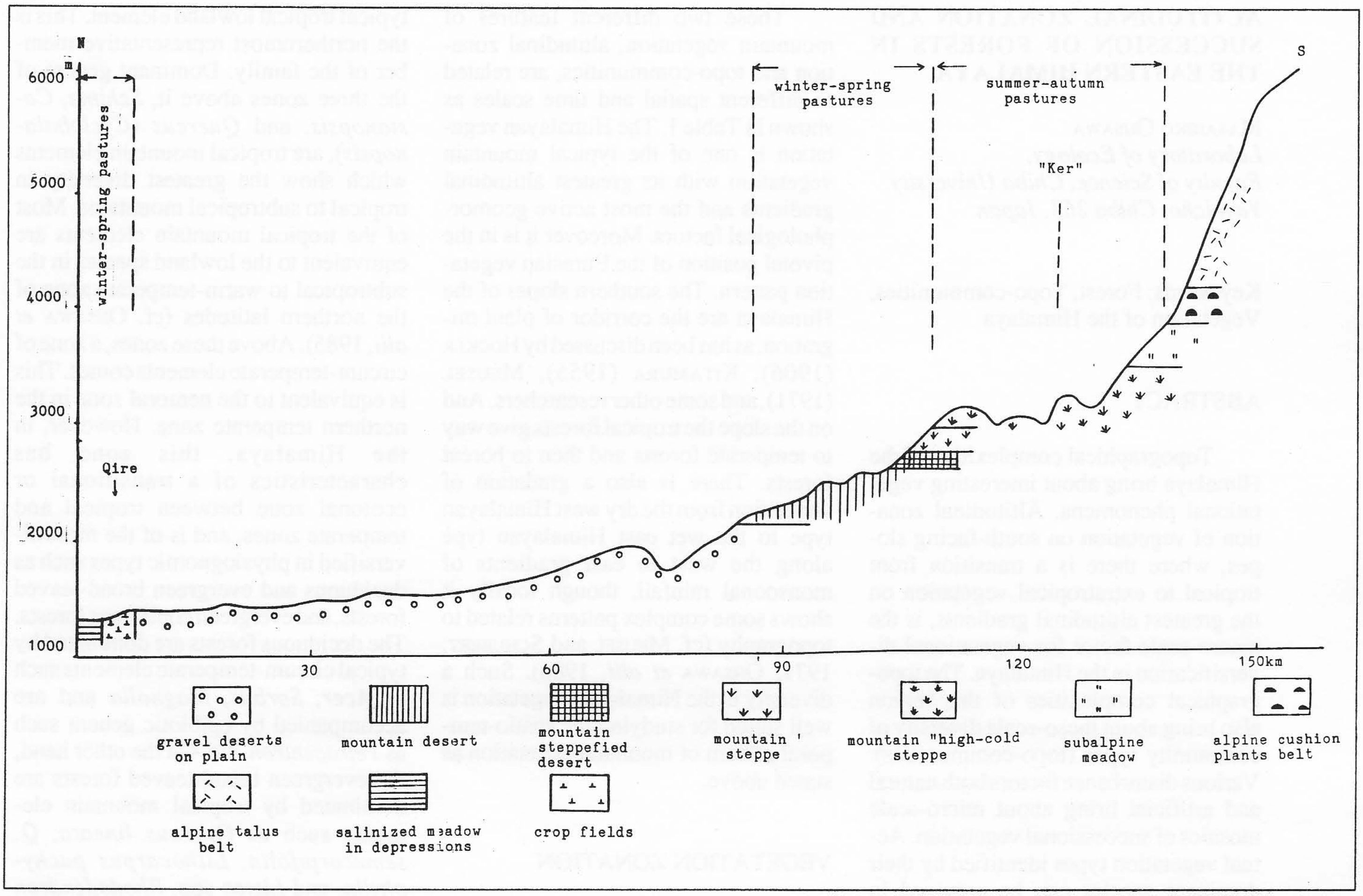

Fig. 3 — The altitudinal belts of vegetation on northern slopes of Mid-Kunlun and their utilization in animal husbandry.

ded. It is therefore urgent that the number of cattle be controlled, the pastures be rationally utilized, and pasture preservation be enhanced.

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ALTITUDINAL ZONATION AND SUCCESSION OF FORESTS IN THE EASTERN HIMALAYA

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Key words: Forest, Topo-communities, Vegetation of the Himalaya

ABSTRACT

Topographical complexities of the Himalaya bring about interesting vegetational phenomena. Altitudinal zonation of vegetation on south-facing slopes, where there is a transition from tropical to extratropical vegetation on the greatest altitudinal gradients, is the macro-scale factor for vegetational diversification in the Himalaya. The topographical complexities of this region also bring about meso-scale diversity of community types (topo-communities). Various disturbance factors both natural and artificial bring about micro-scale mosaics of successional vegetation. Actual vegetation types identified by their dominant species can be arranged in these three causal factors of vegetation differentiation. The resultant "topo-successional matrix of vegetation" gives information on vegetational behaviour in mountainous regions, and is applicable for management and conservation of vegetation.

INTRODUCTION

One of the remarkable features of mountain vegetation is the steep gradient of climatic conditions along altitude. It is so steep that the mountain slopes allow coexistence of different vegetation types in closer proximity compared with the horizontal distribution. This brings great diversity in vegetation zonation on mountains. Another remarkable feature of mountain vegetation is that it develops on topographically unstable habitat in comparison with lowland vegetation. Thus the development of vegetation in mountain regions is maintained in dynamic balance between two sets of natural forces which constantly compete against one another, i.e., the geomorphological forces, which act as a destructive factor upon vegetation, and the successional forces of vegetation, which act as a constructive factor. This dynamic balance at various levels produces greater diversity of topographical communities (topo-communities) on mountains.

These two different features of mountain vegetation, altitudinal zonation and topo-communities, are related to different spatial and time scales as shown in Table 1. The Himalayan vegetation is one of the typical mountain vegetation with its greatest altitudinal gradients and the most active geomorphological factors. Moreover it is in the pivotal position of the Eurasian vegetation pattern. The southern slopes of the Himalaya are the corridor of plant migration, as has been discussed by HOOKER (1906), KITAMURA (1955), MEUSEL (1971), and some other researchers. And on the slope the tropical forests give way to temperate forests and then to boreal forests. There is also a gradation of vegetation from the dry west Himalayan type to the wet east Himalayan type along the west to east gradients of monsoonal rainfall, though locally it shows some complex patterns related to topography (cf. MEUSEL and SCHUBERT, 1971; OHSAWA *et alii*, 1986). Such a diversity in the Himalayan vegetation is well suited for studying the spatio-temporal pattern of mountain vegetation as stated above.

VEGETATION ZONATION

Many schemes for the altitudinal zonation of climax vegetation in the eastern Himalaya have been proposed (cf. NUMATA, 1981; OHSAWA *et alii*, 1986). Although there are some controversies regarding the naming of each zone, the basic pattern of the zonal unit of climax vegetation is the same. Figure 1 shows vegetational zones and their modifications along humidity gradients in the eastern humid Himalaya based on our field surveys in 1971, 1977, and 1981 (OHSAWA, 1983a). This conforms well to the pattern reported previously (SCHWEINFURTH, 1957; TROLL, 1967). In the mesic series of altitudinal zonation, the dominant genera of each zone show distinct patterns of geographical distribution.

The genus *Shorea*, one of the dominant genera in the lowest zone, is a typical tropical lowland element. This is the northernmost representative member of the family. Dominant genera of the three zones above it, *Schima*, *Castanopsis*, and *Quercus* (*Cyclobalanopsis*), are tropical mountain elements which show the greatest diversity in tropical to subtropical mountains. Most of the tropical mountain elements are equivalent to the lowland species in the subtropical to warm-temperate zone of the northern latitudes (cf. OHSAWA *et alii*, 1985). Above these zones, a zone of circum-temperate elements comes. This is equivalent to the nemoral zone in the northern temperate zone. However, in the Himalaya, this zone has characteristics of a transitional or ecotonal zone between tropical and temperate zones, and is of the most diversified in physiognomic types such as deciduous and evergreen broad-leaved forests, and evergreen coniferous forests. The deciduous forests are dominated by typical circum-temperate elements such as *Acer*, *Sorbus*, *Magnolia* and are accompanied by epibiotic genera such as *Tetracentron*, etc. On the other hand, the evergreen broad-leaved forests are dominated by tropical mountain elements such as *Quercus lineata*, *Q. semecarpifolia*, *Lithocarpus pachyphylla*, and *Litsea* spp. *Rhododendron arboreum* and *Tsuga dumosa* often dominate on ridges or rocky cliffs in this zone. Above the temperate forest zone, the upper montane forests dominated by *Abies spectabilis* and *Betula utilis* form relatively simple and homogeneous vegetation. The upper limit of these forests coincides with the forest limit.

DYNAMICS OF TOPOGRAPHICAL COMMUNITIES

The succession series on a certain site is governed by three factors of different scales. The macro-scale factors are zonal ones such as temperature and precipitation, which control species distribution and accordingly determine the floristic potential of the area. The meso-

Table 1 — Spatio temporal scales in mountain vegetation.

	Vegetation zonation	Topo-communities
Spatial scale	Altitudinal/latitudinal	Surface relief
Time scale	Geological time	Successional time

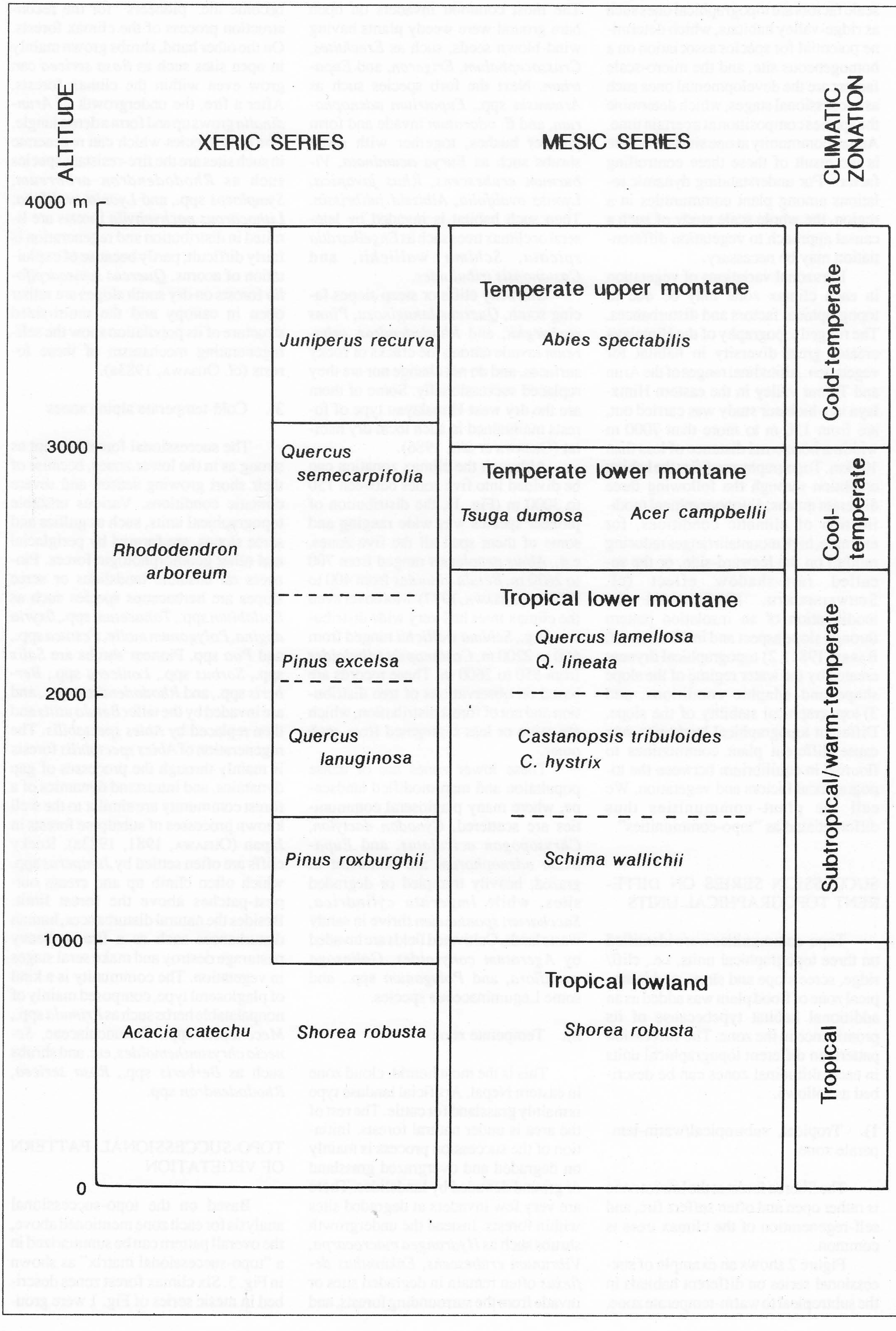

Fig.1 — Altitudinal forest zones and their modification along humidity gradients in eastern Nepal Himalaya. The climatic zonation relates the altitudinal zones to latitudinal zonation.

scale factors are topographical ones such as ridge-valley habitats, which determine potential for species association on a homogeneous site, and the micro-scale factors are the developmental ones such as successional stages, which determine the species composition at a certain time. Actual community at one site at one time is the result of these three controlling factors. For understanding dynamic relations among plant communities in a region, the whole scale study of such a causal approach to vegetation differentiation may be necessary.

Intrazonal variations of vegetation in each climax zone may be due to topographical factors and disturbances. The rugged topography of the Himalaya creates great diversity in habitat for vegetation. Altitudinal ranges of the Arun and Tamur valley in the eastern Himalaya in which our study was carried out, are from 150 m to more than 7000 m within a horizontal distance of less than 100 km. Topography modifies the habitat condition through the following three different means; 1) topographical modification of climatic conditions, for example, high mountain ranges reducing rainfall on the leeward-side, or the so-called rain-shadow effect (cf. SCHWEINFURTH, 1957), and the modification of an insolation pattern through slope aspect and inclination (cf. BARRY, 1981), 2) topographical dryness created by the water regime of the slope shape and edaphic conditions, and 3) topographical stability of the slope. Different topographical land units may cause different plant communities to flourish in equilibrium between the topographical factors and vegetation. We call the plant communities thus differentiated as "topo-communities".

SUCCESSION SERIES ON DIFFERENT TOPOGRAPHICAL UNITS

Topo-communities were identified on three topographical units, i.e., cliff/ridge, scree slope and slope, and in tropical zone of flood plain was added as an additional habitat typebecause of its prominence in the zone. The succession pattern on different topographical units in each altitudinal zones can be described as follows.

1). Tropical, subtropical/warm-temperate zone

The Shorea forest at the lowest zone is rather open and often suffers fire, and self-regeneration of the climax trees is common.

Figure 2 shows an example of successional series on different habitats in the subtropical to warm-temperate zone. The most common invaders on open bare ground were weedy plants having wind-blown seeds, such as *Erechtites*, *Crassocephalum*, *Erigeron*, and *Eupatrium*. Next the forb species such as *Artemisia* spp., *Eupatrium adenophorum*, and *E. odoratum* invade and form pioneer bushes, together with some shrubs such as *Eurya acuminata*, *Viburnum erubescens*, *Rhus javanica*, *Lyonia ovalifolia*, *Albizzia julibrissin*. Then such habitat is invaded by lateseral or climax trees such as *Engelhardtia spicata*, *Schima wallichii*, and *Castanopsis tribuloides*.

On rocky cliffs or steep slopes facing south, *Quercus lanuginosa*, *Pinus roxburghii*, and *Rhododendron arboreum* invade among the cracks of rocky surfaces, and do not change nor are they replaced successionally. Some of them are the dry west Himalayan type of forests maintained in such local dry habitat (OHSAWA *et alii*, 1986).

Although the climax zonation can be divided into five zones between 150 to 3000 m (Fig. 1), the distribution of pioneer species was wide ranging and some of them span all the five zones, e.g., *Alnus nepalensis* ranged from 700 to 2670 m, *Betula alnoides* from 400 to 2780 m (OHSAWA, 1977). Moreover even the climax trees had very wide distribution, e.g., *Schima wallichii* ranged from 600 to 2200 m, *Castanopsis tribuloides* from 550 to 2600 m. These records are based on observations of tree distribution and not of forest distribution, which are more or less segregated from each other.

These lower zones are of dense population and man-modified landscape, where many plagioseral communities are scattered. *Cynodon dactylon*, *Chrysopogon aciculatus*, and *Eupatrium adenophorum* are dominant in grazed, heavily trampled or degraded sites, while *Imperata cylindrica*, *Saccharum spontaneum* thrive in sandy waste lands. Cultivated fields are invaded by *Ageratum conyzoides*, *Galinsoga parviflora*, and *Polygonum* spp., and some Leguminaceous species.

2). Temperate zone

This is the most humid, cloud zone in eastern Nepal. Artificial landuse type is mainly grassland for cattle. The rest of the area is under natural forests. Initiation of the succession process is mainly on degraded and overgrazed grassland or ground denuded by landslides. There are very few invaders at degraded sites within forests. Instead the undergrowth shrubs such as *Hydrangea macrocarpa*, *Vibrunum erubescens*, *Enkianthus deflexus* often remain in degraded sites or invade from the surrounding forests, and become the "pioneers" for the reconstruction process of the climax forests. On the other hand, shrubs grown mainly in open sites such as *Rosa sericea* can grow even within the climax forests. After a fire, the undergrowth of *Arundinalia* grows up and form a dense jungle. The only species which can regenerate in such sites are the fire-resistant species such as *Rhododendron arboreum*, *Symplocos* spp., and *Lyonia ovalifolia*. *Lithocarpus pachyphylla* forests are limited in distribution and regeneration is fairly difficult, partly because of exploitation of acorns. *Quercus semecarpifolia* forests on dry south slopes are rather open in canopy and the multi-sized structure of its population show the self-regenerating mechanism of these forests (cf. OHSAWA, 1983a).

3). Cold-temperate alpine zones

The successional forces are not as strong as in the lower zones, because of their short growing season and severe climatic conditions. Various unstable topographical units, such as gullies and scree slopes, are formed by periglacial and other geomorphologic forces. Pioneers on unstable landslides or scree slopes are herbaceous species such as *Epilobium* spp., *Tanacetum* spp., *Oxyria dygina*, *Polygonum molle*, *Festuca* spp., and *Poa* spp. Pioneer shrubs are *Salix* spp., *Sorbus* spp., *Lonicera* spp., *Berberis* spp., and *Rhododendron* spp., and are invaded by the taller *Betula utilis* and then replaced by *Abies spectabilis*. The regeneration of *Abies spectabilis* forests is mainly through the processes of gap dynamics, and intrastand dynamics of a forest community are similar to the well known processes of subalpine forests in Japan (OHSAWA, 1981, 1983a). Rocky cliffs are often settled by *Juniperus* spp. which often climb up and create outpost-patches above the forest limit. Besides the natural disturbances, human disturbances such as a fire or heavy pasturage destroy and make seral stages in vegetation. The community is a kind of plagioseral type, composed mainly of nonpalatable herbs such as *Primula* spp., *Meconopsis* spp., Ranunculaceae, *Senecio chrysanthemoides*, etc. and shrubs such as *Berberis* spp., *Rosa sericea*, *Rhododendron* spp.

TOPO-SUCCESSIONAL PATTERN OF VEGETATION

Based on the topo-successional analysis for each zone mentioned above, the overall pattern can be summarized in a "topo-successional matrix" as shown in Fig. 3. Six climax forest zones described in mesic series of Fig. 1 were grou-

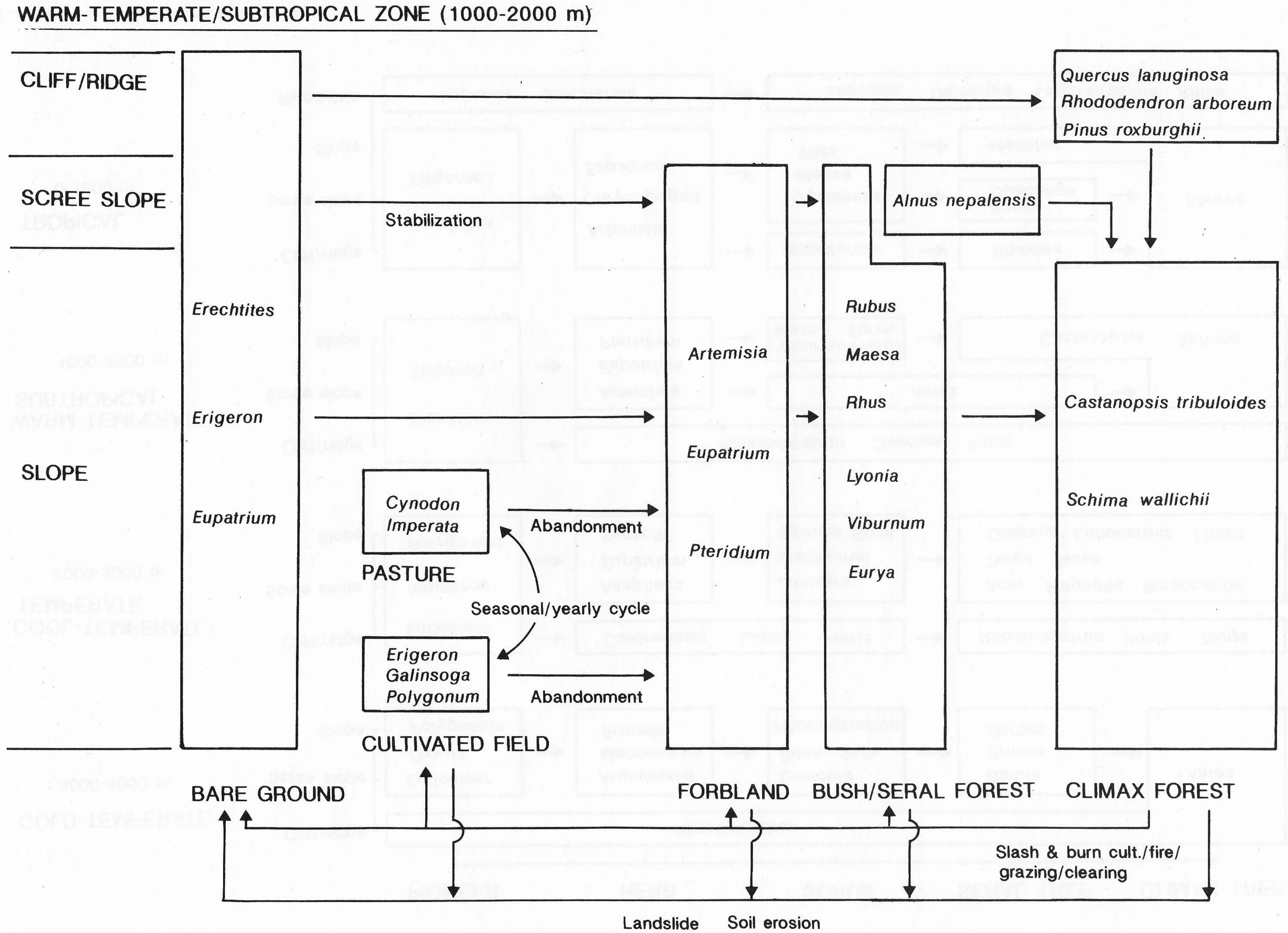

Fig. 2 — Topo-successional pattern in the subtropical to warm-temperate zones of eastern Nepal.

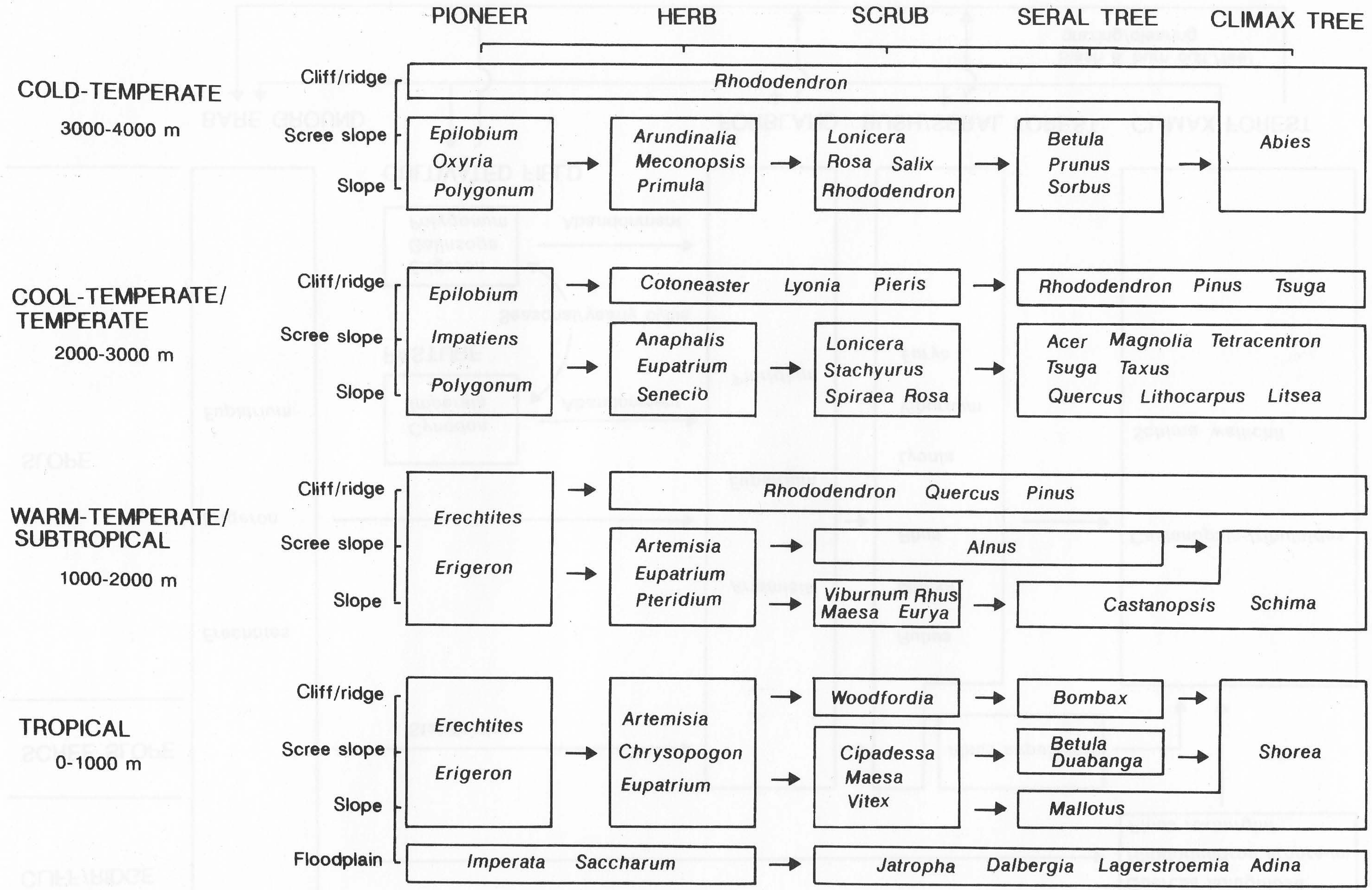

Fig. 3 — Topo-successional matrix in eastern Nepal.

ped into four, i.e, tropical, subtropical/warm-temperate, temperate/cool-temperate, and cold-temperate, according to the similarity of seral stages. Topography was divided into three types, i.e., cliff/ridge, scree slope, and slope. Successional stages are tentatively divided into five stages, i.e., pioneer, herb, scrub, seral tree and climax tree. The names of genera in square blocks in the figure show dominant species or genera in each community type. Each square shows individuality of each community type in the habitat-time matrix. For example in the cold-temperate zone, different community types were found on cliff/ridge and on scree slope and slope from the pioneer to seral tree stage. On cliff/ridge habitats *Rhododendron* and *Abies* invade and form pioneer stage and last till climax stage, while on scree slope and slope herbaceous species such as *Epilobium*, *Oxyria*, and *Polygonum* invade into bare ground and are replaced by shrub and then by seral and climax trees. In the climax stage, the two successional courses may converge into the *Abies* forest. There are several different pattern of community differentiation among the zones. Differentiation of community along topographical gradients is rather simple in higher altitudes such as in the cold-temperate and cool-temperate (at maximum those are two) (Fig. 3). In the tropical zone, seral vegetation differentiates finely along both topographical and temporal gradients, i.e., at maximum, each habitat type defined in spatio-temporal gradients has a peculiar community type, though the climax community become homogeneous. The tropical zone includes Terai plain and flood plain area along the big river, and therefore can be divided into four topographical units.

On the basis of this topo-successional matrix, several pieces of information on spatio temporal pattern of vegetation can be drawn out. Figure 4 indicates zonal differentiation of vegetation along successional courses on slope. There is a tendency towards advancement of altitudinal differentiation along successional courses as reported by NUMATA (1966) and OHSAWA (1984). According to floristic characteristics, pioneer vegetation can be divided into two, tropical to warm-temperate and temperate to cold-temperate in the range from 150 to 4000 m. On the other hand it can be divided into four or six zones in the climax vegetation. A boundary between warm-temperate and temperate zones at around 2500 m has consistency throughout successional stages. This boundary may reflect a coincidence with a floristic boundary between Plaeotropical and Holarctic floristic realms. DE LAUBENFELS (1975) has set the boundary of

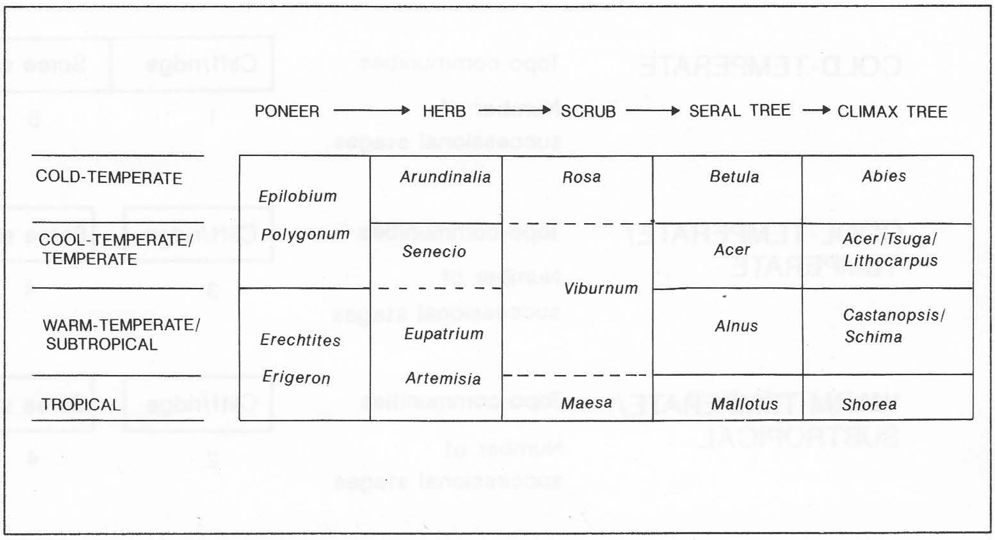

Fig. 4 — Zonal differentiation of vegetation along succession.

the two realms at around this altitude. Figure 5 summarises the differentiation of topo-communities at the forest stages (seral and climax tree stages) and the number of successional stages in four altitudinal zones. Topo-communities are more diversified between subtropical and cool-temperate zones than in tropical and cold-temperate zones at the lowest and the highest altitudinal zone.

The low community diversity in these two zones may reflect the homogeneity of the climatic conditions and the resultant simplicity of phytogeographical elements throughout the Himalaya. The simplicity of topo-communities in these two zones may reflect the situation.

CONCLUDING REMARKS

Great altitudinal span on the slopes of the Himalaya could make possible to compare successional patterns of vegetation among altitudinal zones. Further, the differentiation and dynamics of plant communities within each zone can be understood by introducing the concept of "topo-communities", which also show the greatest diversity in this region. In such a topographically complex mountainous area as the Himalayas, topo-communities are one of the most important units of vegetation for the divergence of succession processes. This pattern is a realization of the dynamic balance between topography and vegetation. For the restoration of land degradation due to various factors on mountainous areas, it is very important to make a proper land classification based on ecological principles. A detailed study of these aspects will hopefully lead to proper management of mountain vegetation.

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COLD-TEMPERATE	Topo-communities	Cliff/ridge	Scree slope	Slope	
	Number of successional stages	1	5	5	
COOL-TEMPERATE/ TEMPERATE	Topo-communities	Cliff/ridge	Scree slope	Slope	
	Number of successional stages	3	4	4	
WARM-TEMPERATE/ SUBTROPICAL	Topo-communities	Cliff/ridge	Scree slope	Slope	
	Number of successional stages	2	4	4	
TROPICAL	Topo-communities	Cliff/ridge	Scree slope	Slope	Floodplain
	Number of successional stages	5	5	4	2

Fig. 5 — Differentiation of topo-communities and number of successional stages at each altitudinal zone.

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THE MOUNTAIN VEGETATION OF SRI LANKA (CEYLON)

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Key words: Forest vegetation, Vegetation belts, Vegetation of South Asia

SUMMARY

Tropical evergreen rainforests form the natural vegetation of the mountains of Sri Lanka, lower montane rain forest between 900 and 1500 m, and upper montane rain forest above. The highest peak, Pidurutalagala (2524 m), is still below timberline. Dipterocarps and palms reach up to 1500 m. No conifers or oaks occur in the forests of Sri Lanka. Grassland may be regarded as secondary vegetation. Since 1823 the mountain forests have been cleared for British plantation industry. Nature reserves include about 50% of the remaining forests.

ENVIRONMENT

The mountains in the central part of the island are built up by pre-cambrian rocks, consisting of gneisses with bands of cristalline limestone. The shape of the mountain chains in the highest parts resembles an anchor: The Peak Wilderness and Haputale ranges run from W to E in a slight curve, the highest plains (1800-2100 m) are situated in the centre, overtopped by Pidurutalagala. From this peak a mountain chain runs NW. In the N of this mountain complex, the Knuckles range builds up into an isolated, NW-SE aligned group.

The tropical climate of Sri Lanka is influenced by the SW-monsoon (June-September) and the NE-monsoon (December-February), both bringing rain to the exposed sides of the island. But only on southwestern or northeastern mountain slopes will the monsoons effect maximum precipitation (>5000 mm/a); in most parts of the island, the maximum is produced by convectional rains of the intermonsoonal seasons. Minimum precipitation occurs on the eastern slopes during the SW-monsoon, combined with hot and dry "foehn" winds. Precipitation in the highland decreases from W to E from 5000 mm to 2000 mm. A dense fog-layer envelopes the mountains above 1500m very often. Average annual temperature in 1900 m (Nuwara Eliya) is 15.4°C; slight frost occurs above 1800 m in some nights between November and May. Very strong winds blow during the SW-monsoon; especially on W-exposed ridges and in funnel-shaped passes they may reach gale-force, thus influencing vegetation.

FOREST TYPES

The natural vegetation of the lowland is composed of evergreen rain forest in the "wet-zone" in SW of the central highlands and semi-deciduos (monsoon) forest types in the "dry zone".

On the western slopes of the highlands, between 600 and 900 m, the lowland rain forest gradually passes into the lower montane rain forest. In favourable sitations, the trees may attain 35 m in height. Most prominent is the endemic Dipterocarp *Doona gardneri*, accompanied by other species of *Doona* and *Stemonoporus* (Dipt.), *Myristica dactyloides*, *Fahrenheitia* (*Ostodes*) *zeylanica*, and various *Calophyllum*, *Syzygium* and *Lauraceae* species. On steep rocks, the palms *Oncosperma fasciculatum* and *Loxococcus rupicola* occur.

On the eastern slopes the lower montane rain forests exist in a dry facies without Dipterocarpaceae. Lauraceae (*Litsea*, *Cinnamomum*, *Cryptocarya*, *Neolitzea*), *Calophyllum*, *Syzygium*, *Myristica*, *Oncospermum* etc. occur as on the western side, but with more floristic importance.

In some parts of the eastern slopes, where strong foehn-winds occur, the natural vegetation between 600 and 1500 m was a sclerophyllous moncane forest, today preserved in small remnants only. *Syzygium spathulatum* is a dominant species, accompanied by species with similar leaves: *Actinodaphne stenophylla*, *Calophyllum trapezifolium*, *Pittosporum tetraspermum*, *Dodonea viscosa* etc.

Above 1500 m follow the upper montane rain forests or "mist" forests. The change from lower to upper montane rain forests is rather abrupt and may be explained by the lower limit of the frequent cloud cover. This forest type is rich in epiphytes, mosses and filmy-ferns cover the stems and branches, lichens hang from the twigs. Various species of epiphytic orchids live on the branches. The trees are stunted, 3-5 m high, only in favourable situations they may reach 15-20 m. The crowns are umbrella-shaped, the branches are gnarled. The size of the leaves is small, nanophyll to microphyll, some even leptophyll, according to RAUNKIAER's leafsize-classes.

Under a dense canopy only sparse regrowth of trees can be observed. The dominant plant of the undergrowth is *Strobilanthes* (Acanthaceae). After 6-12 years the plants will flower and fruit at the same time in one area, and then die and collapse. From the seeds, a new generation will grow. While the plants are low, the forest may be easily penetrated, but when grown up, they form an entangled mass, which supresses other plants of the undergrowth, including saplings of trees. This makes those forests very vulnerable, as regeneration-capacity seems to be very low. The floristic composition of the upper montane rain forests of Sri Lanka is very peculiar, as many characteristic plants of montane forests in tropical Asia do not occur. Podocarpaceae, Fagaceae (*Lithocarpus*, *Castanopsis*), *Schima* (Theaceae) or *Leptospermum* (Myrtaceae) are lacking. Dipterocarpaceae, playing an important role in the rain forests of Sri Lanka, are not represented in the cooler environment of the upper montane rain forests. The most prominent genus is *Calophyllum* (Clusiaceae) regarding frequency and tree size. Next to *Calophyllum* are the Myrtaceae (*Syzygium/Eugenia*, *Rhodomyrtus*). Lauraceae (*Litsesa*, *Actinodaphne*, *Cinnamonum*) and various species of *Symplycos* or *Elaeocarpus*. Theaceae (*Gordonia*, *Adinandra*, *Ternstroemia*) are frequent below 2200 m, *Eurya japonica* also above. Palaearctic elements are restricted to the montane zone above 1500 m. These plants are common with South Indian mountains or even with the Himalaya (e.g. *Michelia nilagirica*, *Ilex wigthtiana*, *Berberis aristata* and *Rhododendron arboreum*). Tree ferns (Cyatheaceae) are widespread in the upper montane rain forest and occur frequently along watercourses.

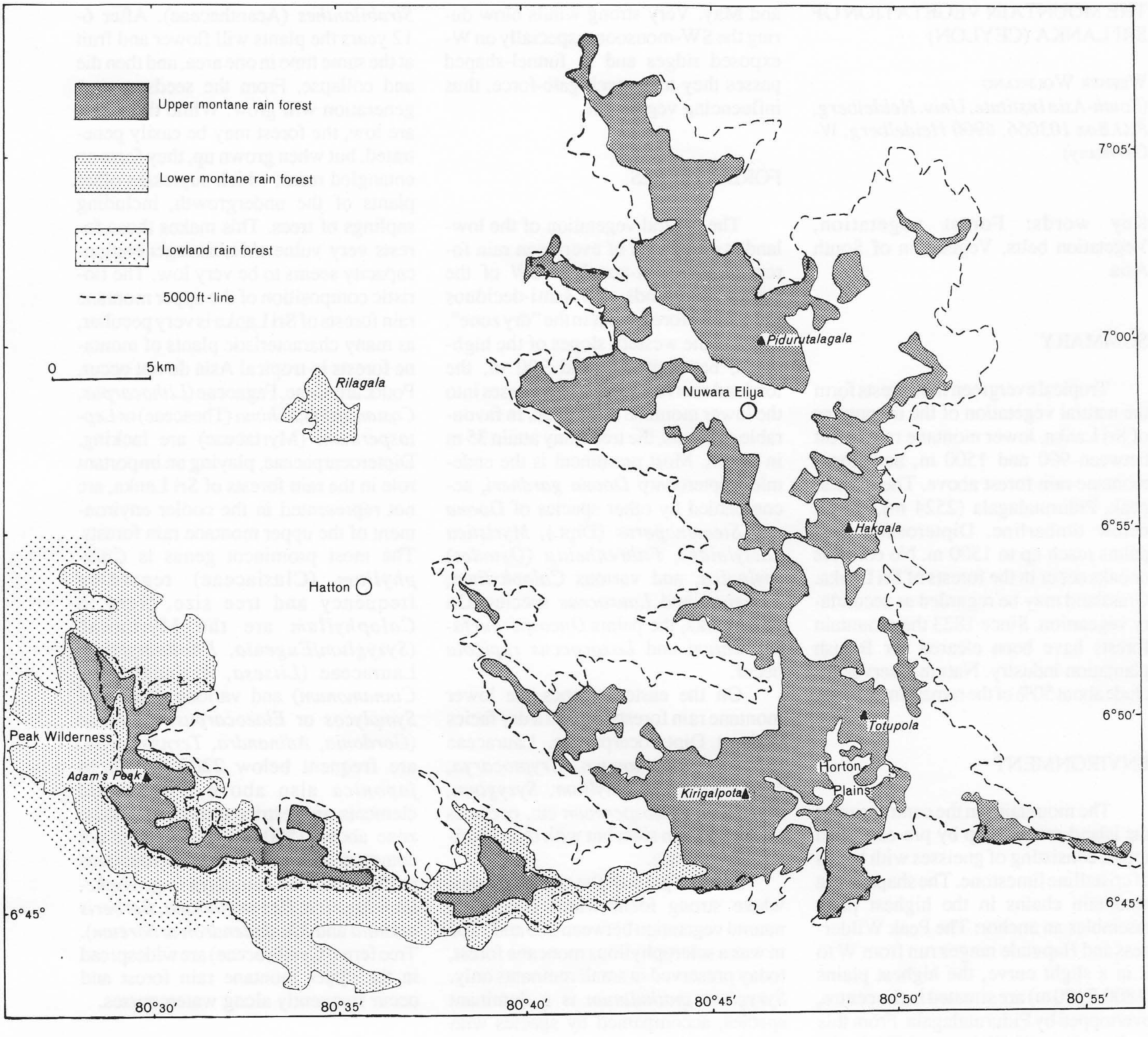
SECONDARY VEGETATION

After felling or burning of natural montane forest, low secondary forest or grassland ("patana") develop.

Rhododendron arboreum is the only tree on these grasslands above 1500 m as it survives the regular fires and occasional frost. The patanas consist of two dominant species of "tussock"-grass, *Chrysopogon zeylanicus* and *Cymbopogon confertiflorus*. In wet depressions *Chimonobambusa* (=*Arundinaria*) *densifolia* dominates.

Regular fires on the patanas enlarge their area, as the forest fringe is often distroyed, though the wet upper rain forests normally do not burn. Regrowth of trees in the grassland is suppressed by various factors, as dense grass-cover, fire, frost and browsing animals.

Where upper montane rain forest is able to regenerate, it consists of pioneer-trees like *Acronychia laurifolia*, *Embe-*



Map. 1 — Forests of the Cental Highlands of Sri Lanka.

lia viridifolia, and *Evodia roxburghiana*. *Lauraceae* like *Litsea ovalifolia* or *L. gardneri*, *Carallia calycina* (Rhizophor.), *Eurya japonica*, *Maesa indica* or *Agrostistachys coriacea*.

Up to 1500 m, *Macaranga peltata* is the typical pioneer tree, often accompanied by *Homalanthus populifolius* or *Mallotus albus*.

HUMAN IMPACT AND CONSERVATION

Although prehistoric artefacts have been found on Horton Plains (2100 m), human influence on montane vegetation was only slight until 1815. After conquest of the Kingdom of Kandy by the British, the highlands of the island were developed, and the forests were cleared for coffee estates since 1823. Tea cultivation replaced coffee since 1867.

In 1890 afforestation with exotic timber trees (*Eucalyptus*, *Cupressus*, *Acacia* and later *Pinus*) began.

While the lower montane rain forest was destroyed almost completely, coherent areas exist on the slopes of Peak Wilderness only, the upper montane rain forests were better conserved since 1885 and about 400 km² of originally 600 km² remained. These forest areas in the upper catchment of rivers, important for irrigation, are threatened today by illicit felling for firewood.

Three substantial nature reserves exist -the mountains of Sri Lanka: Hakgala Strict Natural Reserve (1142 ha), Horton Plains Nature Reserve (3162 ha) and Peak Wilderness Sanctuary (22400 ha), which contain an interesting and partly endemic fauna of leopard, deer, monkeys, birds and lizards

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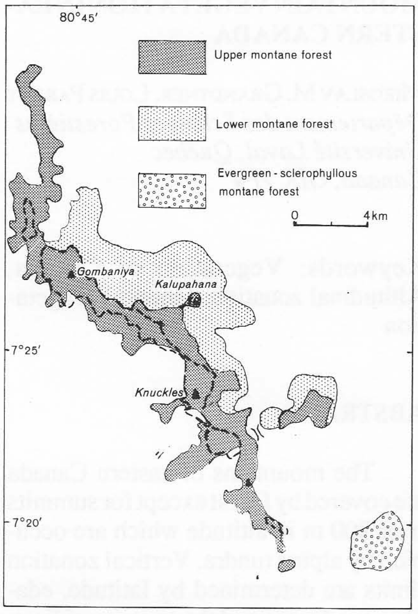

Map 2 — Forests of the Knuckles Range.

Vertical distribution of selected tree species of Sri Lanka

		0	500	1000	1500	2000	2500m
Dipterocarpaceae							
Dipterocarpus zeylanicus	*******	*******					
Doona congestifolia	*******	*******					
Doona trapezifolia		*******	****				
Doona grardneri		**	*******	++			
Stemonoporus cordifolius	****						
Stemonoporus oblongifolius			*****				
Lauraceae							
Cryptocaria wightiana	++++	*******	*******	**			
Litsea ovalifolia			*	*******	****		
Actinodaphne ambigua			++++	+++****	******		
Actinodaphne speciosa			*	*******	******		
Actinodaphne molochiana				*****	******		
Myrtaceae							
Syzygium spissum	*******	*******	*******				
Syzygium spathulatum		*****	*******				
Syzygium rotundifolium			++++	+++****	*******		*
Syzygium sclerophyllum				****	*******		*
Eugenia mabaeoides		***	*******	*******	*******		*
Rhodomyrtus parviflora				****	*******		*
Clusiaceae							
Garcinia echinocarpa			*******	*******			
Calophyllum thwaitesii	*******	*******	*******				
Calophyllum trapezifolium			*******	*******	***		
Calophyllum walkeri			*******	*******	*******		*
Theaceae							
Adinandra lasiopetala			****	*******	***		
Gordonia zeylanica			*******	*******	*		
Symplocaceae							
Symplocos cochinchinensis	*******	*******	*******	*******	*		
Symplocos cordifolia			*	*******	*		
Elaeocarpaceae							
Elaeocarpus glandulifer		****	*******	*******	******		
Elaeocarpus montanus				*******	*+++++		
Michelia nilagirica				++*****	******		
Ilex walkeri				*******	******		
Rhododendron arboreum				*******	*******		*

***: regular occurence
+++: rare occurence

MOUNTAIN VEGETATION IN EASTERN CANADA

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Keywords: Vegetation of Canada, Altitudinal zonation, Mountain vegetation

ABSTRACT

The mountains of eastern Canada are covered by forest except for summits over 900 m in altitude which are occupied by alpine tundra. Vertical zonation limits are determined by latitude, edaphic conditions and the severity of fires. The vegetation of eight mountainous area located between 44° and 49° N latitude, is described from an ecological viewpoint. These massifs belong to the Laurentides and Appalachian chains and are of precambian and primary ages respectively. One of these massifs is formed of serpentine.

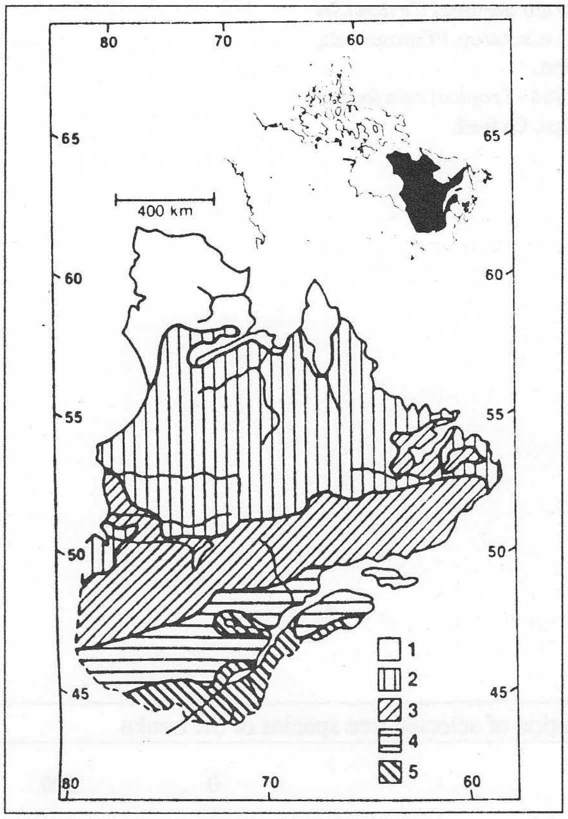

Fig. 1 — Climax great domains of Quebec. 1. tundra, 2. taiga, 3. spruce, 4. fir, 5. maple. (Adappted from Sirois 1984 and Ansseau & Grandtner 1985).

INTRODUCTION

The province of Quebec together with Labrador, forms a vast peninsula in eastern Canada, extending from 45° to 62° N lat. between the Atlantic Ocean and Hudson Bay. With 1.5 x 10^6 km², it is the largest province in Canada (Fig. 1). The precambrian rock of the Laurentides and the primary rock of the Appalachians are covered with a thin quaternary deposit of glacial or post-glacial origin. The landscapes are mostly horizontal lines. Altitudinal differences are minimal and the resulting summits are rounded. True mountains are rare. The relief, does not present a serious obstacle for the establishment of vegetation. The climate, however, according to our viewpoint (Grandtner in Sirois 1984) delimits 5 great domains (Fig. 1) described following Ansseau & Grandtner (1987).

LATITUDINAL ZONATION

The tundra, is the northernmost, treeless great domain. It belongs to the arctic tundra climate sensu Walter *et alii* (1975) that extends northward from about 56° lat. To the south, it includes summits of more than 900 m in elevation.

The taiga, the second great domain, has a climatic climax vegetation mainly dominated by *Picea mariana* either solitary or in clusters dispersed in a nearly continuous lichen cover; the genus *Cladina* being the most abundant. The climate is subarctic, corresponding to the northernmost part of the cold temperate or boreal climate of Walter *et alii* (1975). The equivalent can be found in the sub-alpine zone where *Picea glauca*, *Alnus* and *Salix* predominate.

The spruce great domain, south of the taiga, is the first of the closed forest zones. The climatic climaxes of this great domain belong to the *Piceion marianae*. It extends south of approximately 51° lat. N, belonging to the cold temperate or boreal climate of Walter *et alii* (1975). The natural vegetation of this great domain is a coniferous forest, dominated by *Picea mariana* with a moss understory of *Hypnaceae* and *Sphagnaceae*.

The next great domain to the south is the fir forest with climatic climaxes belonging to the *Abietetalia balsameae*. These closed coniferous forests are dominated by *Abies balsamea* and the flora includes boreal elements such as *Cornus canadensis*.

The fifth and last great domain is the maple forest. The climatic climaxes belong to the *Aceretalia sacchari* and occupie mainly the southwest of Quebec where the climate is typically temperate sensu Walter *et alii* (1975). The stable climatic forests are dominated by *Acer saccharum* and geophytes such as various *Trillium* species.

The mountainous massifs presented in this study are primarily situated in this last great domain.

ALTITUDINAL ZONATION

The latitudinal units or great domains are delimited in altitude by vertical zones. These zones have been analyzed on the principle massifs situated between 44° and 49° N latitude. Mount Washington (1917 m) is in the eastern U.S.A. while the other 3, Mount Megantic (1105 m), Mount Jacques-Cartier (1278 m) and Mount Albert (1150 m) are found in Quebec.

Mount Washington (44° 16' N lat.) is formed of Devonian mica schist. The climatic conditions are extremely rigorous. The heavy precipitation, violent winds, frequent dense fog and a mean annual temperature of -3°C explain the presence of an important artic element in this flora. The vegetation zone begins at about 1500 m and can be subdivided into (1) upper or lichen subzone including *Rhizocarpon geographicum*, *Cetraria nivalis* and *Parmelia centrifuga*; (2) middle or herb subzone dominated by *Carex bigellowii* and *Juncus trifidus*; and (3) lower or shrub subzone with *Vaccinium uliginosum* var. *alpestre* and *Diapensia lapponica*. Below 1500 m is the subalpine zone, characterized by krummholz in the upper portion and by an open fir forest with eroded crowns below. A closed fir zone with *Betula papyrifera*, then *Betula lutea* occurs between 1200 and 750 m, followed by a maple zone.

At Mount Megantic (45°30' N lat.) formed of igneous rock and schist there is no alpine zone and the subalpine zone is represented by a few scattered vegetation units. The mean annual temperature on the summit, at 1105 m in altitude has been estimated at 0°C (MARCOTTE & GRANDTNER 1974). Below 1100 m is the fir zone with *Betula papyrifera* then *Betula lutea* followed by maple below 650 m.

On Mount Jacques-Cartier, (48° 59' N lat.), an intrusion of granite in sedimentary formations, the alpine zone begins at 1000 m. As an Mount Washington, there are 3 physiognomic subzones: upper or lichen, middle or herb and lower or shrub plus vast fields of polygonal soils. The subalpine zone is made up of krummholz then of an open white spruce forest with eroded crowns. At 900 m, it is the lower limit for white spruce and the beginning of fir which forests slopes down to 50 m above sea level.

The neighbouring mountain, Mount Albert (48° 55' N. lat.), is formed of serpentinized peridotite. Due to the effect of magnesium, the alpine zone begins 100 m lower, at an altitude of 900 m. The arctic alpine flora includes several serpentinicole species (SIROIS & GRANDTNER 1992).

DISCUSSION

The massifs of Quebec and the northeastern U.S.A. are essentially covered with forests. The altitudinal vegetation zones present delimit a zonation pattern corresponding to that of the latitudinal climax great domains. The spruce great domain however, is not present on the mountains studied and the taiga is represented by subalpine zones with eroded crowns, rich in herbaceous plants and shrubs.

Considering the altitudinal limits of the vegetation zone (Table 1), it is not possible to determine general limits for each zone as no two massifs in this study were identical. Therefore, the altitudinal limits of the alpine zone must be considered in relation to latitude, substrate, fire history and the geographical location of the massif.

The lower altitudinal limit of zonation is principally determined by latitude and consequently temperature as indicated in GRANDTNER (1966). All conditions being equal, the mean discrepancy is approximately 100-150 m for each degree of latitude. The limit of the alpine zone on Mount Albert, formed of

Table 1 — Lower limitof altitudinal vegetation zones in some mountainous massifs of eastern Canada and the United States of America.

Massif	Northern latitude	Altitude max. (m)	Lower limit of zone (m) Maple	Fir	Subalpine	Alpine
Washington (U.S.A.)	44°16'	1917	?	750	1200	1500
Orford, Qc	45°18'	850		700	.	.
Megantic, Qc	45°30'	1105	.	650	1100	.
Sainte-Anne, Qc	47°05'	775	.	500	.	.
Stoneham, Qc	47°10'	400	.	300	.	.
Lac des Cygnes, Qc	47°40'	980	.	100	850	900
Albert, Qc	48°55'	1150	.	.	750	900
Jacques-Cartier, Qc	48°59'	1278	.	50	900	1000

serpentine, is 100 m lower than that on Mount Jacques-Cartier, only a few kilometers away. The difference is still more striking at Mount of Swan Lake (Lac des Cygnes) where, situated one degree of latitude more to the south, the alpine zone also begins at 900 m but it is severely stressed by fire. On the other hand, the fir zone limit increases 100-200 m on the slopes of isolated mountains such as Mount Sainte-Anne compared to mountainous massifs like Stoneham, located in the Laurentides. In addition to these general factors, physiographical features such as slope, exposure, thickness of loose deposits and drainage must be considered.

In conclusion then, each massif has a unique zonation pattern resulting from the interaction of past and present geographical and ecological factors.

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WHY IS ALPINE VEGETATION SO RESTRICTED IN THE PACIFIC NORTHWEST?

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Keywords: Vegetation of U.S.A., Mountain vegetation, Water stress, Ecotones

INTRODUCTION

Alpine vegetation is restricted in the Pacific Northwest, forming a narrow zone between the upper limit of forests and permanent snow. Due to dominant maritime weather patterns, this area receives heavy winter snow. The rugged mountains are geologically young and support many glaciers and snowfields. Highland benches and plateaus, which provide extensive alpine habitat in other mountain regions, are absent. Despite these limitations, the alpine is governed by the same basic features found within other temperate-zone alpine habitats. Aspect, snow depth and duration are major characteristics influencing community pattern, composition and structure.

Although high elevation vegetation has been studied at a number of sites in the Olympic and Cascade mountains, no synthesis of these studies has been done. Our recent work involves bringing together available research, as well as collecting data on areas that have not been previously studied. This effort is centered around developing a broad-scale picture of alpine environments of the Pacific Northwest, relating community structure and patterns to environmental factors.

The wet, mild, coastal climate of the Pacific Northwest has led to a distinct flora with particular plant communities for both historical and environmental reasons. Past research indicates that these communities differ from those of continental mountain regions of North America where there are more arctic species. This study investigates the ecological factors that affect structure and distribution of present-day communities within a limited phytogeographic region.

STUDY AREA

Location

Studies have been conducted in both the coastal Olympic Mountains and the Cascade Range (Fig. 1). The Cascade Range is a complex chain of mountains extending from southern British Columbia through Washington and Oregon into northern California. The Olympics are located along the Pacific Ocean coastline on the northwest peninsula of Washington, 100 km west of the Cascades. Alpine habitat occurs on high peaks throughout these areas, and becomes a more extensive zone in the North Cascades. Our data and discussion are limited to Washington state.

Geology and soils

The North Cascades have two large, young volcanoes in excess of 3000 m. They rise above numerous alpine ridges that consist primarily of ancient metamorphic rock, ranging in elevation from 1800-2800 m. There are 750 glaciers in the North Cascades, covering over 250 km^2. The variability of parent rock materials, together with rapid erosion and glaciation, restrict soil formation.

The South Cascades consist of a broad highland, supporting three large volcanoes that range from 2800-4400 m. The region is composed almost entirely of volcanic rock, therefore most of the soils are derived from pumice and andesite. Mt. Rainier, 4392 m, dominates the area, ascending 2000 m above the nearby ridges. This mountain has the largest single glacier system in the contiguous U.S., with a total of 34 glaciers covering over 90 km^2.

The coastal Olympic Mountains have the most southern glacial and alpine environments adjacent to the Pacific Coast in North America. This range of rugged, snow-capped mountains is about 80 km across, and covers an area of 8100 km^2 with a number of peaks over 2000 m. The central part of the Olympics is composed of sedimentary rocks from early Cretaceous time. The rim of mountains to the north, east and south are composed of basalt, which was deposited 30-55 million years ago on the seafloor, then uplifted, folded, metamorphosed and eroded. These mountains have undergone extensive glaciation in the past; today there are 60 glaciers concentrated in the high, central peaks with some glaciers descending well below treeline.

Climate

The climate of the Pacific Northwest is influenced by several major factors. Winter storms are generated by low pressure centers in the Gulf of Alaska. The north-south trending mountains force incoming air masses upward, generating clouds, fog, abundant rain and snow at higher elevations. In the

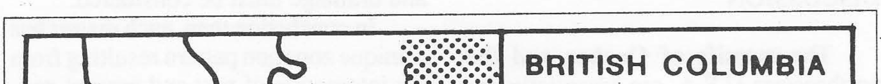

Fig. 1 — Map of Washington State with major study sites in the Olympic Mountains, the North and South Cascades.

spring, the low pressure center is displaced northward by a fair-weather system centered between Hawaii and North America. Summers are warm and relatively dry, with total precipitation between June and August composing only 8-12% of annual precipitation.

In the Olympic and Cascade ranges, a pronounced climatic change occurs from west to east (Fig. 2), and is accompanied by marked changes in vegetation. This phenomenon is the result of the decreasing influence of the maritime climate on the east side of the mountains, and is evidenced by a 300 m rise in timberline. The west side of the Olympics average over 500 cm of precipitation annually, making this the wettest place in the United States. A temperate rain forest extends along the west side of the range, whereas the northeastern peaks are characterized by a rainshadow that keeps this area relatively dry. Similarly, the west Cascades receive greater precipitation compared to the east Cascades.

PREVIOUS STUDIES

A number of subalpine and alpine research projects have been undertaken in recent years. Early work in the Olympic mountains was carried out by FONDA and BLISS (1969) and KURAMOTO and BLISS (1970). The North Cascade communities have been studied by DOUGLAS (1972) and by DOUGLAS and BLISS (1977). A study of the Enchantment Lakes Basin in the Cascades was conducted by del MORAL (1979), who has also done studies on Mt. St. Helens (1983). Mt. Rainier has been studied by various researchers, most recently by EDWARDS (1980). An early overview appears in FRANKLIN and DYRNESS (1973).

Subalpine Forests and Parklands

The subalpine is extensively developed in the Pacific Northwest. Deep, late-lying snowpack that characterizes the region is hypothesized to be a major reason for the extended nature of this zone. The forest-tundra ecotone is not a sharp line, but rather a transitional zone which can span 300-400 m, and consists of a mosaic of tree islands and krumm delete-holz, with meadows at higher elevations. Major tree species include *Abies lasiocarpa* and *Tsuga mertensiana* on the west side of the Cascades and in the Olympics. *Chamaecyparis nootkatensis* is also found in the Olympics, while *Larix lyallii*, *Pinus albicaulis* and *P. contorta* are found in drier areas on the east side of the Cascades. Subalpine meadow communities are generally less developed to the east, and are often found in protected sites.

Subalpine and alpine herbaceous vegetation

Most studies separate vegetation into community types. For this overall survey, we have grouped the communities into large units, called vegetation types (VT). These may occur over broad areas, or they may be found only in scattered sites. Often a mosaic is seen. The following six VT have been found to be characteristic of non-forested subalpine-alpine plant communities throughout this region.

Heath shrub VT - occurs in the subalpine, extending with elfinwood to the alpine. These areas receive a great amount of snow, soils remain generally moist during the growing season and sites are often located in areas with moderate slope. Dominants include the heath species *Phyllodoce empetriformis*, *Cassiope mertensiana* and *Vaccinium deliciosum*. Heath-shrub is more common on the west side of the Olympics and the North Cascades; similar communities are reported for the west side of Mt. Rainier.

Moist meadow VT - these communities occur in areas of substantial snow accumulation, habitats that make tree establishment difficult. Areas are characterized by lush herbaceous vegetation, including *Valeriana sitchensis*,

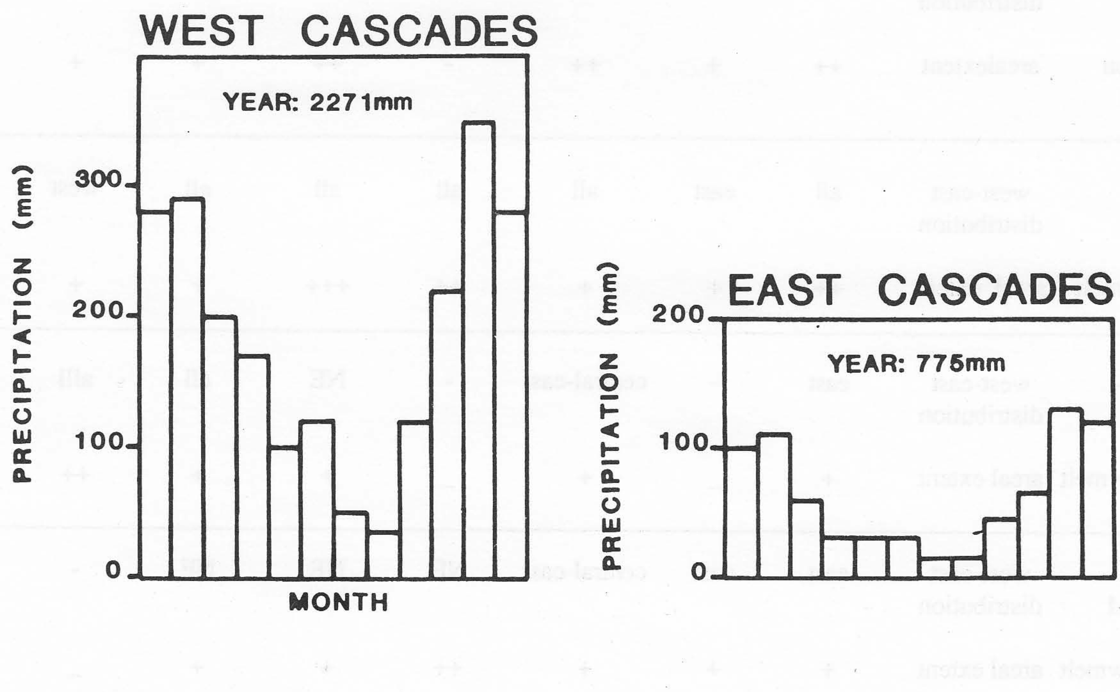

Fig. 2 — Precipitation data for East Cascades (CleElum station) and West Cascades (Paradise, Mt. Rainier) for 1970-1980. (U.S.Weather Bureau station data.)

Veratrum viride, *Lupinus latifolius*, sedges and grasses. In the Olympics, a moist *Valeriana*-forb, as well as a more mesic *Saussaurea*-forb community are found. In the North Cascades, two mesic herb communities are indicated, grading from wetter sites with *Valeriana* and *Veratrum* to drier sites with *Festuca viridula*.

Dry forb - grassland VT - this type is found on the east side of the Olympics and North Cascades, and is dominated by *Festuca viridula* and *F. idahoensis*, on generally warm, dry slopes. *Aster* spp., *Ligusticum grayi* and *Eriogonum pyrolifolium* are major associates in different regions. In the Olympics, *Festuca idahoensis* is dominant, with *Arenaria* spp., *Lupinus latifolius* and *Phlox diffusa*. The east side of the North Cascades has comparable vegetation. A similar type is found only on volcanic soils in the South Cascades. Communities are dominated by *Agrostis diegoensis*, *Polygonum newberryi*, *Danthonia intermedia* and *Eriogonum pyrolifolium*. Such vegetation is dominant in the subalpine, especially on Mt. St. Helens. Very few sites of this type are found on Mt. Rainier.

Snowbed VT - these are areas with long-persisting snow; growing season is short, and species diversity is generally low. A number of communities are found, including areas dominated by *Saxifraga tolmiei*, *Luetkea pectinata*, *Luzula piperi*, *Antennaria lanata*, and *Carex nigricans*. "Dwarf sedge" communities are widespread in the Olympics, but only form small areas. Such communities are more prevalent in the North Cascades, where six communities have been described.

Dwarf graminoid VT - these sites are characterized by high elevation, exposure to wind, and relatively early snow-free conditions, resulting in dry soils in summer. Two major groups of communities are found within this VT. One is dominated by various *Carex* and forb species that form dense mats. These communities occur in the northeast Olympics. They are particularly abundant in the northeast Cascades, and are dominated by *Danthonia intermedia*, *Calamagrostis purpurascens*, *Carex scirpoidea*, *C. nardina* and *Kobresia myosuroides*. On Mt. Rainier, sedgeturf areas dominated by *Carex breweri* are found, ranging from unbroken turf to

Table 1 — Subalpine and Alpine Vegetation Types of Washington State.

Vegetation type	Distribution Abundance	Olympics subalpine	Olympics alpine	North Cascades subalpine	North Cascades alpine	Mt. Rainer subalpine	Mt. Rainer alpine	South Cascades* subalpine
Moist Meadow	weast-east distribution	all	east	west-central	-	all	-	all
early snowmelt	areal extent	++	+	++	-	++	-	+
Heath Shrub	west-east distribution	all	east	west-central	-	all	all	west
mid-season snowmelt	arealextent	++	+	++	-	++	+	+
Snowbed	west-east distribution	all	east	all	all	all	all	west
late snowmelt	areal extent	++	+	+	++	+++	+	+
Dry Forb-grassland	west-east distribution	east	-	central-east	-	NE	all	alll
early snowmelt	areal extent	+	_	+	_	+	+	++
Dwarf Graminoid	west-east distribution	east	east	central-east	NE	NE	NE	-
early snowmelt	areal extent	+	+	+	++	+	+	_

Key: + present -not present * no data available for South Cascades alpine hummocks and striped ground. Subshrubs like *Dryas octopetala* and *Salix* spp. dominate the other communities in the North Cascades.

Specialized VT - areas with very low plant cover or communities restricted to specialized habitats. Boulderfields, stream banks and other small but distinct communities are scattered throughout the alpine area.

DISCUSSION AND CONCLUSION

In this paper only the area above erect trees and krummholz is considered alpine (TRANQUILLINI 1979). The ecotone between subalpine and alpine is an irregular line due to the patterning of snow.

Based upon Table 1, only the dwarf graminoid vegetation type is exclusively alpine and this type occurs mostly on the drier east side of the mountains. The west to east gradient in precipitation and temperature are the key factors for these vegetation patterns. The mild coastal climate depresses treeline and favors heavy snowfall. These factors, combined with steep slopes and the lack of broad uplands, greatly restrict alpine vegetation. The volcanic mountains in the Southern Cascades have well-drained soils and somewhat hotter summers. This results in extensive subalpine herb meadows but limits true alpine vegetation.

The mountains of the Pacific Northwest have less pronounced summer drought than the Sierra Nevada of California. Winters are milder than in the Rocky Mountains and snowcover is deeper and melts later. Both the Rocky Mountains and the Sierra Nevada have broad uplands with large areas above erect trees and krummholz which explains the larger extent of alpine vegetation in these areas.

ACKNOWLEDGEMENTS

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RECOVERY OF SUBALPINE HERBACEOUS VEGETATION FOLLOWING THE MOUNT ST. HELENS ERUPTION OF 1980

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INTRODUCTION

The May 18, 1980, eruption of Mount St. Helens severely impacted more than 400 km². At the outer fringe of disturbance, 15 to 20 km from the crater, trees were killed but remained standing. Most understory herbs and shrubs died except where protected by snow or lee slopes. Closer to the crater, trees were broken off or uprooted. Within 1 to 8 km of the crater, most trees and much of the soil were carried away by the blast, avalanches, lahars (mud flows), and debris flows. Pyroclastic flows of hot magmatic and lithic fragments, ejected from the crater, covered large areas, presenting sterile new surfaces for soil and plant development. Tephra (air fall deposits of volcanic matter) covered the entire cone to depths ranging from 5 to over 50 cm. LIPMAN and MULLINEAUX (1981) describe details of the eruption.

Our research has concentrated on three sites with very different disturbance histories. The Spirit Lake study area (1200 m, 5 km N of the crater) is on pyroclastic flows overlying avalanche material, which have been subsequently modified by tephra, lahars, and erosion. The Pine Creek site (1500 m, on the lower cone, 3 km SE of the crater) was covered by a lahar generated by a large, rapidly melting glacier. The lahar caused substantial plant mortality, but most mud was removed by sheet erosion during the winter of 1980-81. The pre-eruption soil, now covered by a veneer of tephra, has soils with a weakly developed profile. The Butte Camp sites (1365 and 1575 m, on the lower cone, 3 km SW of the crater) received 5 to 10 cm of coarse tephra. Numerous small lahars filled the canyons, so that these site is a mosaic of tephra covering old lava flows (450 yr), old lahars with many surviving plants, as well as new lahars with no surviving plants.

This paper summarizes data on survival and colonization of plants at these sites with strongly contrasting disturbance intensities.

RESULTS

Spirit Lake -Pyroclastic Flow

This site was devastated except for a few individuals of *Lupinus lepidus* that survived either in the form of seeds or rootstocks in materials transported from higher elevations. These plants have reproduced, forming several distinct colonies that together occupy over 500 m² and are comprised of 'thousands of individuals. Heavy seeds prevent primary dispersal more than a few centimeters from the parent. However secondary dispersion by rodents and erosion has been important in the relatively rapid expansion of these populations. Insects, spiders, and microtines have occupied this site since 1982 (ANDERSON and MACMAHON 1985; J. E. EDWARDS, pers. comm.). At our meterological station, 300 m upslope, a few seedlings of *Epilobium angustifolium*, *Anaphalis margaritacea*, *Agrostis diegoensis*, and some mosses became established in 1984-1985.

Aside from lupine colonies, most of the pyroclastic flow above Spirit Lake, extending to the crater, lacks plants. This is due to the high intensity of disturbance, that permitted virtually no survival, the large extent of the disturbance, that has limited immigration, and the poor survivorship of widely dispersed species (DEL MORAL and CLAMPITT 1985, WOOD and DEL MORAL 1987). Species richness is low and cover remains virtually nil after six growing seasons. It is not possible to predict when even a limited plant cover of 5-10% will develop.

Solar radiation (shortwave) is high, averaging 20-30 MJ m^{-2} d^{-1} in summer. Light-colored surfaces result in high albedo, but the absence of plants results in warm soils. Air and soil surface temperatures were on average 3° and 7°C higher the dry summer of 1984 compared with the wetter summer of 1983 (REYNOLDS and BLISS 1986). The course-textured soils dry considerably near the surface, yet retain considerable moisture with depth.

Pine Creek-Lahar and Erosion

The deposition of a veneer of mud on Pine Creek Ridge smothered most of the existing vegetation. However, erosion of mud in the spring of 1981 resulted in many individual plants surviving. Although the disturbance was extensive and distances to undisturbed vegetation was 1-2 km downslope, the surviving plants ensured a relatively rapid recovery of species richness but a much slower recovery of plant cover (DEL MORAL and WOOD 1986) (Figs. 1, 2).

The slow increase in net annual plant production (aboveground) and litter accumulation at Pine Creek is associated with the limited flora (mean of 10 spp/plot) and low plant cover (12%) at this site. Plant production increased through 1984 but dropped in 1985, the second consecutive year of drought (Fig. 3). These periodic summer droughts are very significant in slowing plant recovery. The rate of litter accumulation was initially low in this wind-swept landscape, but now is slowly increasing.

Annual variation in temperature and precipitation does not result in high mortality of adult plants, but drought stress is a significant factor in seedling survival. Seeds of *Lupinus lepidus* and *L. latifolius* germinate with snowmelt. Seedling mortality is correlated with the length of time separating snowmelt and the initiation of drought period along with the subsequent duration of the drought period. If a sufficient root mass reaches a depth of 10 to 15 cm before surface soils dry to -1.3 MPa, seedling survival is enhanced (BRAATNE and CHAPIN 1986). Sites with *Lupinus lepidus* melt out 3 to 5 wk earlier than those of *L. latifolius*, often allowing a longer time for seedling establishment. Therefore seedling mortality is lower in the alpine species than in the subalpine *L. latifolius*. Most of the 1983, 1984, and 1985 cohort seedlings of *L. latifolius* died during the drought periods of 1984-85 when July and August precipitation was low (7 mm, 1984; 56 mm, 1985 vs. 104 mm, 1982; and 213 mm, 1983).

Butte Camp -Tephra Fall and Lahars

Airfall tephra covered large areas on the SW flanks of the mountain, but survival of individuals was over 50% due to a deep snowpack and the limited depth of tephra deposition. During 1981 and 1982 there was a pulse of plant recovery, probably related to higher precipitation during the growing season. Thereafter, species richness has largely stabilized (mean of 18 spp/plot) and plant cover has declined from 30 to 21% in response to lengthy droughts in 1984 and 1985 (DEL MORAL and WOOD,

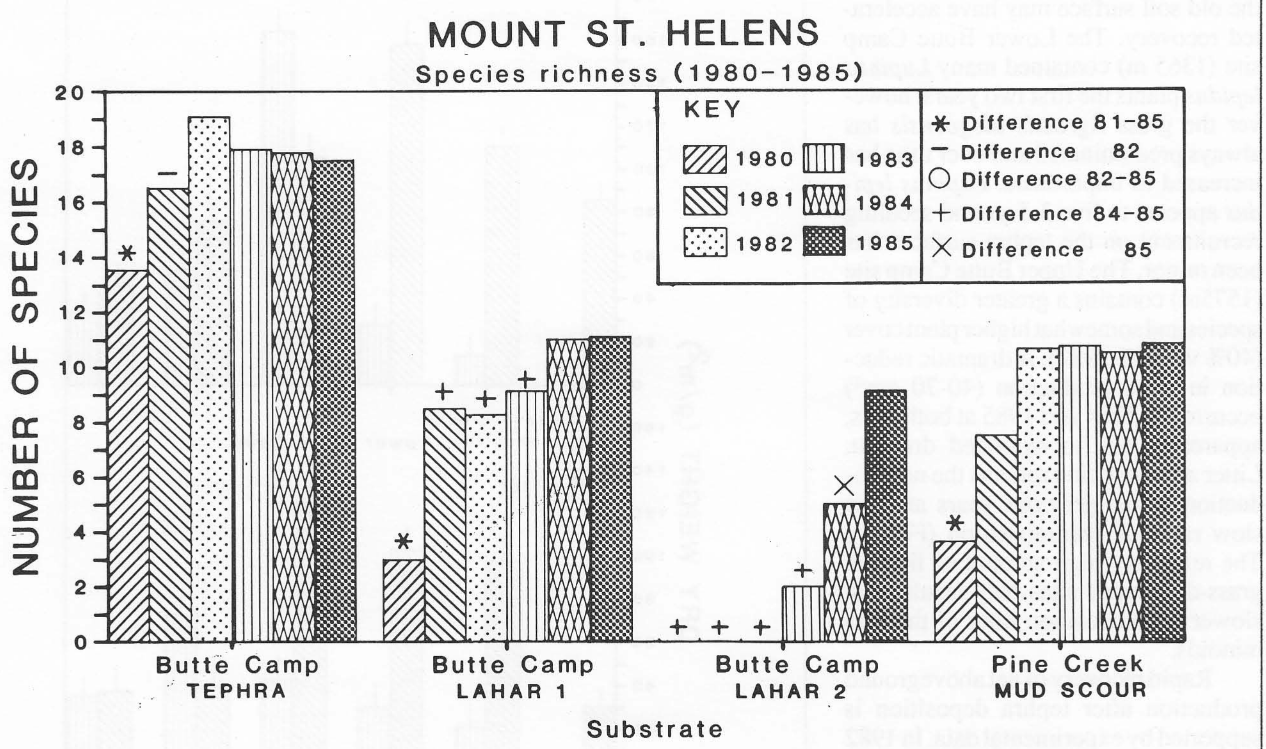

Fig. 1 — Average number of species per 250 m² for 1980-1985 at three sites at Butte Camp and at one site at Pine Creek. Significant differences (p =<.05] are presented for between year comparisons.

1986) (Figs. 1, 2).

The lahars at this site created an intense, but localized impact. Recovery on these new substrates depends greatly on seed dispersal and distance from adjacent vegetated sites. Plant establishment is more rapid on lahars adjacent to established plants than lahar sites over 100 m from vegetated areas. The rate of plant invasion is very slow but is gradually accelerating. The retarded invasion rate here and in the other profoundly impacted sites results from the balance between seed dispersal and seedling establishment. Large seeds produce vigorous seedlings, but disperse poorly. Small seeds may disperse long distances, but are correspondingly less vigorous (WOOD and DEL MORAL 1987). Experiments have demonstrated the irony that good dispersers such as *Aster ledophyllus* and *Hieracium gracile* have little chance of colonizing isolated, new volcanic substrates, whereas large seeded species (e.g. *Lupinus lepidus*, *L. latifolius*, *Stipa occidentalis*, *Sitanion historix*, *Eriogonum pyrolifolium*, and *Polygonum newberryi*) can establish more readily. Correspondingly, seedlings of these latter species occur primarily near established adult plants.

Net annual production aboveground recovered rapidly following tephra

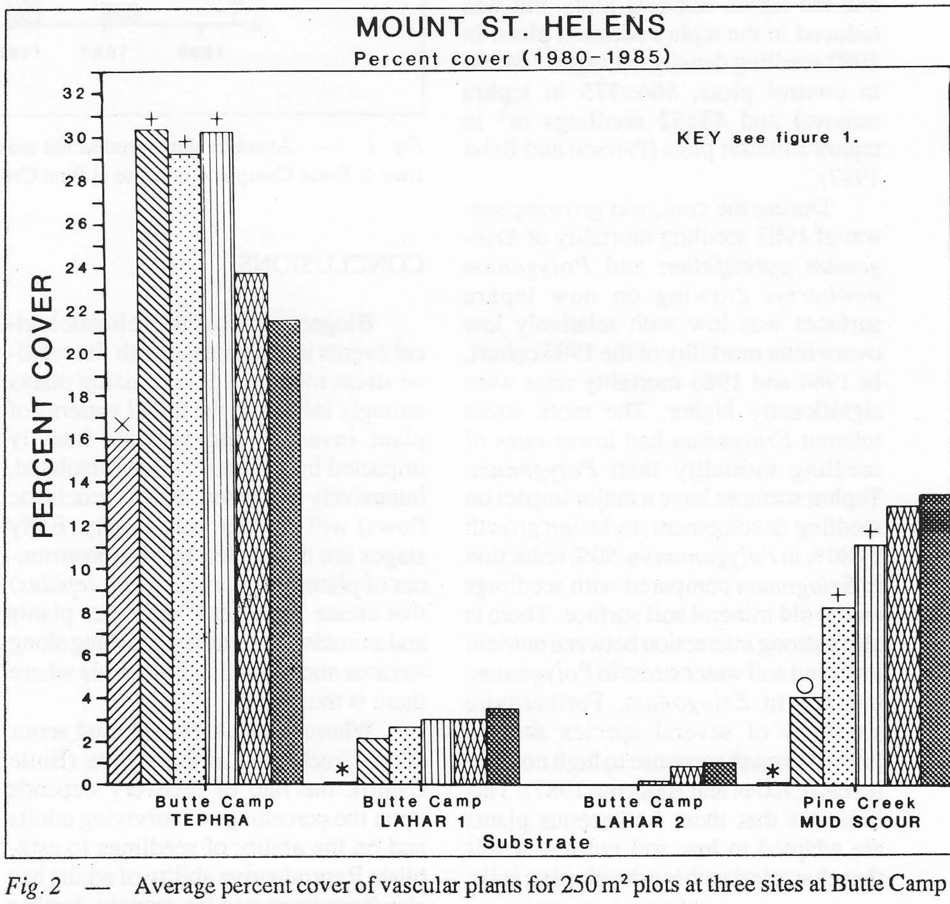

Fig. 2 — Average percent cover of vascular plants for 250 m² plots at three sites at Butte Camp and one site at Pine Creek for 1980-1985. See Fig. 1 for the key to symbols.

deposition in 1980, averaging 100 to 160 gm^{-2} from 1981 through 1983. Litter decomposition with a nutrient flush at the old soil surface may have accelerated recovery. The Lower Butte Camp site (1365 m) contained many *Lupinus lepidus* plants the first two years; however the grass *Agrostis diegoensis* has always predominated and over time has increased in importance. *Lupinus lepidus* appears to live 3-5 yr and seedling recruitment on the tephra surfaces has been minor. The Upper Butte Camp site (1575m) contains a greater diversity of species and somewhat higher plant cover (40% vs. 56% 1982). A dramatic reduction in plant production (40-70 gm^{-2}) occurred in 1984 and 1985 at both sites, apparently due to extended drought. Litter accumulation reflects the net production of the previous years and the slow rates of decomposition (Fig. 3). The relatively high amount of litter in grass-dominated sites may result from slower decomposition rates of the graminoids.

Rapid recovery of net aboveground production after tephra deposition is supported by experimental data. In 1982 there were no significant differences in net production between control plots (original tephra depth 4-5 cm), tephra removal plots, and plots with twice the initial tephra depth (8-10 cm) after only one year. After four years, species richness was unchanged in the control plots, and the tephra removal plots, but was reduced in the tephra addition plots. In 1982 seedling density averaged 164±94 in control plots, 566±375 in tephra removal and 43±52 seedlings m^{-2} in tephra addition plots (Pfitsch and Bliss 1987).

During the cool, wet growing season of 1983 seedling mortality of *Eriogonum pyrolifolum* and *Polygonum newberryi* growing on new tephra surfaces was low with relatively low overwinter mortality of the 1983 cohort. In 1984 and 1985 mortality rates were significantly higher. The more stress tolerant *Eriogonum* had lower rates of seedling mortality than *Polygonum*. Tephra surfaces have a major impact on seedling development; reducing growth by 80% in *Polygonum* vs. 50% reduction in *Eriogonum* compared with seedlings on the old mineral soil surface. There is also a strong interaction between nutrient level and soil water stress in *Polygonum*, but not in *Eriogonum*. Furthermore seedlings of several species show a limited growth response to high nutrient levels (Chapin and Braatne 1987). This indicates that these herbaceous plants are adapted to low soil nutrient levels that characterize these developing soils.

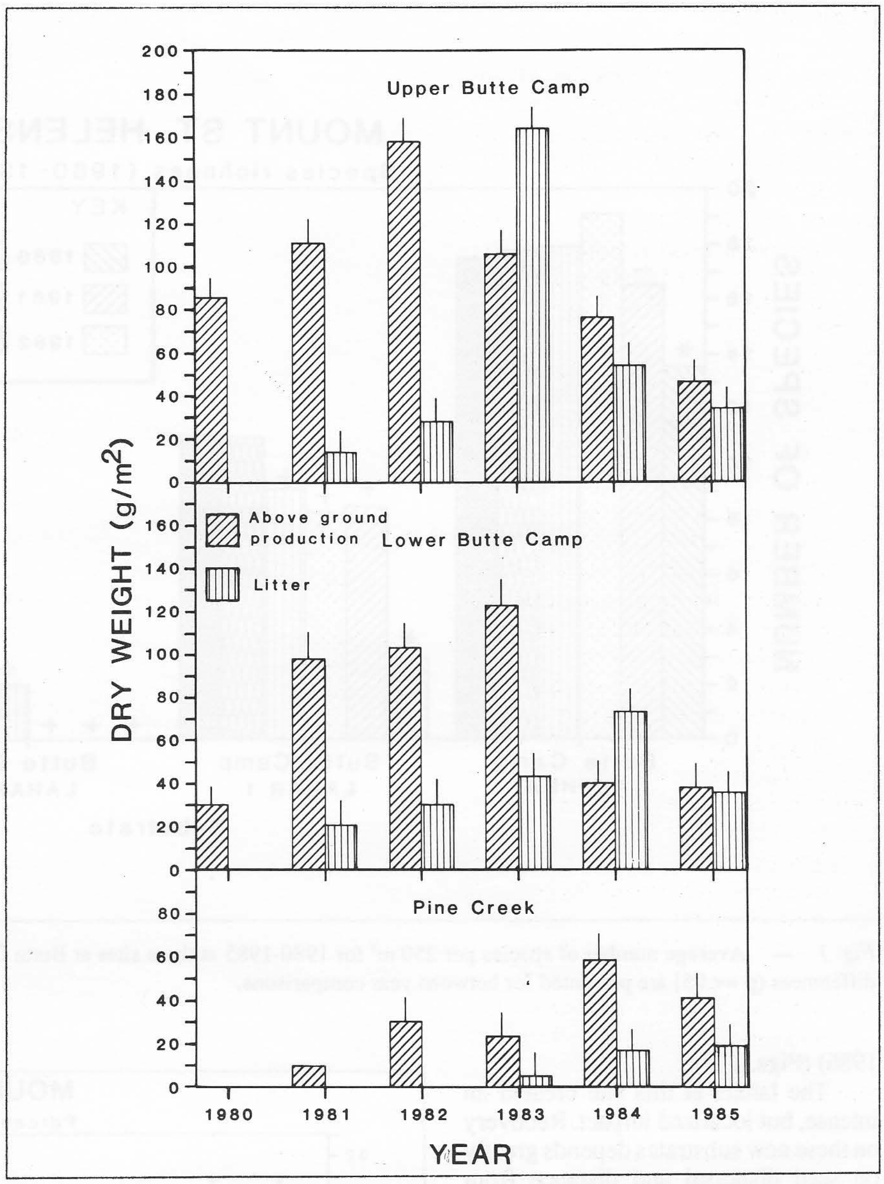

Fig. 3 — Average aboveground net annual production and litter accumulation for two sites at Butte Camp and one site at Pine Creek for 1980-1985. Error bar is for P = <.05.

CONCLUSIONS

Biogeographical and climatological events in association with the relative stress tolerance of colonizing plants strongly influence the initial patterns of plant invasion into habitats heavily impacted by volcanic activity. Isolated, intensively impacted sites (pyroclastic flows) will recover very slowly. Early stages are dominated by rare occurrances of plant survivors (*Lupinus lepidus*) that create "safe sites" for other plants and animals. Plants are establishing along streams and around old fumerals where there is moisture.

Where plants survived mud scour (Pine Creek) and airfall tephra (Butte Camp), the rate of recovery depends upon the percentage of surviving adults and on the ability of seedlings to establish. Reproductive ability of adults has also been impacted by drought, further compounding slow seedling establishment. Some species are better environmental stress-tolerators (*Eriogonum*) than others (*Lupinus, Polygonum*). This greatly influences seedling mortality rates during summers of prolonged drought (1984, 1985). Rates of colonization of lahars near areas of plant survival (Butte Camp) depend upon distance from the sources of colonists and seed size. Survival of adult plants appears little affected by summer drought, though net annual production and seedling establishment are severely impacted and thus slow the general rate of ecosystem recovery.

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POSTGLACIAL FLUCTUATIONS IN THE VEGETATION OF THE CAIRNGORM MOUNTAINS (SCOTLAND) AND THE CHANGES EFFECTED BY HUMAN ACTIVITIES.

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Keywords: Mountain vegetation, Human impacts on vegetation, Palinology.

INTRODUCTION

The Cairngorm Mountains in the Central Highlands of Scotland encompass some of the highest land in the British Isles, with peaks up to 1309 m. Their core consists of a major Devonian granitic pluton, which is surrounded by Precambrian Moinian Schists. Weathering under tropical to arctic climatic regimes in the next four hundred million years exposed this bedrock and modelled it into the landforms we know today. Of particular significance in this connection were the glaciations in the course of the Quaternary. At the height of each glaciation the massif was totally submerged under continental ice sheets, which had a smoothing effect on the topography. However, each glaciation was also preceded and concluded by a phase of mountain glaciation, which gouged out major corries on the slopes above ±915 m (SUGDEN, 1969) and shattered the bedrock, thereby creating extensive blockfields. Stone polygons and stone stripes formed in the loose regosol. On lower ground meltwater from the retreating glaciers filled the valleys with a mass of fluvioglacial sediments (eg. YOUNG, 1974), varying in coarseness from sands to boulder beds. Where the last isolated pockets of ice melted kettle holes formed. It was into this varied terrain that plants once more migrated at the end of the Weichselian (Devensian) Ice Age, about 10,000 years B.P.

The resurgence of the vegetation can be followed in the available palynological and macrofossil influx diagrams (BIRKS, 1970; O'SULLIVAN, 1974a; VASARI, 1977; BIRKS and MATHEWES, 1978). Quantitative studies reveal a ten-to fifteen-fold increase in pollen-influx at the beginning of the Holocene, reflecting the speed at which colonization took place. Those species thriving in open habitats, e.g. *Artemisia* and *Rumex acetosella* agg. were soon to disappear from low ground, to be replaced by an *Empetretum*. This dwarfshrub vegetation was in turn displaced by a *Juniperetum*, which soon gave way to a *Betuletum*.

Initially the soil was able to support a somewhat basiphilous community with, e.g. *Botrychium lunaria, Bryum pseudotriquetrum, Campylium stellatum, Filipendula ulmaria, Saxifraga aizoides, Selaginella selaginoides, Thalictrum* and *Valeriana repens*. However, in the course of a few thousand years, the effects of leaching began to be felt, no doubt stimulated by increased oceanity after 8000 B.P. The number of basiphilous plants decreased significantly and such communities are presently restricted to a number of scattered sites on Moinian outcrops.

RECONSTRUCTING PAST ZONATION

Using our knowledge of the present zonation of the vegetation (see Fig.1), in combination with information from palaeobotanical and historical sources, we can attempt to reconstruct the zonation in times past. One of the valuable sources of information lies in the stumps of *Pinus sylvestris* to be found on the slopes of Cairngorm between 485 m and 770 m. Radiocarbon dating indicates that these span a time-interval from 7350 ±90 until 1190±55 B.P. Although DUBOIS and FERGUSON (1985) have been careful to point out that their presence or absence may be related to suitability for preservation, they do give us minimum figures for the past tree-line. About 7000 B.P. the tree-line must have extended at least 130 m higher than its present limit between 425 m and 600 m. Since there is still no evidence for blanket-bog at this stage of time, one must assume that an iron-pan had not yet developed and that precipitation rapidly drained away into the porous fluvioglacial sediments. Since there was little humus to retain moisture, the differences in the vegetation between the exposed ridges and the sheltered valleys would by present standards be less pronounced. This presumably implies that a hygrophilous vegetation was largely restricted to the immediate vicinity of streams.

Assuming the *Callunetum*, which presently extends upwards from the treeline for some 300 m to have been of similar width in the past, then the *Vaccineto-Empetretum* cannot have occured much below 1000 m (see Fig. 2). Moreover, the typical snow-patch species, some of which were encountered in the Late Glacial e.g. *Pohlia, Polytrichum alpinum, P. norvegicum, P. sexangulare* and *Salix herbacea* must have been eliminated completely from the summits. This raises the problem of their immigration from distant sources at a later date.

No doubt due to a combination of higher precipitation and a reduction in soil porosity, blanket-bogs began to form about 6000 B.P. On the less steeply sloping ground with an angle of slope less than 12° the *Callunetum* was replaced by a bog vegetation with *Erica tetralix, Eriophorum vaginatum* and *Sphagnum* (DUPONT, 1983). The presence of *Salix* branches, 2-3 cm in diameter, i.e. clearly belonging to a shrubby species, indicates that a certain minerotrophic influence still persisted. Although *Pinus* may have survived on the ridges, the initiation of blanket-bogs depressed the tree-line elsewhere. No pine was to be found on gentle slopes above 620 m until the beginning of the Subboreal, a thousand years later.

THE ROLE OF STABLE ISOTOPES

The use of stable isotopes in fossil wood cellulose has proved particularly valuable in charting the oscillating climate and resulting changes in vegetation (DUBOIS, 1984; DUBOIS and FERGUSON, 1985). The Deuterium/Hydrogen ratios are primarily related to the amount of precipitation and air humidity with low D/H ratios reflecting relatively wet conditions. Low ratios between ± 6210 and ±5790 B.P. (= ±5150 - ± 4705 B.C. according to KLEIN *et alii*, 1982) confirm the wet conditions which lead to blanket-bog formation. However, the situation was clearly more dynamic than one might have assumed from a superficial examination of the plant-remains in the blanket-peat. The initially wet conditions were succeeded by a dry phase about 5690 B.P. (±4565 B.C.), followed by a return to wetter circumstances. Thus the vegetation must have been in a continuous state of flux. The gradual increase in the D/H ratio which followed (± 5460 - ± 4350 B.P. = ±4198 - ±3025 B.C.) clearly demonstrates that the invasion of the peat-bog by *Pinus* represents the culmination of a process, rather than a sudden change to drier conditions. In less than two hundred years these drier conditions were reversed, with a consequent rejuvenation of the peat-bogs. This phase lasted some four hundred years (±4200 - ±3940 B.P. = ±2845 - ±2433 B.C.). Shortly after 2880 B.P. (= ±1100 B.C.) *Pinus* disappeared from the slopes above 530 m and it is no longer possible to follow the climatic changes in any detail - the land below 450 m is afforested. The reason for its restriction to the lower slopes is still debatable. While a human cause has been suggested for a reduction in numbers at lower levels (O'SULLIVAN, 1974b), it seems unlikely

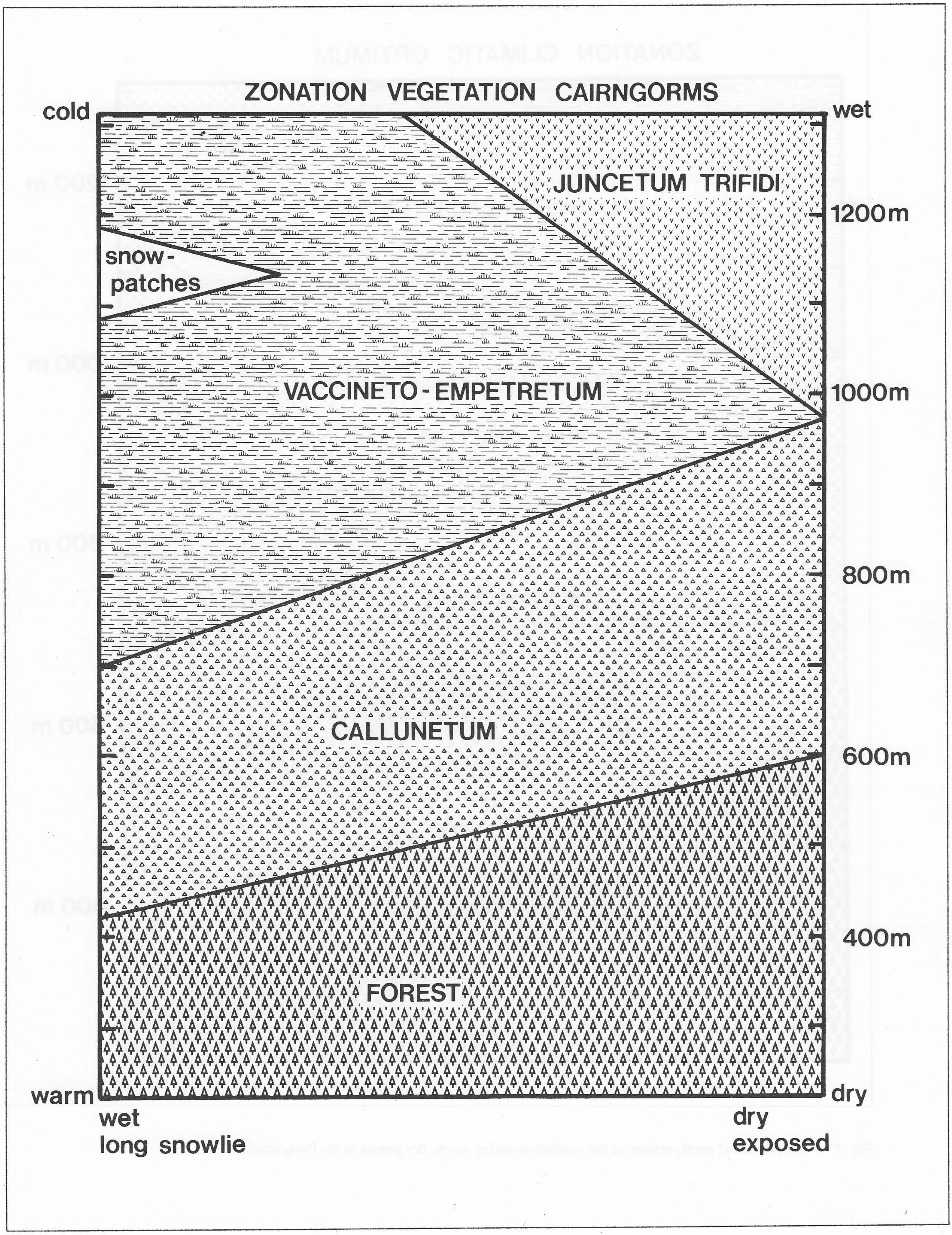

Fig. 1 — The present zonation of the vegetation in the Cairngorms in relation to a number of parameters.

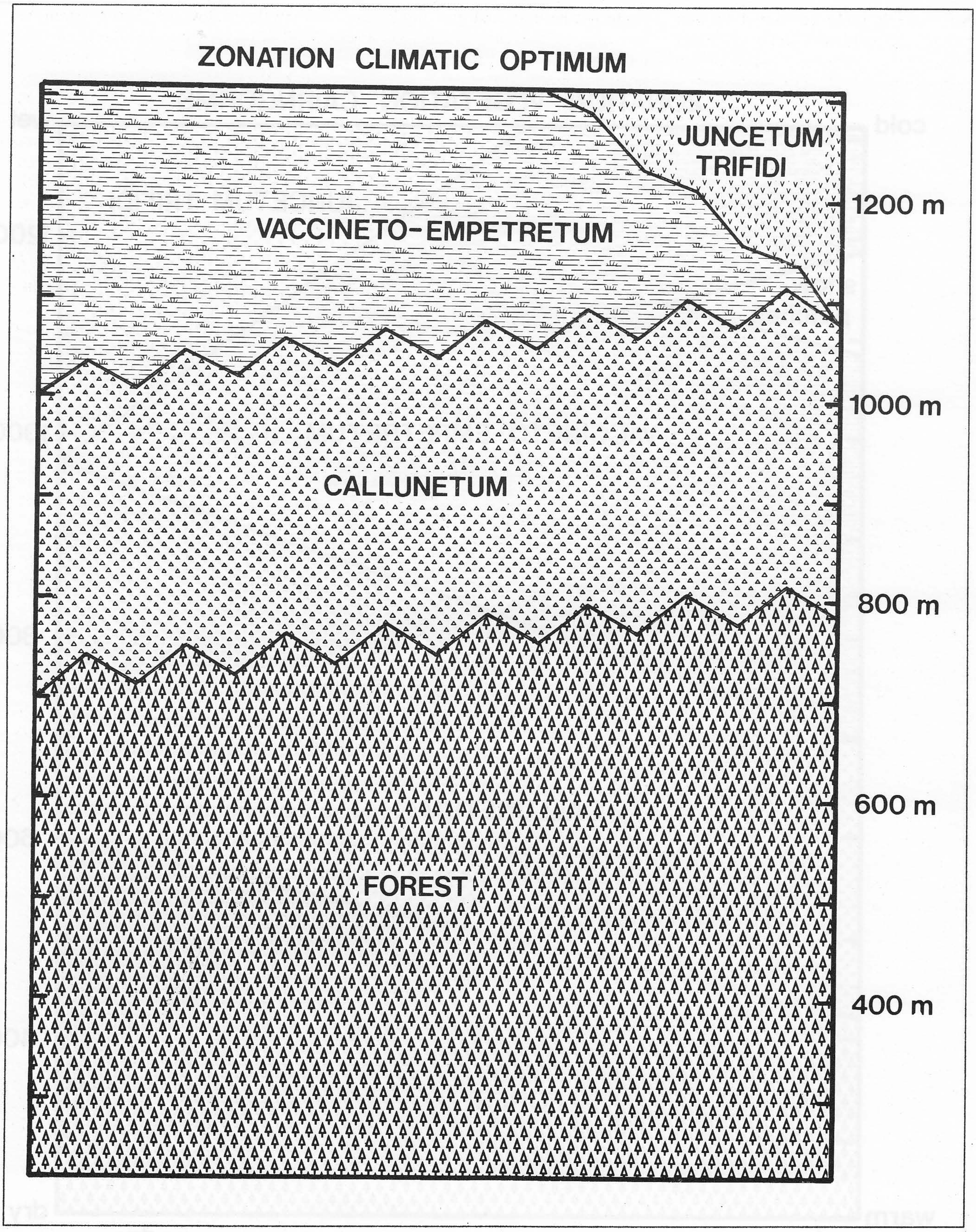

Fig. 2 — The postulated configuration of the vegetation during warm, dry phases in the Postglacial.

that the relatively restricted human population would have had much affect on the vegetation of the less-productive higher slopes. A climatological explanation would seem more plausible and is borne out by a deuterium 'low' at ±3310 B.P. (= ±1603 B.C.) just prior to the disappearance of *Pinus sylvestris*.

Although we have little information relating to the Subatlantic, it is perhaps significant that the D/H ratios suggest a drier climate around 775 A.D. Documentary evidence for dry summers in Britain between 700 and 800 A.D. as collated by LAMB (1977, Fig. 17.2.) support this claim. Thus the vegetation must once again have taken on a drier aspect.

RECENT FLUCTUATIONS

There is little evidence for climatic fluctuations in the Cairngorms during the succeeding eight centuries. However, by the beginning of the 17th Century the medieval warm epoch had given way to the Little Ice Age. By then permanent snowbeds had developed on the summits (TAYLOR, 1618). The cold conditions continued on late into the 18th Century (PENNANT, 1772). During the Little Ice Age the mean annual temperature was in the order of 1.3 - 1.5°C lower than at present (LAMB, 1977). This would suggest a downward displacement of the vegetational zones in the order of anything up to 275 m with respect to their present limits (the Cairngorms display a lapse rate varying between 0.55°xC/100 m on the lower slopes and 1.2°C/100 m above 930 m (DYBECK and GREEN, 1955). According to General Roy's survey (1746 - 1755) of Abernethy Forest the tree-line there stood at 400- 450 m with the exception of some subalpine birchwood to 610 m (O'SULLIVAN, 1973, p. 100). On the other hand, coring has shown that at the end of the 18th Century the steep slopes of Creag Fhiaclach bore pine trees up to 550 m (see Fig. 3).

The increased snow-cover would be expected to favour the Vaccineto-Empetretum at the expense of the Callunetum and the Juncetum trifidi. Since prolonged snow-cover is sufficient to kill *Juncus trifidus* (INGRAM, 1958, p. 724), the presence of snow-capped summits must have wiped out any Three-leaved Rush there. Other evidence suggests that permanent snowbeds were able to persist as low as 900 m. Thus SUGDEN (1971, 1977) has pointed to the small size of the crustose lichen *Rhizocarpon* inside the limits of the corrie moraines. Taking the known rate of growth in a similar environment in Norway, he estimated that the lichens could not have started growing before the late 17th Century. Outside the moraine limits the lichens have much larger dimensions. Growth of the chionophobous *Rhizocarpon* was apparently prevented by the presence of semipermant snowbeds within the corries.

The 19th and 20th Centuries saw an increase in the temperature and the snowline retreated. At the present day only a few semi-permanent snow-patches are left high up in the Cairngorms, mainly between 1100 m and 1170 m. On the drier parts of the Cairngorm plateau *Juncus trifidus* was able to reestablish itself once more. Considering the size of some of the tussocks (diameters up to 90 cm have been recorded) and their slow rate of growth INGRAM, 1958, p. 714 and P. PRYOR in GILBERT and FOX, 1985, p. 53 suggest an average radial growth of +- 2-3 mm per annum), some of these clones may date from the initial wave of colonization in the first half of the 19th Century. Both macrofossil input (DUPONT, 1983) and pollen analysis (LEMBRECHTS, 1980) indicate that *Juncus squarrosus* and *Eriophorum vaginatum* diminished and that the blanket-bogs were overrun by *Calluna vulgaris* and *Scirpus cespitosus* in the final stages of their development. The mite *Ceratoppia* reached its maximum development in the uppermost 5 cm (DUPONT, 1983, p. 38), a sign of extreme dryness. In the past two centuries the blanket-bog has become largely moribund, which would explain its liability to erosion. The development of peat haggs has furthered the process of desiccation. While bonzai-like seedlings of *Pinus sylvestris* are present on the drier sites up to at least 850 m, it is uncertain whether they represent a new wave of invasion or simply an unsuccessful attempt at colonization (none of the runts are more than 35 years old) - only time will tell.

It should be clear from the above that the vegetation in the Cairngorms is in a constant state of flux and that any interference however minor may be sufficient to tip the scales one way or another.

HUMAN INFLUENCE

It has been suggested above that human interference was limited in the past. Admittedly pollen of *Plantago lanceolata* and *P. major* have been encountered in the blanket-peat from ±5000 B.P. on (LEMBRECHTS, 1980). The latter species in particular is often considered to be a human indicator. Cereal pollen put in a first appearance about 3000 B.P., but it seems unlikely that these crops were grown on higher ground (steep slopes, low pH). Field systems (? Neolithic) are however know on flat ground between 260 and 270 m. However by the 16th Century cattle grazing up to ±1000 m was a well-established practice. The need for shelter for both man and beast at the higher levels must have had a considerable impact on the forest margins (PEARS, 1967, 1968). Towards the end of the 18th Century cattle farming was gradually replaced by flocks of free-roaming sheep. The extermination of the wolf (*Canis lupus*), which made this possible,also lead to an increase in the number of deer (*Cervus elaphus*, *Capreolus capreolus*) which in large numbers are notorious for their detrimental effects on woodland. By this time timber extraction on a large-scale was also underway. The lumberers, while extracting a good deal of the closegrained timber did not destroy the forest wholesale. Areas previously felled were fenced off or clumps of trees left from which reseeding by natural pine for building, fuel etc. had in the long run the effect of seriously depleting the extent of the boreal forests here and elsewhere in Scotland.

At a time when the public is becoming increasingly aware of the need for conservation, the last remnants of this primaeval forest are still under considerable pressure. Not only is recreation on the increase, but large tracts of native *Pinus sylvestris* have been interplanted with non-indigenous pine, and other exotic conifers (*Larix decidua L. kaempferi*, *Picea abies*, *P. sitchensis*, *Pinus contorta* and *Pseudotsuga menziesii*). The Forestry Commission has even established an experimental plot between 605 and 685 m. The idea of planting conifers above the present tree-line can probably be linked with the presence of pine-stumps in and under the blanket-bog. If successful, such high-level plantations will yield high quality close-grained timber. An earlier experimental plot established in 1930 at 470 - 490 m lead to widespread afforestation, so concern as to the exact intentions of the Forestry Commission is indeed well-founded. If the Caledonian Pine Forest is to regain some of its primaeval character, it is imperative that conservation be undertaken before it is too late. FORSTER and MORRIS (1977) have outlined a scheme worth implementing.

In the past, the plateau above 1100 m, notorious for its low temperatures (air-frost on ±200 days per annum and day temperatures below freezing-point for about a quarter of the year), high windspeeds (gusts up to 230 km/h) and high precipitation (±2250 mm per annum) held little attraction for all but alpine botanists., hillwalkers and mountaineers. Roughly half of the precipita-

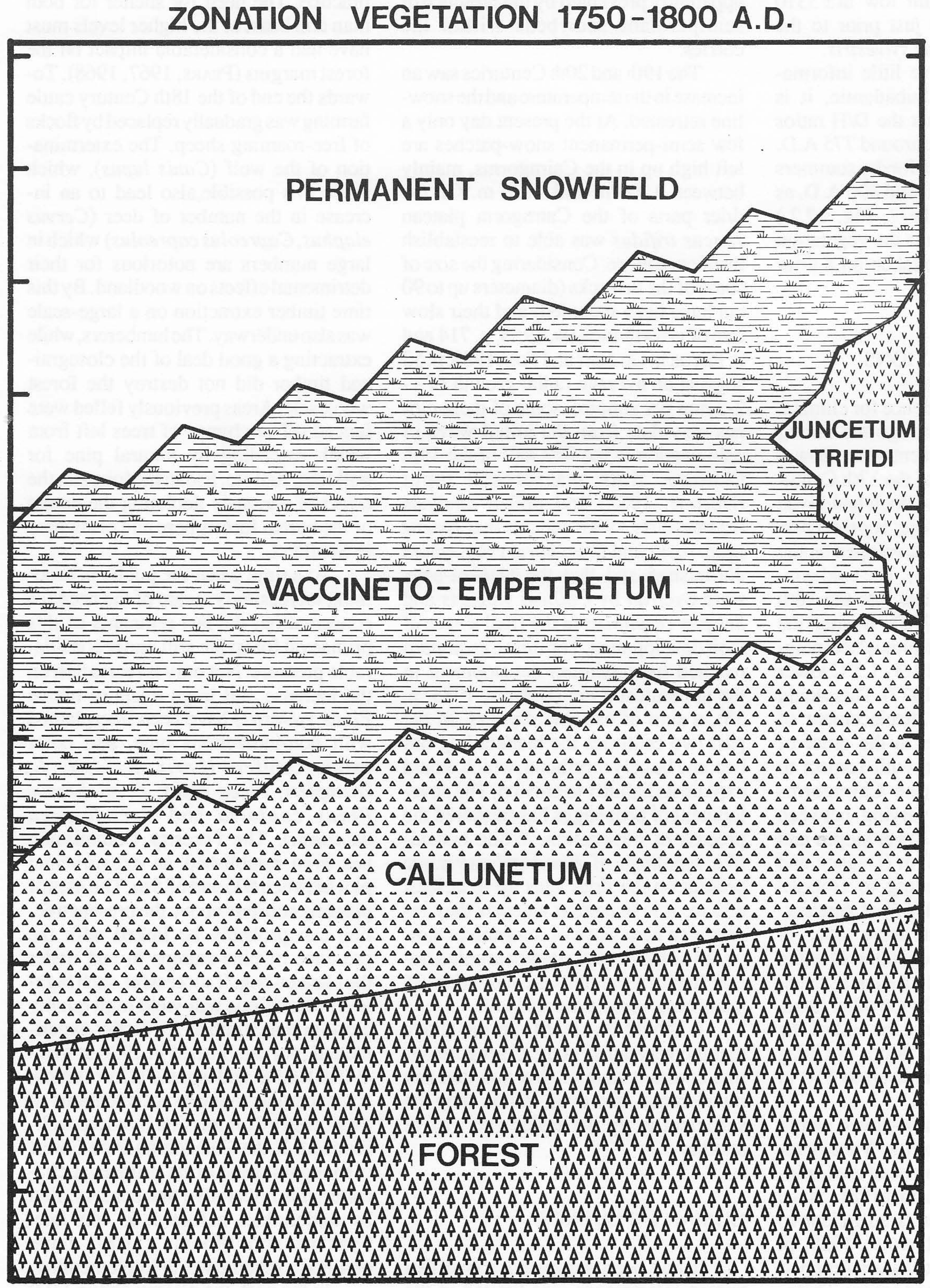

Fig.3 — The zonation of the vegetation at the end of the Little Ice Age.

tion falls in the winter months October to February in the form of snow, resulting in the most extensive area of snowbed communities in the British Isles. This snow-has in the past few decades begun to attract a large number of visitors to the area for some of the best skiing to be had in Britain. The blasting and bulldozing of access roads, ski-runs and the erection of restaurants, chairlifts and diverse ski-tows between 550 m and 1115 m have left deep wounds in the mountainside and lead to the introduction of a number of plantspecies normally restricted to lower altitudes e.g. sown grassland species along with ruderal taxa and basiphilous lichens such as *Peltigera spuria* and *Steinia geophana* (GILBERT and FOX, 1985, p. 54). In order to make this enterprise profitable one of the chairlifts is even kept running during the summer months. Trampling of the alpine vegetation by summer visitors has caused its wholesale destruction at the top of Cairngorm. Plans to expand the area under development, which would have meant destroying some of the blanket-bog have been temporarily shelved.

On top of this, grazing by sheep (*Ovies aries*) and reindeer (*Rongifer tarandus*) inevitably takes its toll of the slow-growing vegetation. While officially excluded from the area, the presence of sheep at altitudes up to 1150 m can be demonstrated directly (sightings) or indirectly (fresh faeces). A few sheep are almost always encountered at the top of one of the chair-lifts, no doubt attracted by leftovers from the Ptarmigan Restaurant (1090 m) and have been seen grazing in Margaret's Coffin (1100 m) where so many snowbed rarities are to be found (GILBERT and FOX, 1985). The reindeer, which were reintroduced into Scotland by the late M.Utsi in 1952 and presently form a major tourist attraction, are kept in an enclosure on the lower slopes (450 - 560 m) of Cairngorm. Occasionally a few animals manage to escape and may be found feeding on the vegetation at more than 1100 m. The vegetation at these heights is particularly susceptible to such grazing pressure.

While the Cairngorms still have much to offer in the way of wildlife and continue to yield cryptogamic species new to Britain (LONG, 1982; GILBERT and FOX, 1985), it is imperative that active measures be taken now to safeguard this heritage for the future.

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REGENERATION PROCESS OF A SUBALPINE CONIFEROUS FOREST AND THE COEXISTENCE MECHANISM OF TREE COMPONENTS

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Keywords: Subalpine conifers forest, Regeneration mosaic, Gap, Life-span.

Subalpine coniferous forests on the Pacific Ocean side of central Japan consist of *Tsuga diversifolia*, *Abies veitchii*, *Abies mariesii*, *Picea jezoensis* var. *hondoensis*, and *Betula ermanii*. Their distribution overlap each other especially in the lower part of the subalpine zone, though their relative dominance are strongly affected by topographic conditions. The regeneration process of the mixed forest and the coexistence mechanism of tree species were studied on the southern slope of Mt. Tekari (alt.2591 m) between 1900 m and 2200 m in altitude (Fig. 1).

MOSAIC STRUCTURE IN A FOREST.

The mosaic structure (Watt, 1947) was examined using a detailed age census of a 30 m x 30 m quadrat in a mixed mature forest dominated by *T. diversifolia*. An age distribution had several peaks and the trees in the plot was divided into four age groups with age ranges of about 100 years (Fig. 2). Individuals belonging to each age group older than 100 years were distributed contagiously in the plot. Thus, the study forest was assumed to be a mosaic of tree patches in different developmental phases, which originated from gaps formed in the forest canopy (Kanzaki, 1984).

The regeneration process starting from a gap formation was examined from three points of view, initial floristic composition in gaps, growth of tree population in gaps, and death of canopy trees after canopy closure.

INITIAL FLORISTIC COMPOSITION IN GAPS.

Sixteen gap plots of 20 m x 20 m were set up in forests where gaps had formed 20 - 50 years ago by wind related disturbances (Kanzaki, 1986). The stand structure and species composition of each plot just before the gap formed were reconstructed from size measurments and anatomical determination of the genus of dead canopy trees (dbh > 10 cm). Floristic composition and age structure of saplings was also studied in the gaps.

The floristic composition in gaps had no close relation to the floristic composition of the canopy trees prior to

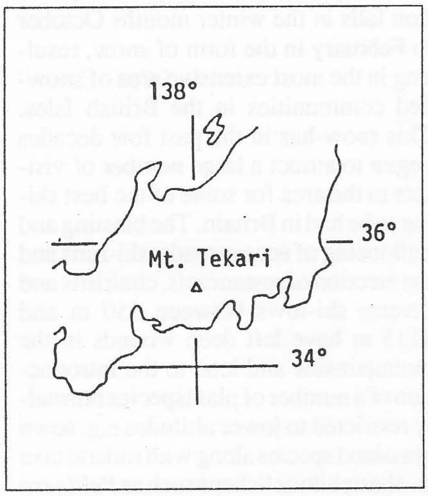

Fig. 1 — Map showing the study site.

the disturbance, but it could be explained by the disturbance magnitude (percentage of basal area of dead trees) and the mean suppressed duration (MSD) (Fig. 3). The MSD is the mean age of the advance regenerated saplings on the forest floor at the time of gap formation.

Betula spp. (*B. ermanii* and *B. corylifolia*) attained their maximum dominance ratio when the MSD was low and disturbance magnitude was high, while *Abies mariesii* and *Tsuga* (these species were lumped together) attained their maximum dominance ratio when the MSD was high and disturbance magnitude was low (Fig. 3).

As the MSD index significantly correlated with the developmental stage of the preceding canopy population, it

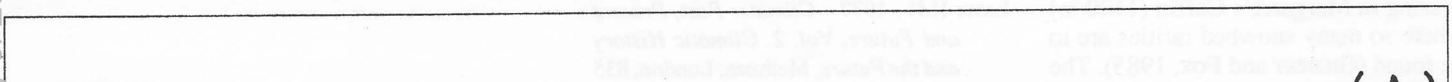

Fig. 2 — Age structure in a mature mixed forest dominated by *Tsuga diversifolia* (Kanzaki, 1984). Trees were classified into four age groups. Av, *Abies veitchii*; Am, *Abies mariesii*; Pj, *Picea jezoensis* var. *hondoensis*; Td, *Tsuga diversifolia*.

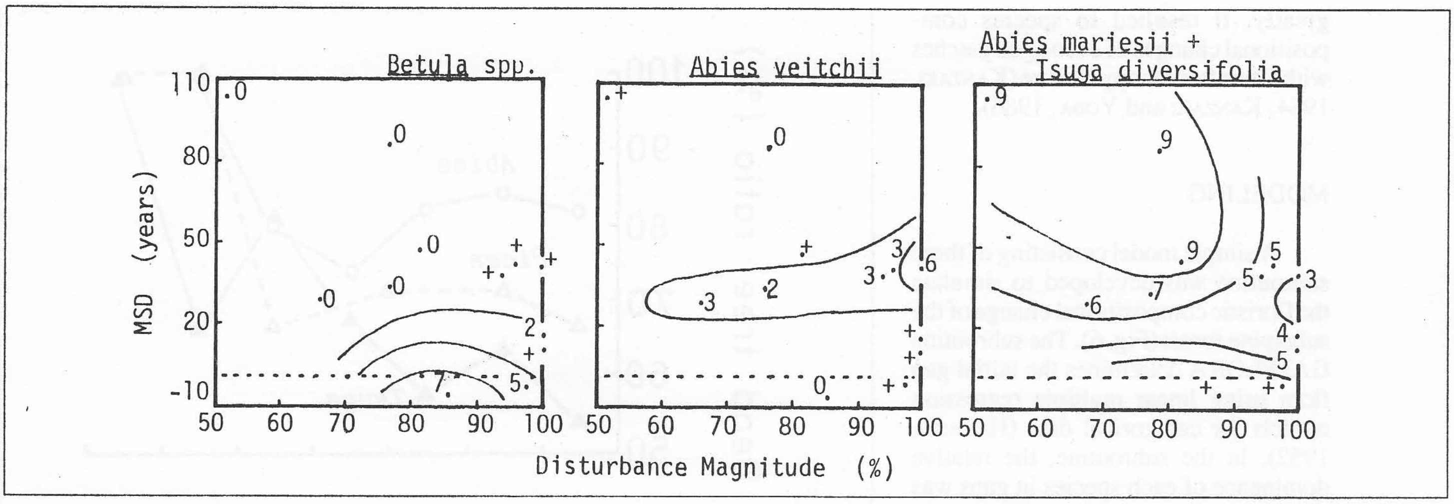

Fig. 3 — Isogramm maps of the relative dominance in gap plots (Kanzaki, unpublished). Disturbance Magnitude indicates the percentage of basal area of dead trees. MSD is the mean suppressed duration before a gap formation for dominant saplings in a gap. +, 0 - 10% dominance; 1, 11 - 20% dominance; 2, 21 - 30% dominance, and so on.

was concluded that the species composition in gaps was controlled by exogenous factors, relating to disturbance regime, and endogenous factors, relating to the development stage of the forests (KANZAKI, 1985).

GROWTH RATE

The comparison of diameter growth rate of trees before and after a gap formation is shown in Fig. 4. Sample trees were in a 100-200 years old patch. Before the gap formation, the saplings of four conifers have similar diameter growth rate (Fig. 4a). In the early stage after the gap formation, diameter increments of *Picea* and *Abies* spp. obviously increased, but that of *Tsuga* did not (Fig. 4b) (KANZAKI, 1984).

Growth analyses in the gap plots also revealed that *Betula* and *Picea* are fast growing species, *Abies* spp. are intermediate, and a *Tsuga* is a slow growing species (KANZAKI, unpublished). The differences in initial growth rate in gaps resulted in the stratified canopy structure among these species.

LIFE-SPAN

Percentages of dead trees to total canopy trees in 16 plots were calculated for three genera and for each 10 cm size class (Fig. 5). The probability of death for three genera were greatest in the largest dbh class, and the death probability for a *Tsuga* was lowest in three genera. These differences might have resulted in differences in the observed maximum ages. From an age census for 177 canopy trees in the study area, the maximum observed age of *Abies veithcii* and *Abies mariesii* were 225 and 270 years, respectively (short-lived), while for *Picea* and *Betula*, those were 337 and 301 years, respectively (intermediate), and for *Tsuga* that was 437 years (long-lived). After attaining the canopy layer, the surviving probability varied

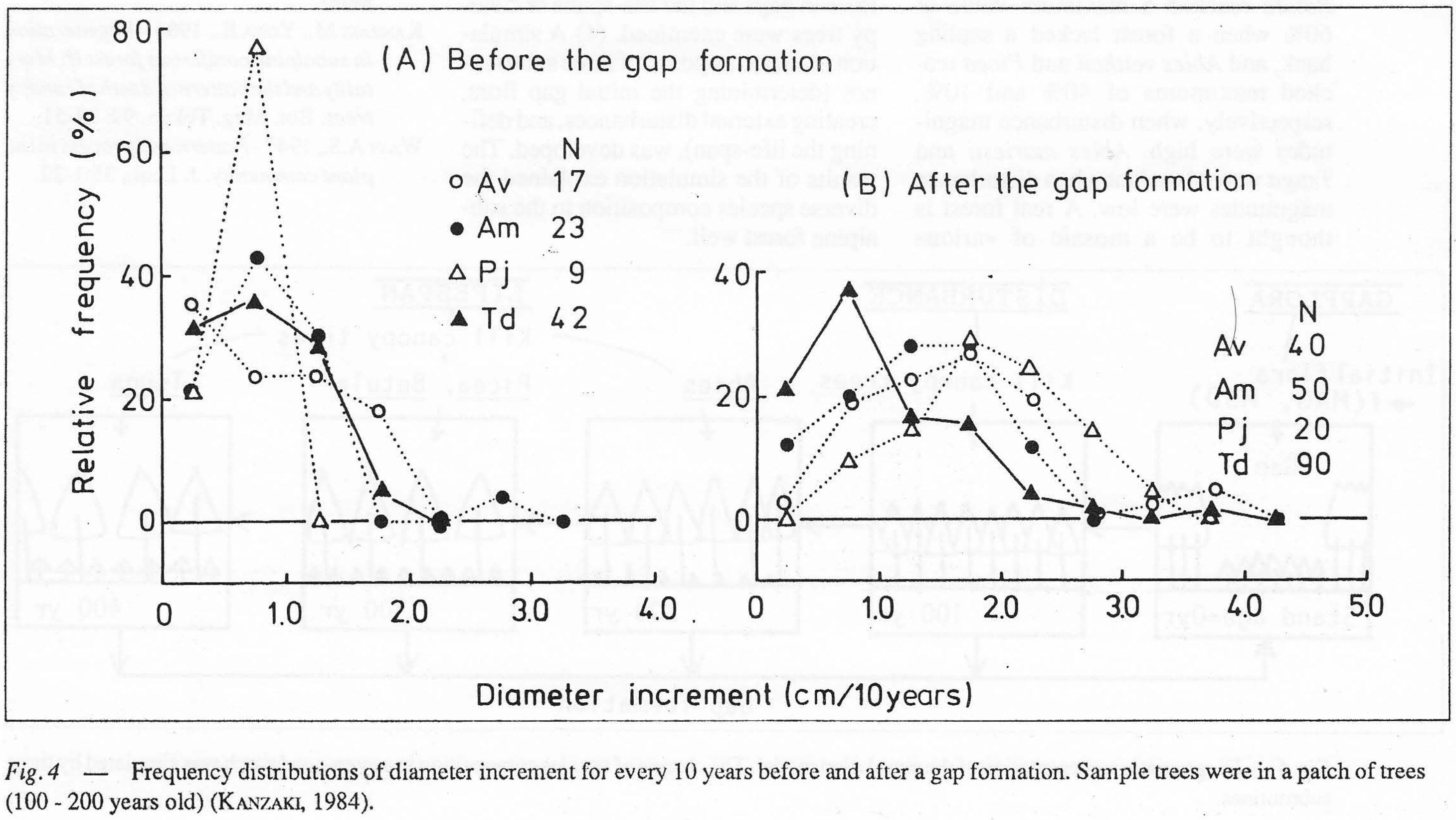

Fig. 4 — Frequency distributions of diameter increment for every 10 years before and after a gap formation. Sample trees were in a patch of trees (100 - 200 years old) (KANZAKI, 1984).

greatly. It resulted in species compositional changes of even aged patches with time after canopy closure (KANZAKI, 1984; KANZAKI and YODA, 1986).

MODELING

A simple model consisting of three subroutine was developed to simulate the floristic compositional change of the subalpine forest (Fig. 6). The subroutine GAPFLORA determines the initial gap flora using linear multiple regression models for categorical data (HAYASHI, 1952). In the subroutine, the relative dominance of each species in gaps was predicted by two explanatory variables, the disturbance magnitude and the sapling bank types defined by MSD index (Fig. 7). The subroutine DISTURBANCE creates external disturbances and kills canopy trees using the mortality curve of each species (Fig. 5). The subroutine LIFESPAN kills survivor trees when they reach the end of their life-span. The simulations were started from the initial forest in which five species shared the dominance, and under the condition of 12 combinations of the disturbance magnitude and the sapling bank types (Fig. 7). The three subroutine altered the species composition of a model forest every 100 years.

Species composition reached to an equilibrium after more than 1000 years simulation, and the equilibrious species composition under the various combinations of the disturbance magnitude and the sapling bank types were shown in Fig. 7. The relative dominance of *Betula* reached a maximum value of 60% when a forest lacked a sapling bank, and *Abies veithcii* and *Picea* reached maximums of 40% and 10%, respectively, when disturbance magnitudes were high. *Abies mariesii* and *Tsuga* were abundant when disturbance magnitudes were low. A real forest is thought to be a mosaic of various compositional patches resulting from various disturbance magnitudes and sapling bank types as shown in the model simulations.

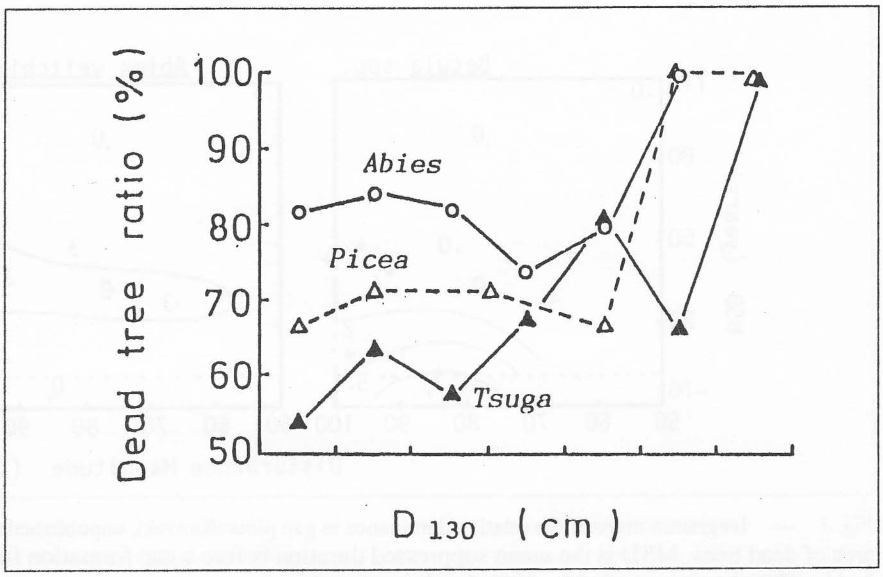

Fig. 5 — Relationships between the dbh and mortality of canopy trees killed by wind-related disturbances (KANZAKI, 1986).

SUMMARY

The regeneration process of the subalpine mixed forest in central Japan was examined. (1) The age structure and spatial distribution of canopy trees indicated the forest was a mosaic of various developmental phases originating from gaps formed in the canopy. (2) Initial flora in gaps were explained by the disturbance magnitude and characteristics of regenerated saplings. (3) Growth of trees in gaps and the life-spans of canopy trees were examined. (4) A simulation model, composed of three subroutines (determining the initial gap flora, creating external disturbances, and defining the life-span), was developed. The results of the simulation explained the diverse species composition in the subalpine forest well.

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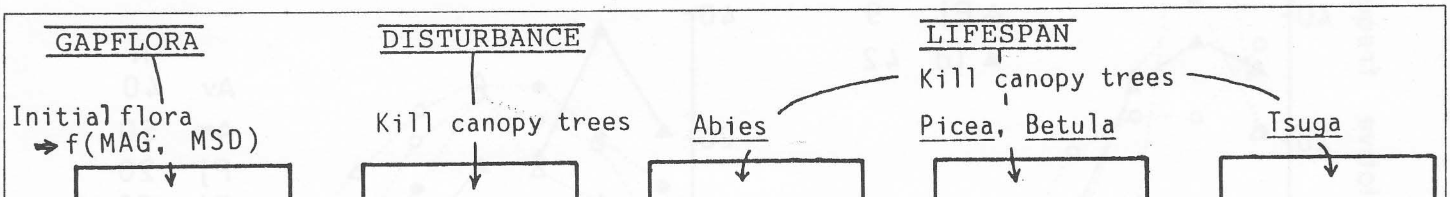

Fig. 6 — Diagramatic representation of the simulation model. The change of species composition in a even-aged patch was simulated by three subroutines.

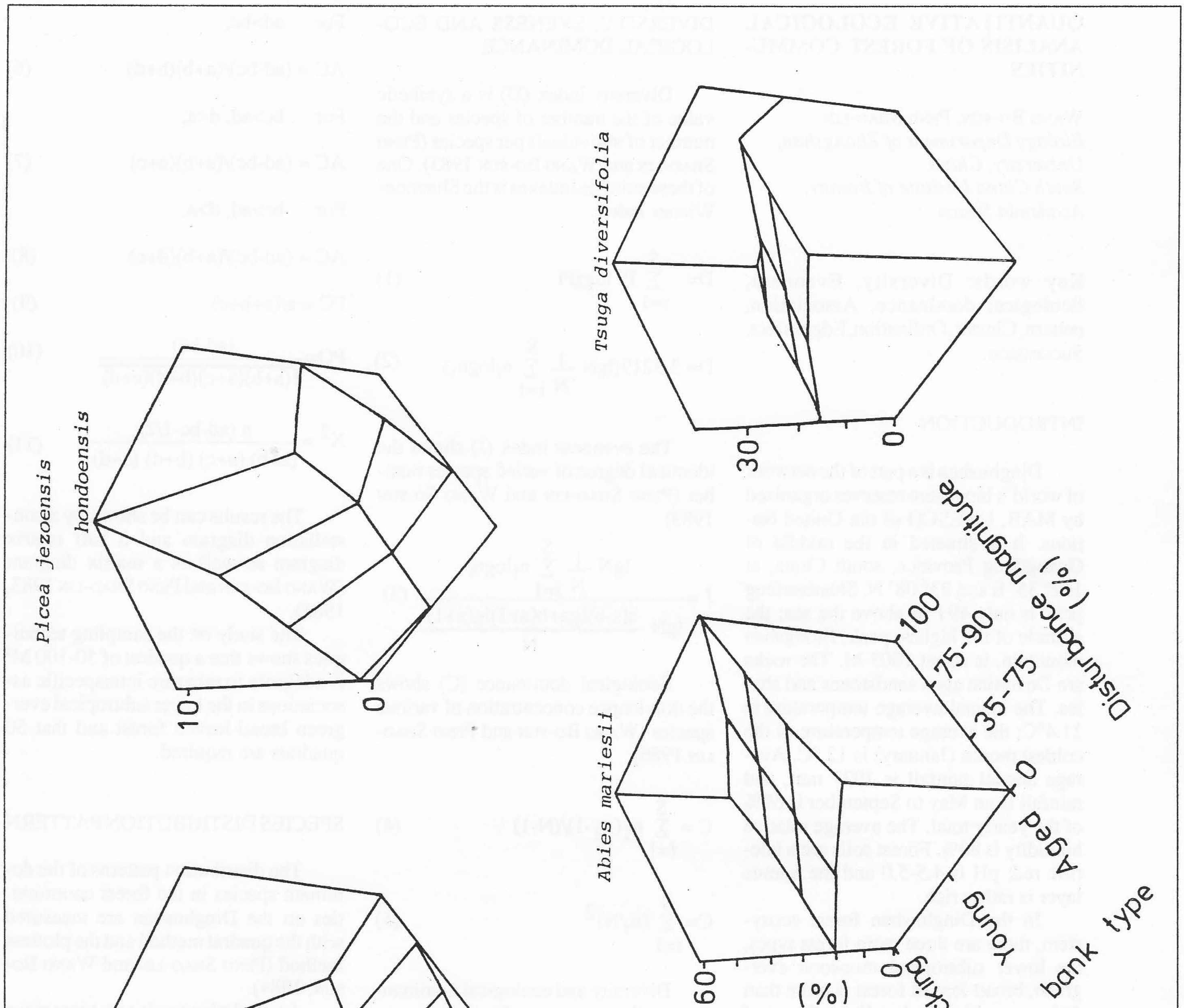

Fig. 7 — Relationshps between initial definitions of the simulation and obtained equiliblium species composition. Three sapling bank types were defined based on the MSD index (lacking, MSD<20; young, 20≤MSD<40; aged, MSD≥40) (KANZAKI, 1985).

QUANTITATIVE ECOLOGICAL ANALISIS OF FOREST COMMUNITIES

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Key words: Diversity, Evenness, Ecological dominance, Association, pattern, Cluster, Ordination, Edge effect, Succession.

INTRODUCTION

Dinghushan is a part of the network of world's biosphere reserves organized by MAB, UNESCO of the United Nations. It is situated in the middle of Guangdong Province, south China, at 112° 35' E and 23° 08' N. Shanbaufeng peak is only 491 M above the sea; the altitude of the highest peak, Jilongshan mountain, is about 1003 M. The rocks are Devonian aged sandstones and shales. The annual average temperature is 21.4°C; the average temperature of the coldest month (January) is 12.°C. Average annual rainfall is 1927 mm, and rainfall from May to September is 69% of the yearly total. The average relative humidity is 80%. Forest soils are a lateritic red; pH is 4.5-5.0 and the humus layer is rather rich.

In the Dinghushan forest ecosystem, there are three main forest types, the lower subtropical monsoon evergreen, broad-leaved forest is more than 400 years old. It is the climax forest of this region and the dominant genera are *Castanopsis* and *Schima*. The pine and broad-leaved mixed forest is also dominated by broad-leaved species such as *Schima* and *Castanopsis*. Only one needle-leaved tree is planted, i.e. *Pinus massoniana*. In addition, there are ravine rain forests, evergreen broad-leaved forests, river-bank forests, and shrubby grasslands. The flora is quite rich with 181 families, 713 genera, 1489 species of angiosperms, and many bryophyte and pteridophyte as well as gymnosperm species.

The quantitative features of these forest communities on Dinghushan, including species diversity, community evenness, ecological dominance, distribution patterns, interspecific association, community clusters, gradient patterns, succession, stability, and edge effect are known after an intensive series of vegetation studies.

DIVERSITY, EVENESS AND ECOLOGICAL DOMINANCE

Diversity index (D) is a synthetic value of the number of species and the number of individuals per species (PENG SHAO-LIN and WANG BO-SUN 1983). One of these suitable indexes is the Shannon-Wiener index:

$$D = -\sum_{i=1}^{S} Pi \log_2 Pi \tag{1}$$

$$D = 3.3219\left(\lg N - \frac{1}{N}\sum_{i=1}^{S} n_i \log n_i\right) \tag{2}$$

The evenness index (J) shows the identical degree of varied species number (PENG SHAO-LIN and WANG SO-SUN 1983).

$$J = \frac{\lg N - \frac{1}{N}\sum_{i=1}^{S} n_i \log n_i}{\lg N - \frac{a(s-b)\lg a + b(a+1)\lg(a+1)}{N}} \tag{3}$$

Ecological dominance (C) shows the dominance concentration of various species (WANG BO-SUN and PENG SHAO-LIN 1986).

$$C = \sum_{i=1}^{S} n_1(n_1-1)/(N-1) \tag{4}$$

$$C = \sum_{i=1}^{S} (n_i/N)^2 \tag{5}$$

Diversity and ecological dominance as well as evenness of forest communities on the Dinghushan are measured according to the above formulae.

These indices help to describe the ecological structure, the stage of succession, the stability, and the character of the habitat of this lower subtropical forest. Shannon-Wiener diversity is about 4.2, Simpson ecological dominance index is about 8.12 and the evenness index is about 70%.

SPECIES ASSOCIATION ANALYSIS

Species association of the forest communities is analyzed by association coefficient (AC), percentage co-occurrence (PC), point correlation (PO) and the chi-sguare method (X^2). A is the number of joint occurrence, b and c are the number of occurrences of one, but not the other, species, and d is the number of empty quadrats.

For ad>bc,

$$AC = (ad-bc)/(a+b)(b+d) \tag{6}$$

For bc>ad, d<a,

$$AC = (ad-bc)/(a+b)(a+c) \tag{7}$$

For bc>ad, d>a,

$$AC = (ad-bc)/(a+b)(d+c) \tag{8}$$

$$PC = a/(a+b+c) \tag{9}$$

$$PO = \frac{(ad-bc)}{\sqrt{(a+b)(a+c)(b+d)(c+d)}} \tag{10}$$

$$X^2 = \frac{n\,(ad-bc-1/2)}{(a+b)\,(a+c)\,(b+d)\,(c+d)} \tag{11}$$

The results can be shown by a constellation diagram and a half matrix diagram as well as a matrix diagram (WANG BO-SUN and PENG SHAO-LIN 1983, 1985).

The study on the sampling techniques shows that a quadrat of 50-100 M² is adequate to measure interspecific associations in the lower subtropical evergreen broad-leaved forest and that 50 quadrats are required.

SPECIES DISTRIBUTION PATTERN

The distribution patterns of the dominant species in the forest communities on the Dinghushan are measured with the quadrat method and the plotless method (PENG SHAO-LIN and WANG BO-SUN, 1984).

A population tends to a contagious (clumped) distribution when it is developing, to a random distribution when it is declining, and to an even distribution when it is a planted population. The primary causes of the change in the distribution of individuals are species interactions, change of habitat conditions, and succession patterns within the community. Different age-classes of a population have varied distribution patterns.

CLUSTER ANALYSIS AND ORDINATION

The techniques of cluster analysis and ordination are used to illustrate the structure of forest communities, the relationships between varied communities, and to explore the effects of varied ecological factors (WANG BO-SUN and PENG SHAO-LIN, 1985; PENG SHAO-LIN and WANG BO-SUN, 1985). The results are shown in Figures 1-6.

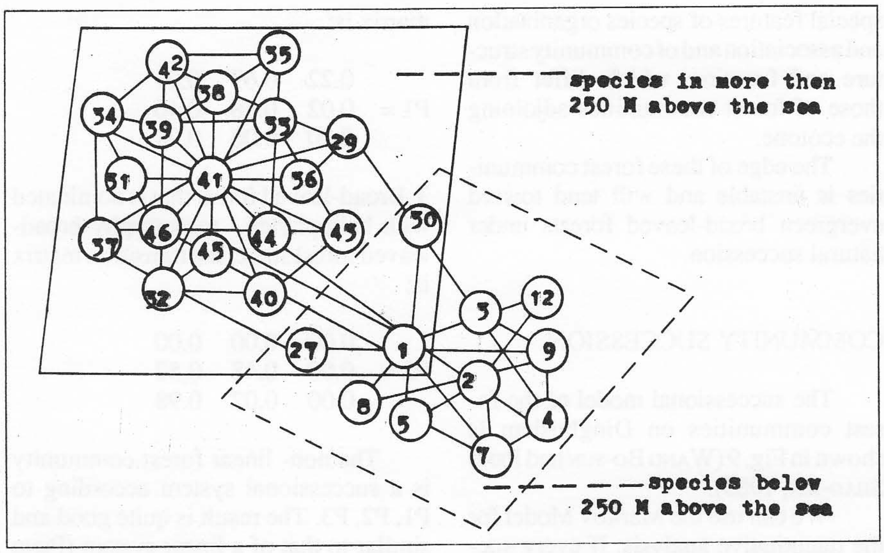

Fig. 1 — Species association construction constellation of *Cryptocarya chinensis* community, showing that there are two ecological components in the community.

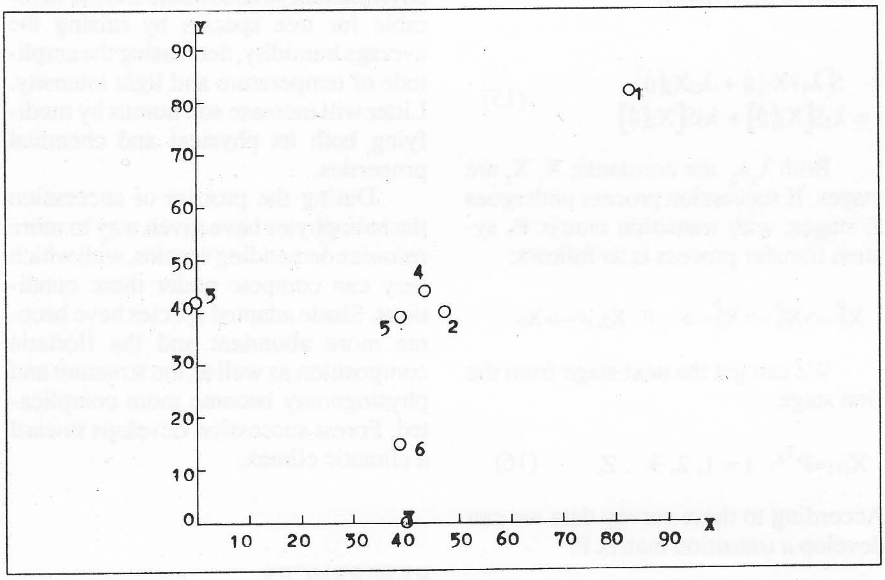

Fig. 2 — Polar ordination of seven forest communities on Dinghushan, Y axis shows the increase of forest communities complexity, there three tree species and two-layer structure in community 7, 34 species and four-layer structure in community 6, 49 species and five-layer structure in community 4; X axis shows the increaseof strength of moisture ecological facture.

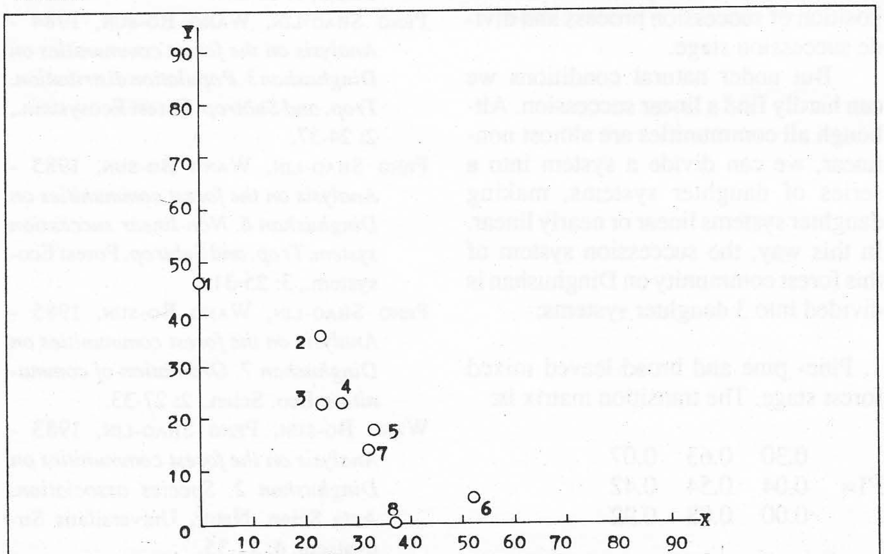

Fig. 3 — Polar ordination of 8 quadrats of *Cryptocarya chinensis* community in varied altitude X axis shows the strength increase of light and temperature ecological factors, Y axis shows the strength increase of moisture and soil ecological factors.

COMMUNITY STABILITY

The stability of the forest communities on Dinghushan is measured after the age-class structure of the communities is known. Then the developing trends of the dominance species are analyzed. The results show:

1. Species diversity increases from pine forest to pine and broadleaved mixed forest, and then to broad-leaved forest. But in the latter stage of succession in the pine and broad-leaved mixed forest, species diversity is quite high, similar to that of the evergreen broad-leaved forest.
2. In the developing forest community, species diversity increases gradually from the top sub-layer to the second and to the third sub-layer.
3. In the degenerative forest community, species diversity is lower from the top sub-layer to the second and to the third sub-layer.
4. In the stable forest community, species diversity of the different sub-layers tend toward constancy.

EDGE EFFECT

The edge effect is a general phenomenon. It occurs in every ecotone between two or more communities. Forest edge effect has special features. To study the edge of forest communities, the formula for the edge effect was developed by WANG BO-SUN and PENG SHAO-LIN (1986). In formula (12), Y is a structure

$$E=mY/\sum_{i=1}^{m} y_i \qquad (12)$$

value of the ecotone and y is that of community i which adjoins the ecotone. This is a general value. It can be replaced by one or more indices, such as formula (1), (4) etc.

$$E=mD/\sum_{i=1}^{m} d_i \qquad (13)$$

$$E=mC/\sum_{i=1}^{m} c_i \qquad (14)$$

The community edge effects were studied between a pine forest and a pine and broad-leaved mixed forest, and between a pine and broad-leaved forest and a broad-leaved forest.

We define the concept "plant community edge effect" after studying these forest communities on Dinghashan. In the plant community ecotone, there are

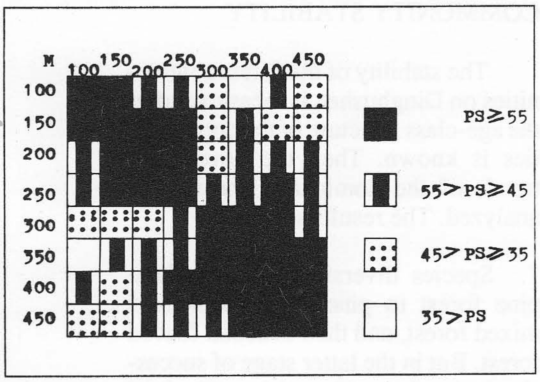

Fig. 4 — Percentage similarity matrix of varied quadrats in *Cryptocarya chinensis* community, showing ecological structure of the community.

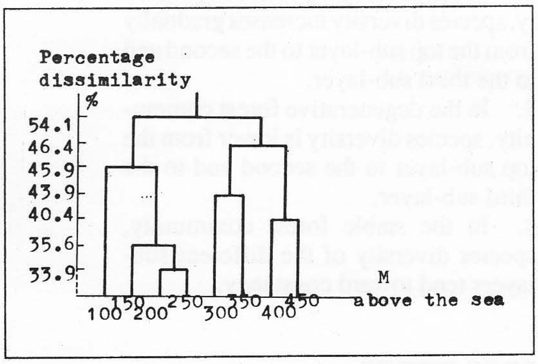

Fig. 5 — Cluster analysis to varied quadrats in *Cryptocarya chinensis* community, showing ecological structure of community.

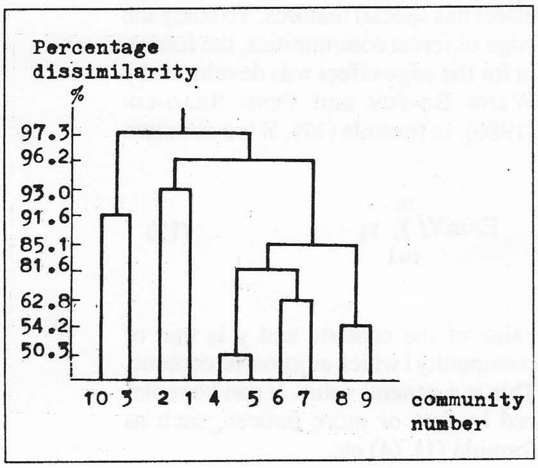

Fig. 6 — Cluster analysis to ten forest communities showing the raltionships between ten communities.

special features of species organization and association and of community structure and function, which differ from those of forest communities adjoining the ecotone.

The edge of these forest communities is unstable and will tend toward evergreen broad-leaved forests under natural succession.

COMMUNITY SUCCESSION

The successional model of the forest communities on Dinghushan is shown in Fig. 9 (Wang Bo-sun and Peng Shao-lin, 1985).

We can use the Markov Model for the quantitative analysis. If every successional stage is a daughter systems all succession is a system. If the linear system is S(X), then:

$$S[\lambda_1?X_1(t) + \lambda_2 X_2(t)] = \lambda_1 S[X_1(t)] + \lambda_2 S[X_2(t)] \qquad (15)$$

Both $\lambda_1 \lambda_2$ are constants; X_1 X_2 are stages. If succession process undergoes Z stages, with transition matrix P, system transfer process is as follows:

$$X_1^P \dashrightarrow X_2^P \dashrightarrow X_3^P \dashrightarrow \ldots P \dashrightarrow X_{Z-1}P \dashrightarrow X_Z$$

We can get the next stage from the first stage.

$$X_{i+1}=P^{T}X_i \quad i = 1, 2, 3\ldots Z \qquad (16)$$

According to these survey data we can develop a transition matrix P:

$$p = \begin{matrix} 0.26 & 0.66 & 0.08 \\ 0.01 & 0.56 & 0.13 \\ 0 & 0.3 & 0.97 \end{matrix}$$

We can, then, expect the tree composition of succession process and divide succession stage.

But under natural conditions we can hardly find a linear succession. Although all communities are almost nonlinear, we can divide a system into a series of daughter systems, making daughter systems linear or nearly linear. In this way, the succession system of this forest community on Dinghushan is divided into 3 daughter systems:

1. Pine- pine and broad-leaved mixed forest stage. The transition matrix is:

$$P1= \begin{matrix} 0.30 & 0.63 & 0.07 \\ 0.04 & 0.54 & 0.42 \\ 0.00 & 0.08 & 0.92 \end{matrix}$$

2. Pine and broad-leaved mixed forest - broad-leaved forest stage that is dominated with heliophtes. The transition matrix is:

$$P1 = \begin{matrix} 0.22 & 0.69 & 0.09 \\ 0.02 & 0.58 & 0.40 \\ 0.00 & 0.06 & 0.94 \end{matrix}$$

3. Broad-leaved forest that is dominated with heliophytes - mesotrophy broad-leaved forest stage, the transition matrix is:

$$P2 = \begin{matrix} 0.00 & 0.00 & 0.00 \\ 0.00 & 0.48 & 0.52 \\ 0.00 & 0.02 & 0.98 \end{matrix}$$

The non- linear forest community is a successional system according to P1, P2, P3. The result is quite good and similar to that of a linear system (Peng Shao-lin and Wang Bo-sun, 1985).

Forest succession has modified the environment so as to make it more favorable for tree species by raising the average humidity, decreasing the amplitude of temperature and light intensity. Litter will increase soil humus by modifying both its physical and chemical properties.

During the process of succession the heliophytes have given way to more resource demanding species, with which they can compete under these conditions. Shade adapted species have become more abundant and the floristic composition as well as the structure and physiognomy become more complicated. Forest succession develops toward a climatic climax.

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STRUCTURE AND FUNCTION OF GRASSLANDS ABOVE TIMBERLINE IN SOUTHERN EUROPE

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Key words: Diversity, Pastures, Mountain vegetation

INTRODUCTION

In the Southern part of Europe there are several mountain system: the Alps (maximal altitude: 4807 m), Pyrenees (3404 m), Sierra de Guadarrama and S. de Gredos (2661 m), Sierra Nevada (3482 m), the Apennines (2914 m), the Dinarids (2522 m), Rhodopi (2925 m), the greek mountains (2918 m) and, more isolated from a phytogeographical point of view, the insular mountains of Kriti (2498 m), of Corsica (2710 m) and the Etna volcano (3279 m) in Sicily.

All these mountain systems present a continuous vegetation above timberline: formations of thorny cushions (mostly endemic species of *Astragalus*) in the Southern parts (Sierra Nevada, Etna, Greek mountains, cf. PIGNATTI *et alii* 1980) or grasslands. The substrate is in prevalence calcareous, but important zones of silicates are on the Alps, on some Iberian mountains and obviously on the Etna volcano. Only grasslands on limestone substrate are treated in the present paper, in order to obtain a survey of comparable objects. Such grasslands are mostly characterized by the presence of species of *Sesleria* and *Festuca* (Graminaceae).

The aim of this study is to investigate if some regularities between structural and functional parameters can be detected in the vegetation of mountain grassland of Southern Europe.

SOME CONCEPTS AND DEFINITIONS

The present paper deals with "diversity", a word used in different ways by different Authors and which can be hardly considered to have an unambiguous scientific meaning. Consequently we will use two better defined concepts:

Entropy - This is the measure of entropy given by the Shannon-Weaver formula, which corresponds to a measure of disorder. In the analysis of phytosociological data entropy is low when one species results dominant and it is high when the vegetation is given by a mixture of species, each covering more or less the same percentage of the investigated area.

Evenness - Represents the entropy value expressed as percentage of the maximum entropy which is possible in the given system. For the use of this value cf. HAEUPLER (1982).

MATERIAL AND METHODS

7 phytosociological tables of the Authors (mostly from earlier publications, only one still unpublished) and 7 tables from other sources (all published) have been analyzed. These tables give information on the vegetation structure of the major mountain systems of the area.

All vegetation types considered belong to the class Seslerietea.

Following vegetation tables have been treated:

1 - *Caricetum firmae* from Graubuenden (Switzerland) by BRAUN-BLANQUET and JENNY (1926)
2 - *Seslerio-Semperviretum* id.
3 - *Elynetum* from Graubuenden (Switzerland) by BRAUN-BLANQUET (1931).
4 - *Caricetum firmae* from Stelvio (Alps, Italy) by GIACOMINI and PIGNATTI (1955).
5 - *Seslerio-Semperviretum* id.
6 - *Caricetum firmae* from the Lienzer Dolomiten (Austria) by WIKUS (1961).
7 - *Seslerio-Semperviretum* tab. 14, id.
8 - *Seslerio-Semperviretum* tab. 15, id.
9 - *Crepidi-Plantaginetum*, id.
10 - *Festucetum scopariae* from the Eastern Pyrenees by BRAUN-BLANQUET (1948).
11 - *Elyno-Oxytropidetum*, id.
12 - *Caricetum firmae croaticum* from the Dinarids (Yugoslavia) by HORVAT (1931)
13 - *Laevi-Helianthemetum*, id.
14 - *Seslerietum tenuifoliae*, 7 rel. (unpublished) from Central Italy by the Authors.

The phytosociological data have been treated with different statistical methods in order to analyze the regularities underlying the vegetational structure.

Evenness and Shannon-Weaver entropy have been calculated using the program Entropia ML developed by L. Celesti. The ordination of the results was carried out with the package Orloci/Wildi.

Values of production have been calculated only on the basis of observations carried out in Italy (Alps, Apennines) by the Authors and mostly unpublished.

The results exposed in Tab. 1 have been treated as a matrix and submitted to ordination procedures usig the Wildi-Orloci package to obtain the geographical representation given in Fig. 1.

The values of the different structural characters have been calculated separately for each releve, but in Tab. 1 they are expressed in form of the mean values belonging to each association. In general there are single releves strongly deviating from the average, but they do not seem to affect the calculated average.

In critical cases the standard deviation has been calculated: the values obtained (not reproduced in Tab. 1) demonstrate that the averages are reliable.

For an adequate interpretation of the results it must be pointed out that the values calculated for the same association in different regions are more diverging than the values of distinct associations occurring in one single region. It seems likely that these data are strongly affected by the characteristics of the regional floras. Consequently a direct comparison among the different values is of little interest. These data are not to be considered as absolute measures but only as relative ones. In fact the data appear more meaningful if they are ordered in dynamic series: for most investigated regions there is a couple of tables (sometimes more) which can be interpreted as belonging to a single succession, e.g.

Switzerland tab.	1 -> 2 -> 3
Stelvio	4 -> 5
Lienz	6 -> 7 -> 8 -> 9
Croatia	12 -> 13

It is possible to order the vegetation tables according to dynamic series only for the Alps and the Dinarids; in mountain systems further South Seslerietea vegetation is represented by one association only (Apennines) or by associations which are not linked syndinamically (Pyrenees).

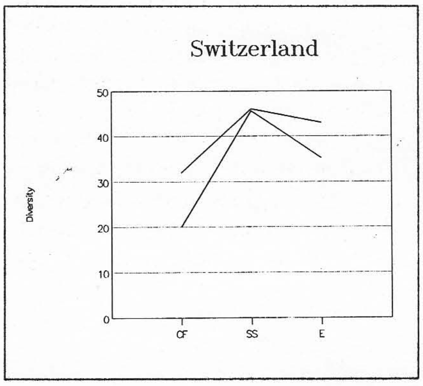
When the data are ordered in dynamic series it is possible to observe two tendencies:

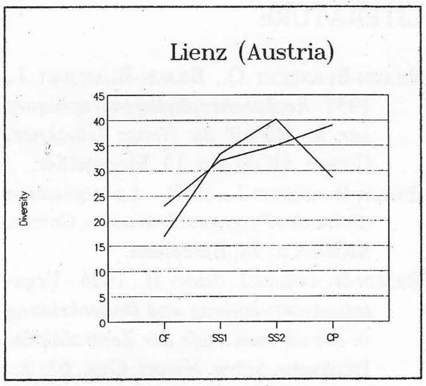
(A) - the floristic richness (average number of species present in the tables) increases with the development of the series to a top value and then again decreases in the final vegetation type; in the latter stadium the productivity is on the contrary at its maximum.

(B) - the evenness increases continuously with the development of the succession and reaches its maximum in the final vegetation types.

Table 1 —Values of the different structural characters.

	Number of releves	Species/ releves	Generic Index	Family Index	Entropy in families	Entropy of releves	Maximal entropy	Evennes
1. Caricetum firmae	14	20	1.24	2.3	2.819	1.259	2.975	42.2
2. Seslerio-Sempervirctum	10	45.6	1.31	2.96	2.885	1.733	3.812	45.5
3. Elynetum	11	35.2	1.39	2.6	2.808	1.667	3.538	46.6
4. Caricetum firmae	15	22.5	1.27	2.55	2.776	1.683	3.088	54.7
5. Seslerio-Sempervirctum	8	43.7	1.25	2.62	3.03	2.248	3.769	59.5
6. Caricetum firmae	25	18.9	1.28	2.07	3.03	1.254	2.831	45.1
7. Seslerio-Sempervirctum	14	33.3	1.22	2.27	3.187	1.728	3.472	49.9
8. Seslerio-Sempervirctum	20	42	1.26	2.75	3.115	1.878	3.728	50.3
9. Crepidi-Plantaginetum	24	28.6	1.22	2.73	2.89	2.128	3.339	63.6
10. Festucetum scopariae	12	28.6	1.17	2.72	2.971	2.123	3.315	63.6
11. Elyno-Oxytropidetum	17	35	1.27	2.74	2.993	1.833	3.527	52.1
12. Caricetum firmae croaticum	20	23.1	1.2	2.56	3.02	1.535	3.142	48.5
13. Laevi-Helianthemetum	28	35.3	1.06	1.96	3.09	1.87	3.23	58.1
14. Seslerio tenuifoliae	7	36.1	1.28	3.06	3.112	2.509	3.542	70.7





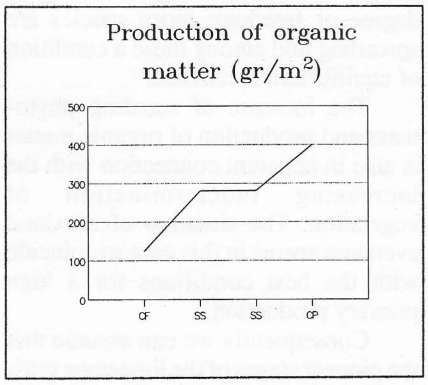


Fig. 1 — Relations between diversity and productivity in the alpine succession: Switerland - variation of species number and entropy in *Caricetum firmae* CF), *Seslerio-Sempervirctum* (SS) and *Elynetum* (E); Lienz (Austria) - variation of species number and entropy in *Caricetum firmae* (CF), *Seslerio-Sempervirctum* pioneer (SS), *Seslerio-Sempervirctum* ripe (SS) and *Crepidi-Plantaginetum* (CP); production of organic matter in the previous succession.

Some exemples:

Switzerland:	no. of species	20.0	-> 45.6	->	35.2			
	evennes	42.2	-> 45.5	->	46.6			
Austria:	no. of species	16.9	-> 33.3	->	40.2	->	28.6	
	evennes	45.1	-> 49.9	->	50.3	->	63.3	

The same tendencies can be shown also in the other cases examined. In the examples given above only evenness has been considered but the results do not change if the absolute values of entropy are used.

Other parameters which have been calculated show no meaningful variations between the different associations; for instance: generic index (= no. of species/no. of genera) varies from (1.06) 1.17 to 1.39; the differences are too small to be significative; family index (no. of species/no. of families varies from 1.96 to 3.06 i.e. it show relatively strong variations without any apparent regularity.

Entropy of families (calculated with the Shannon-Weaver formula in wich each family enters with the frequencies of species included in the given family) varies very little from 2.776 to 3.112.

Generic index and entropy of families seem to be more or less constant factors in the whole limestone grasslands of the South European mountains above timberline. It remains to demonstrate if the family index has a meaning at all.

The production of organic matter was estimated by cutting the aerial parts of the plant population: the vegetation above tiberline has a short vegetative period (about 3 months) and consequently the above-ground phytomass has the tendency to coincide with the annual production. The results are expressed as dry weight:

Caricetum firmae*		125gr/m²
Sesl. tenuifoliae	*	150
Sesl. semperv.	**	210-350
" "	***	281
Crepidi-Plant.	*	400

DISCUSSION

In the grasslands on limestone of the South European mountains above timberline it is possible to detect a tendency to increase ezntropy parallel to development of the vegetational succession. The variations of the floristic richness on the contrary show only an incomplete parallelism to the variations of evenness and entropy: richness increases with the succession, but reaches its top before the final stages, in which a reduction of species number took place.

The increase of entropy can be considered equivalent to an increase of indetermination in the spatial disposition of the plant individuals. This may be interpreted as an effect of environmental influences on the vegetation: in the pioneer stages there are strong constraints affecting the development of the vegetation and this condition is reflected by an ordered disposition of plants (only well adapted species can survive and spread with high vitality); in the mature stages constraints are low and plant individuals are granted a higher degree of freedom; more species are spreading and among these a condition of equilibrium is reached.

The increase of standing phytomass and production of organic matter is also in apparent connection with the increasing indetermination of vegetation. The situation of maximal evenness seems in this case to coincide with the best conditions for a high primary production.

Consequently we can assume that the pioneer stages of the limestone grasslands are colonized by very specialized species, which can reach locally a high frequency, but mantain a condition of low productivity. On the contrary the final stages are lesser specialized and show a certain floristic decay and none of the present species has the tendency to became very frequent, but the sum of the production performances results markedly higher.

CONCLUSIONS

In the limestone grasslands of South European mountains above timberline a relation seems to exist between structural and functional parameters. The structural parameters are based on the calculation of entropy, which corresponds to a measure of disorder in the spatial distribution of plant individuals. Disorder is a negative quality, therefore it can hardly be considered a parameter at all but it is to be taken as the inverse of order. Consequently we conclude that in the investigated vegetation an inverse relation exists between spatial order (structure) and primary production (function).

SUMMARY

Different statistical features of alpine grasslands on limestone in the South European mountains have been analyzed. The comparison between entropy values (on the basis of the Shannon-Weaver procedure) or evenness and annual production of organic matter demonstrates that in this vegetation an inverse relation exists between structural and functional parameters.

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*** From a determinations of Villani (cf. Studia Geobotanica, 4: 191-220, 1983).

STRUCTURAL AND CHOROLOGICAL ANALYSIS OF A MOUNTAIN PASTURE OF NE ITALY UNDER DIFFERENT AGRONOMIC TREATMENTS

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Keywords: mountain vegetation, pastures, vegetation of Italy

INTRODUCTION

The present study has been developed within the framework of the FAO project n. 1 (Sous-reseau pour les Alpes) and the project IPRA of Italian C.N.R. devoted to the recovery of marginal areas.

The research has been carried out in the locality Vals Corona (Prealpi Tramontine, PN, NE Italy), the elevation of the pasture is about 900 m s.l., its exposition is ESE with an inclination ranging between 30 and 40 degrees, pH is ranging between 4 and 6. The mean montly temperature and the montly precipitation for the period 1980-1984 are given in Table 1. The pasture is of secondary origin being within the belt of beech woods. The dominant species are *Bromus erectus*, *Sesleria varia*, *Anthoxantum odoratum*, *Brachypodium pinnatum*, *Koeleria pyramidata*, *Festuca nigrescens* and *Agrostis tenuis*, in total 167 species have been recorded, they belong to 125 genera and 39 families. Among these, *Compositae* include 26 species, *Graminaceae* 15, *Papilionaceae* 12, *Compositae* 7, *Umbelliferae* 6, *Plantaginaceae* 5, *Rubiaceae* 4. From a syntaxonomical point of view the pasture could be assigned to *Mesobromion* s.l. within the class *Festuco-Brometea*.

About six hectares of the pasture have been fenced off. Within this area, 3.3 hectares have been grazed by cattle (885 kg/ha on the average). Each of the areas have been subdivided into seven sections, more or less of the same surface. Three of these have been fertilized yearly only with 100 kg/ha of P_2O_5 and 100 kg/ha of K_2O and three have been fertilized also with 120kg/ha of N (urea 46%). One section of the seven was left unfertilizated. The grazing period runned from the half of June to the end of September. The sections were grazed by turns of six-seven days. The experiment started in 1980, some results have been already presented by PARENTE *et alii* (1983) and PARENTE *et alii* (1985). The aim of this paper is to analyze in more detail how the floristic and syntaxonomic variations, already described, are related to structural and chorological variations (if any) of the pasture after 5 years of grazing.

DATA AND METHODS

Every year, from 1980 to 1984, fifteeen releves of 1 squared meter have been done in each section following a systematic sampling (see ORLOCI, 1978), before the grazing. For each species the frequency (x100) in the 15 releves has been computed. The species have been assigned to life forms-growth forms and to chorological elements according to PIGNATTI (1982). Nomenclature for life forms-growth forms follows ELLENBERG and MUELLER-DOMBOIS (1965/66). In Table 2 the percentages (x100) of life-growth forms (a), of the chorological elements (b) and of the combinations life-growth form-chorological elements (c), as suggested by FEOLI and GANIS (1985), are given for 1980 and 1984. The percentages have been calculated taking into account the frequency of species as weight. The matrices a), b) and c) have been obtained using the software for data banking developed by LAGONEGRO *et alii* (1982) and GANIS (1985). Among the realized combinations of matrix c) (53 in total), only the most important are considered. The importance has been estimated by the method suggested by ORLOCI (1973) - the 19 combinations account for 90% of the total sum of squares of the 53 combinations. To each of the matrices (a, b, c) in Table 2, the method of principal component analysis, based on the correlation coefficient between rows (R-type) and the method of clustering by sum of squares, based on the oblique distance (see ORLOCI, 1978, ORLOCI and KENKEL, 1985) have been applied. Clustering of rows of all the three matrices has been done by average linkage (ORLOCI, 1978) based on the correlation coefficient. Canonical correlation analysis has been applied in order to test the correlation between the first three principal components of matrix a) and the first three of matrix b). The method suggested by ORLOCI (1981) and FEOLI and ORLOCI (1985) has been used to analyse the dispersion profiles of the combinations in matrix c) during the 5 years within each treatment. All the computations have been done by a personal computer Olivetti M2A by the package of LAGONEGRO and FEOLI (1985).

RESULTS

The ordinations given by principal component analysis applied to the three matrices and the classifications by sum of squares show a clear separation between the descriptions of the sections of 1980 and those of 1984. As a consequence, the separation is quite evident also in the ordination scattergram produced by the first canonical variate related to matrix b) (X axis), and the first canonical variate related to matrix a (Y axis). The correlation between the two sets of data resulted significant at more than 2% probability level on the basis of the Bartlett's test. The unfertilized sections of 1984 are always located in the middle of the ordination scattergrams and represent a well separated cluster in the dendrograms obtained by the sum of squares method. The treatments NPK 1984 and especially those grazed by cattle are located at the positive extremes of the first components or at the positive extremes of the curve fitting the points of ordination scattergrams given by the first two components (see FEOLI and FEOLI CHIAPPELLA, 1980), the unfertilized section of 1980 is always located nearby the fertilized sections of 1980. These facts prove that in the first year the effects of fertilization are irrelevant and that the fertilization by N and grazing by cattle produce the greatest effects on the structural and chorological variation of vegetation. If we consider the results of ordination and clustering based on matrices a) and b) the differences between the sections grazed by sheep and those grazed by cattle are not evi-

Table 1 — Mean montly temperature (T=Celsius degrees) and montly precipitation (P=mm.) during the years of trailing (1980-1984). The data have been recorded by a climatic station located near the pasture.

	G	F	M	A	M	G	L	A	S	O	N	D
T	-2.0	-1.1	5.0	10.1	13.0	16.9	17.9	17.2	15.8	9.2	3.0	-0.8
P	65	70	128	82	250	198	165	173	222	248	172	158

Table 2 — Life form-growth form, chorological and combined life form-growth form-chorology spectra (x100) of the different treatments in the first (1980) and last year (1984) of trial.
Abbreviations: T= unfertilized; PK= fertilized by P and K; NPK= fertilized by N, P and K; S= Sheep; C= cattle; H= hemicryptophytes; Ch= Chamaephytes; G=Geophytes; caesp and cs= caespitose; scap and sca= scapose; ros and rs= rosulate; bien= two-year; rpt and rept=reptant; suff and suf= Semi-woody; frut= woody; rhiz= rhizome; bulb= bulbous.

Treatments	T	PKS	NPKS	PKC	NPKC	TS	TC	PKS	NPKS	PKC	NPKC
year	80	80	80	80	80	84	84	84	84	84	84
a)											
H caesp	26	28	24	27	26	27	24	27	28	25	27
H scap	43	41	46	44	46	51	49	50	53	53	52
H ros	11	11	10	7	7	13	13	12	9	11	9
H bien	0	0	0	0	0	0	0	0	0	0	1
H rept	0	0	0	0	0	0	0	0	1	1	1
Ch suff	7	7	8	8	9	5	3	3	2	2	3
Ch rept	1	1	1	2	2	2	3	1	2	1	2
Ch frut	1	0	0	1	1	1	0	1	0	0	0
G rhiz	6	7	6	7	6	0	7	5	4	4	4
G bulb	4	4	4	5	4	1	2	2	1	3	3
b)											
Eurasiatic	13	14	13	13	14	15	16	18	16	18	18
European	29	29	28	27	29	36	31	35	33	31	33
S-Europ.	22	20	20	17	19	18	21	18	20	19	19
Euroamer	1	1	1	1	1	0	0	1	1	1	0
Eurymedit.	5	6	7	8	8	2	4	3	2	4	3
Submedit	2	3	2	2	2	0	0	1	1	1	1
Europ-Mont	15	15	16	18	17	15	14	4	5	5	5
Illyrian	1	3	1	2	2	0	1	0	0	1	0
Endemic	2	1	2	2	1	5	4	5	5	5	5
Cosmopolitan	0	0	0	0	0	0	0	1	1	1	1
Circumboreal	2	3	4	3	2	4	1	7	8	6	6
Paleotemper.	6	5	5	7	6	5	8	8	9	9	10
c)											
Hcs-Euras	7	8	7	9	7	9	6	9	9	7	8
Hcs-Europ	10	14	10	10	10	8	9	9	8	8	8
Hcs-Mont	3	3	3	4	4	3	4	1	1	1	2
Hcs-Paleot	4	4	3	5	4	2	4	5	6	7	7
Hsca-Euras	5	7	6	6	7	6	6	8	6	8	8
Hsca-Europ	13	14	16	15	17	19	18	26	26	24	24
Hsca-SEuro	11	11	13	9	10	12	13	8	12	13	12
Hsca-Euryme	3	4	5	6	6	0	3	2	1	4	2
Hsca-Eu-Mon	8	9	9	10	10	8	6	3	4	3	3
Hsca-End	2	1	2	1	1	6	4	6	6	5	5
Hsca-Paleot	2	2	3	3	3	4	5	5	5	4	4
Hrs-Euras	5	4	5	3	3	11	6	5	3	3	3
Hrs-Europ	11	5	3	3	2	1	2	1	1	1	0
Hrs-circub	7	0	1	0	1	0	0	4	5	4	5
Chsuf-Eur	2	3	2	2	2	0	0	0	1	1	1
Chsuf-Seur	3	2	3	3	3	1	1	3	2	2	3
Chsuf-Eu-Mon	3	3	4	4	3	3	3	1	1	1	1
Chrpt-Euryme	1	1	1	2	2	2	2	2	2	1	2
Grhiz-SEurop	4	4	4	3	3	5	5	4	4	4	3

dent as it appears by using the species (PARENTE *et alii*, 1985). This proves that, in the present case, the fertilization has greater effects on the structure and on the chorology of vegetation than the type of grazing. The differences between the effects of different grazing become evident if the matrix c) is considered, i.e. the combination structure-chorology. In this case the similarity of the sections grazed by sheep (PK and NPK) and those grazed by cattle (PK and NPK) is evident in the ordination scattergram and in the dendrogram. This shows a clear cluster of the sections of 1980, to which the cluster of unfertilized sections of 1984 (TC84 and TS84) is linked, and a clear cluster of sections of 1984, with two subclusters , one with NPKC and PKC (grazed by cattle), and the other with NPKS and PKS (grazed by sheep).

If we consider the classification of the structural variables (matrix a) they result arranged in three clear clusters:

1) Caespitose hemicryptophytes, fruticose chamaephytes. These are life-growth forms which show a certain stability.

2) Semi-woody chaemaephytes (suffrutticose chamaephytes), bulbous geophytes, rhizome geophytes. These show a clear decrement in the fertilized sections

3) Scapose hemicryptophytes, reptant hemicryptophytes, biennial hemicryptophytes, reptant chamaephytes, rosulate hemicryptophytes. These show an evident increment in the fertilized sections. The classification of the chorological elements presents only two clear clusters:

1) Eurasiatic, Paleotemperate, Cosmopolitan, Circumboreal, European, Endemic (only Phyteuma scheuchzeri). These chorological elements show a clear increment in the fertilized sections.

2) South-European, Euro-American, Eurymediterranean, Illyrian, Submediterranean, European-Montane. Among these the first is stable, the others show a clear decrement.

The classification of the combinations (matrix c) presents five main clusters:

1) This includes only the Eurasiatic caespitose hemicryptophytes, which show a certain increment in the section grazed by sheep.

2) This presents two well separated subclusters:

2a) Paleotemperate caespitose hemicryptophytes, Euroasiatic scapose hemicryptophytes. These show an increment only in the fertilized sections and a relative stability in the unfertilized ones.

2b) European scapose hemycryptophytes, Endemic scapose hemicryptophytes, Paleotemperate scapose hemicryptophytes, Eurymediterranean, reptant chamaephytes. The first three combinations show a clear increment, the last combination only a very little one.

3) Circumboreal rosulate hemicryptophytes, S-European semi-woody chamaephytes. These show an increment in the fertilized sections, the first one more evidently then the last one.

4) European caespitose hemicryptophytes, European semi-woody chamaephytes, Eurymediterranean scapose hemicryptophytes, European montane caespitose hemicryptophytes, European montane semi-woody chamaephytes, European rosulate hemicryptophytes.

These show a clear decrement.

5) S-European scapose hemicryptophytes, Eurasiatic reptant hemicryptophytes, S-European rhizome geophytes. These show an increment in the unfertilized sections.

DISCUSSION

The scapose hemicryptophytes were the most abundant life-growth form in the pasture at the beginning of the grazing. They are still the most abundant after five years showing an increment in the fertilized sections and a certain stability in the unfertilized ones. However the analysis of the combinations (matrix c)) proves that not all of them behave in the same way. A remarkable increment is due mainly to European species which compensate the decrement due to Eurymediterranean and European montane species.

The caespitose hemicryptophytes are the second life-growth form in terms of importance. These life-growth forms show a certain stability: the decrement of European montane species is made up for by the increment of paleotemperate. If we consider the life-growth form spectra and the chorological differences between the sections of 1980, the fertilized sections of 1984, and the unfertilized ones of 1984, are greater than the structural differences. The ratio: between sum of squares/within sum of squares, for the dendrogram based on life-growth form is 8.007, while it is 22.120 for the dendrogram based on chorological elements. Floristic variation associated with fertilization and grazing have smaller effects on the proportions between life-growth form, than on the proportion between chorological elements. On the average, we can say that fertilization and grazing have incremented the quantity of species of large ranges and cooler regions (Eurasiatic, Circumboreal, Cosmopolitan, Paleotemperate) and have depressed species of smaller ranges and warmer regions (S-European, Eurymediterranean, European montane, Illyrian). The structural variation can be characterized by a general decrement of diversity mainly due to the substantial increment of European scapose hemicryptophytes, but also by a decrement of semi-woody chamaephytes and bulbous and rhizome geophytes.

SUMMARY

The structural and chorological analysis of the vegetation of a pasture of NE Italian Alps has proved that agronomic treatment used have more effect on the chorology of the vegetation than on its structure. On the average the fertilization and grazing have produced an increment of species of large ranges and cooler regions and a depression of the species of smaller ranges and warmer regions.

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A MATRIX MODEL OF POPULATION GROWT OF A TROPICAL RAIN FOREST DOMINANT SPECIES, *VATICA HAINANENSIS*, IN HAINAN ISLAND

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Key words: Hainan Island; Tropical rain forest; Matrix model; Dominant latent root; Stable stage distribution.

INTRODUCTION

Vatica hainanensis (*V. astrotricha*), a dominant species and a valuable hardwood of tropical rain forests in Hainan Island, China, is extensively distributed in the southeast, southcentre, and southwest below 1,000 m a. s.i. and along the southeastern coast of the island (CHANG HONGTA 1963, HU YUJIA 1983, WANG LANZHOU 1985). In this paper a matrix model of the population growth of *V. hainanensis* is developed by testing data and the Lefkovitch matrix. Possible changes on the dynamics of the population growth are simulated with the model, so that it can provide information for protecting tropical vegetation and for forest management.

LIFE TABLE

A life table (Table 1) for *V. hainanensis* is tabulated, based on the results collected in a study plot (2,000 m²) on Bawany Ridge in Hainan Island from November 1982 to October 1983. In the table, thirteen unequal stages ranging from seeds to trees >60 cm d.b.h. are used to represent the life cycle of *V. hainanensis*.

In the table, the seed (stage 1) data are estimated from five trees (15-18 cm d.b.h.) from a ground survey of seeds in the crown of the trees. The total estimated seed input (on 2,000 m²) is multiplied by the total seeds and seed mortality rate to obtain the number of live seeds. Since all viable seeds germinate, the proportion moving up to the seedling class is 1.00. For stages 2 through 15, the total number of individuals was investigated on November 1982 and the number of live individuals was investigated on October 1983 in a 2,000 m² plot. The growth rates are all based on the study of marked individuals in the plot of the undisturbed forest. For use in the model, it is assumed that the proportion of individuals moving to the next stage consists of those individuals that are promoted into the next stage when the average annual growth increment for their size class is added to their actual height or diameter. For example, of the 96 living individuals in stage 3, only 26 are between 51 and 80 cm tall, thus the proportion is 0.27 moving to stage 4. The proportion remaining is simply the remainder since no mortality enters into these calculations. The proportional seed input values are estimated from the record of mature seed trees in the plot. The number of seeds per adult in each stage is calculated by multiplying the total seed input by the proportion of total seed input and then dividing by the number of individuals in that stage.

INITIAL MATRIX

According to LEFKOVITCH's (1965) description of the population model, Nt+1= MNt is for unequal stage groupings in the life cycle of an organism. The 13 stages in the life cycle of *V. hainanensis* are represented in the model by the matrix:

$$M = \begin{matrix} M_{1,1} & M_{1,2} & M_{1,3} & M_{1,13} \\ M_{2,1} & M_{2,2} & M_{2,3} & M_{2,13} \\ M_{3,1} & M_{3,2} & M_{3,3} & M_{3,13} \\ \vdots & \vdots & \vdots & \vdots \\ M_{13,1} & M_{14,2} & M_{13,3} & M_{13,13} \end{matrix}$$

where Mi, j is the contribution of stage j (j =1,2,3,...13) to stage i (i= 1,2,3,...13). Data from the life table (Table 1) are used to calculate the coefficients of the initial matrix for *v. hainanensis* (Table 2). The M1,1 coefficient comes from two sources, both of which egual zero: (1) the number of seeds produced by an individual in stage 1 (for example, seeds do not produce seeds); and (2) the proportion of individuals that remain in that stage. Stage 2 through 8 do not produce seeds, so coefficients M1,2 through M1,8 are also zero. Coefficients M1,9 to M1,13 are the number of seeds produced by each adult the respective stages (Table 1, line 9). The diagonal coefficients (where i = j, for example M2,2, M3,3,... M13,13) are the proportion of individuals remaining in stage j (Table 1', line 7) multiplied by the survival rate of stage j (Table 1, line 3). The subdiagonal coefficients (where i = j+1, for example, M2,1, M3,2,... M13,12) are the proportion of individuals that move up into stage j+1 from stage (Table 1, line 6) multiplied by the survival rate of stage j (Table 1, line 3). Except on the diagonal and subdiagonal, all the coefficients in rows 2 to 13 of the initial matrix are zero because a *V. hainanensis* individual does not regress a stage (for example, M2,3 = 0, indicates an individual goes from stage 3 to stage 2) nor does it pass through two stages in one year (for example, M3,1 = 0 indicates an individual moves from stage 1 to stage 3).

DOMINANT LATENT ROOT AND STABLE STAGE

Distribution

Of the several methods available, exponentials of the initial matrix were used to determine the dominant latent root. A program was written to obtain the dominant latent root of the initial matrix on the Apple II computer. The computation shows that, when the initial matrix is raised to the 128th power, the dominant latent root for the initial matrix of *V. hainanensis* is 1.0004, which is remarkably close to the theoretical value of 1.0 for population stability. So far, three other estimates of the dominant latent root for plant populations have been published: BOSCH's (1971) erroneous value of 12.87 for redwoods, a value of 1.204 given by USHER (1966) for a managed Scot's pine forest in England and a value of 1.002 given by HARTSHORN (1975) for *Pentaclethra macroloba* in Costa Rica.

However, the dominant latent root only indicates whether the population is increasing, remaining the same, or decreasing in size (number), but it gives no information on the distribution or stability of individuals in the defined size classes. By multiplying the stable matrix by the initial stage distribution, we see that the stable stage distribution of individuals for the actual (initial) and for the predicted (stable) population is very similar (Table 3). Both the dominant latent root and stable stage distribution are very strong evidence for the stable climax status of this *V. hainanensis* population.

POPULATION GROWTH SIMULATION

The effect of changes on the survival rate of the population can also be simulated with the model by simply changing one or more coefficients of the initial matrix and calculating the dominant latent root for the new initial matrix. The dominant latent root from the simulation run can then be compared to the dominant latent root of the original initial matrix. This comparison is a sensitivity analysis for the population.

Table 1 — Life table for *Vatica hainanensis* on study plot (2000 m^2) Bawang Ridge in Hainan Island, from November 1982 - October 1983.

Stage number	1	2	3	4	5	6	7	8	9	10	11	12	13
Height (cm)		<15	15-50	50-80	80-150	>150							
Diameter (cm)	seeds					<5	5-10	10-15	15-20	20-30	30-40	40-60	>60
Total individuaals	9104	1087	189	151	43	18	28	21	16	16	6	3	3
Number of live individuals	1639	136	96	79	31	16	27	20	16	15	6	3	3
Survival rate	0.18	0.125	0.509	0.56	0.71	0.89	0.95	0.96	0.97*	0.94	0.99*	0.75*	0.75*
Mortality	0.82	0.875	0.491	0.474	0.29	0.11	0.05	0.04	0.03*	0.06	0.01*	0.25*	0.25*
Growt rate (cm)	- -	9.6	18.7	30.8	31.7	0.12	0.32	0.36	0.35	0.32	0.27	0.22	0.22
Proportion moving up to next class	1.0	0.97	0.27	0.35	0.43	0.20	0.25	0.09	0.187	0.06	0.04*	0.01*	0
Proprotion remaning in size class	0	0.03	0.73	0.65	0.57	0.80	0.75	0.91	0.813	0.94	0.96*	0.99*	1.0
Proportion of total seed input	0	0	0	0	0	0	0	0	0.157	0.314	0.176	0.147	0.206
Number of seeds per adult	0	0	0	0	0	0	0	0	89	178	267	446	625

* indicates interpolated values

Table 2 — Initial matrix for *Vatica hainanensis*

0	0	0	0	0	0	0	0	178	267	446	625
0.18	0.004	0	0	0	0	0	0	0	0	0	0
0	0.121	0.372	0	0	0	0	0	0	0	0	0
0	0	0.137	0.342	0	0	0	0	0	0	0	0
0	0	0	0.184	0.404	0	0	0	0	0	0	0
0	0	0	0	0.3	0.712	0	0	0	0	0	0
0	0	0	0	0	0.178	0.713	0	0	0	0	0
0	0	0	0	0	0	0.234	0.874	0	0	0	0
0	0	0	0	0	0	0.086	0.789	0	0	0	0
0	0	0	0	0	0	0	0.18	0.88	0	0	0
0	0	0	0	0	0	0	0	0.056	0.95	0	0
0	0	0	0	0	0	0	0	0	0.04	0.75	0
0	0	0	0	0	0	0	0	0	0	0.007	0.75

Comparisons of this sort are very useful for testing hypotheses and making predictions. The changes made in the initial matrix and the dominant latent root, resulting from the changes, are given in Table 4 for many simulation runs. This sensitivity analysis shows that the seed stage (stage 1) and old tree stages (stages 12 and 13) are less sensitive to a 50% reduction in survival, with the smallest reduction in the dominant latent root. The dominant latent roots of these stages are 0.9872, 0.9993 and 1.0001, respectively (see Table 4, lines 2, 14, 15). We could conclude from this analysis that the population would still be stable when seeds are picked or old trees are cut. The most sensitive stage of *V. hainanensis* to a 50% reduction in survival is stage 8, the dominant latent root of this stage is 0.9635 (Table 4, line 10). Stages 9 and 10 are also guite sensitive to the same 50% reduction in survival, the dominant latent roots of these stages are 0.9705 and 0.9672, respectively (Table 4, line 11, 12). Stage 8 is the last prereproductive stage, and it is reasonable that a lowering of its survival has a strong effect on the population. The maximum reproduction and reduced survival at this stage of the li fe cycle should have a strong reproductive potential, especially in a species with a long prereproductive period. The sensitivity of stages 8 to 10 to reduced survival is probably accentuated by the very slow movement of individuals through these stages. We could conclude from these analyses that if we protected the vegetation, we should protect these dominant trees with their maximum reproductive potential. The greatest reductions in dominant latent roots occurred, when survival in all stages (1 to 13) were reduced by 10% and 50%. Their respective dominant latent roots became 0.9031 and 0.0 (Table 4, line 16, 17) the latter suggesting population extinction.

Table 3 - Comparison of the initial stage distribution with the stable stage distribution for *Vatica hainanensis.*

Stage Number	Initial Stage	Distribution	Stable Stage	Distribution
1	9,104	85.21	10,398	80.87
2	1,087	10.18	1,879	14.62
3	189	1.77	362	2.82
4	151	1.42	76	0.59
5	43	0.41	24	0.19
6	18	0.17	25	0.20
7	28	0.27	15	0.12
8	21	0.20	28	0.22
9	16	0.15	12	0.10
10	16	0.15	17	0.14
11	6	0.06	19	0.15
12	3	0.03	3	0.03
13	3	0.03	1	0.01
Total	10,685	100.05	12,859	100.06

DISCUSSION

The Lefkovitch's matrix model described in this paper has been successfully used to describe the population dynamics of the tropical rain forest dominant species *V. hainanensis* in Hainan Island, China. This study shows that the matrix model should be applicable essentially to any plant population if only morphological characteristics of the population can be distinguished in the life cycle of the plant.

This model should be very useful for determining the successional or sociologic status of a population. A successional population should have a dominant latent root considerably greater than 1.0 until the canopy closes at which time the dominant latent root should drop below 1.0. Late successional species should have a dominant latent root initially between those of early successional and climax species.

The dominant latent root for the initial matrix of *V. hainanensis* is 1.0004 by computing, which is remarkably close to the theoretical value of 1.0 for population stability. Both the dominant latent root and stable stage distribution indicate that *V. hainanensis* is a stable climax population. Simulated changes in the model for population growth show that the seed stage and old-age tree stage are less sensitive to disturbance but the tree stage for maximum reproductive potential is the most sensitive to disturbance in the population life cycle.

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Table 4 — Dominant latent roots resulting from simulated changes in Survival of *Vatica hainanensis* population.

	Change Mode in the Initial Matrix			
Stage Number	Coefficient	Old	New Values	Dominant Latent Root (for X 128)
None	Base run			1.0004
1	$M_{2,1}$	0.18	0.09	0.9872
1	$M_{2,1}$	0.18	0.009	0.9590
	$M_{2,2}$	0.004	0.002	
2				0.9870
	$M_{3,2}$	0.12	0.06	
	$M_{3,3}$	0.372	0.186	
3				0.9828
	$M_{4,3}$	0.137	0.069	
	$M_{4,4}$	0.342	0.171	
4				0.9831
	$M_{5,4}$	0.184	0.092	
	$M_{5,5}$	0.404	0.202	
5				0.9821
	$M_{6,5}$	0.30	0.15	
	$M_{6,6}$	0.712	0.356	
6				0.9738
	$M_{7,6}$	0.178	0.089	
	$M_{7,7}$	0.713	0.357	
7				0.9738
	$M_{8,7}$	0.234	0.117	
	$M_{8,8}$	0.874	0.437	
8				0.9635
	$M_{9,8}$	0.086	0.043	
	$M_{9,9}$	0.789	0.395	
9				0.9705
	$M_{10,9}$	0.18	0.09	
	$M_{10,10}$	0.88	0.44	
10				0.9672
	$M_{11,10}$	0.056	0.028	
	$M_{11,11}$	0.95	0.475	
11				0.9780
	$M_{12,11}$	0.04	0.02	
	$M_{12,12}$	0.75	0.75	
12				0.9993
	$M_{13,12}$	0.007	0.00035	
13	13,13	0.75	0.375	1.0001
1 - 13	10% reduction of all coefficients			0.9031
1 - 15	50% reduction of all coefficients			<0.0

DISTRIBUTION PATTERNS OF VEGETATION IN RELATION TO MICRO-SCALE GEOMORPHIC UNITS ON SLOPES

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Keywords: Mountain vegetation, Japanese vegetation, Vegetation patterns.

The ground surface of an area consists of many kinds of slopes which can be distinguished as being of various scales. For example, a slope of a hillside as a detailed-scale geomorphic unit can be divided into several micro-scale gemorphic units such as a crest slope, a side slope, a head hollow, a head floor, a channel way, etc. (TAMURA, 1969, 1974). Such units possess their own properties as habitats for plants. Consequently, a plant community on a hillside varies in its species composition from place to place, or is partly replaced by other types of communities. Vegetation consists of such variants of plant communities.

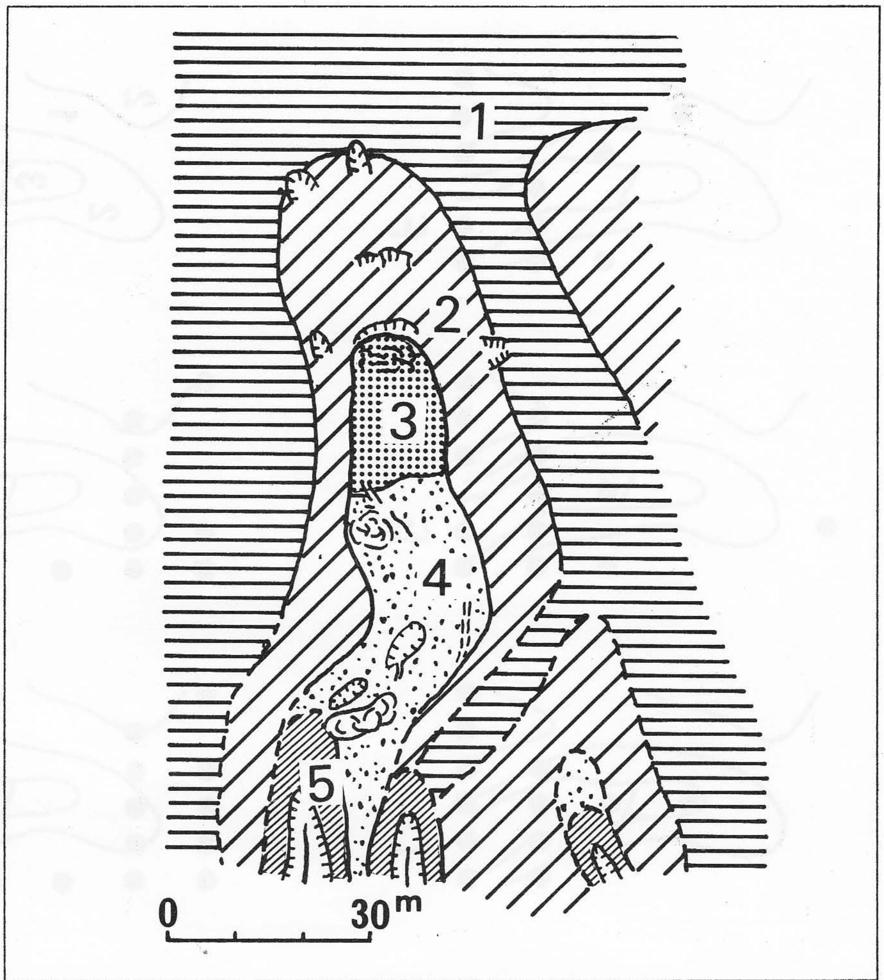

Fig. 1 — Micro-scale geomorphic map of a valley head on a hillside near Sendai (partially modified from MIURA & KIKUCHI 1978). 1: crest slope, 2: side slope, 3: head hollow, 4: head floor, 5: channel way.

EVIDENCE OF MICRO-SCALE DISTRIBUTION OF PLANTS RELATED TO GEOMORPHOLOGY

The micro-scale geomorphic units mentioned above comprise a valley head where a stream starts. Such valley heads are arranged side by side on a slope which is described overall as a detailed-scale geomorphic unit (TAMURA, 1980, 1981). Fig. 1 shows an example of such an arrangement of micro-scale geomorphic units in and around a valley head on a hillside in Sendai, Northeast Japan. The hillside investigated was covered by vegetation where *Abies firma* and several deciduous trees such as *Fagus japonica*, *Carpinus tschonoskii*, etc. were prominent. According to the analysis of inter-specific association by means of qui-square-test, two groups of undergrowth exhibited significant negative association; one group consisted of *Leptogramma mollissima*, *Salvia omerocalyx*, *Spuriopimpinella calycina*, *Chamaele decumbens*, *Ainsliaea acerifolia* and *Phyryma leptostachya*, and the other one of *Carex lasiolepis*, *Solidago virga-aurea* var. *asiatica* and *Cymbidium goeringii*. Fig. 2 shows that the former group was distributed thoughout the head hollow, the head floor and the side slope, while the latter was found only on the crest slope. In addition, *Carex conica* and *Ainsliaea apiculata* were found on both the crest slope and the side slope. Thus, some plants selected certain micro-scale geomorphic units as their habitats (MIURA & KIKUCHI, 1978).

MICRO-SCALE GEOMORPHIC UNITS DISTINGUISHED FOR THE PRESENT ANALYSIS

Streams can be classified as first-order streams, second-order streams, etc. (HORTON 1945, STRAHLER 1952, 1957). Likewise, ridges can be assigned orders as follows: first-order ridges are those which have no branches, second-order ridges are those which only branch off the first-order ridges, third-order ridges are those which branch off the first- or second-order ridges, etc. A crest slope is located on each of these various-order ridges. The sideward crest slopes of a valley head (see Fig. 1) are examples of such slopes found on first-order ridges. On the other hand, upward crest slopes of valley heads occur on second- or higher-order ridges. Their properties as habitas are expected to be different.

The terminal part of a first-order ridge was distinguished as a micro-scale geomorphic unit and was called "nose end" based on the nomenclature of HACK and GOODLET (1960). Other micro-scale geomorphic units were distinguished according to TAMURA (1969, 1974), and MIURA and KIKUCHI (1978). Moreover, a unit consisting of a gentle slope was found at the foot of a hillside. As a result, micro-scale geomorphic units such as crest slopes on first-, second- and third-order ridges, side slopes, head hollows, head floors, channel ways, nose ends and foot slopes, were distinguished on a hillside as detailed-scale geomorphic units (Fig. 3). The area of these units was usually 10^1 to 10^3 m^2.

DISTRIBUTION OF PLANT COMMUNITIES CORRESPONDING TO MICRO-SCALE GEOMORPHIC UNITS

A vegetation survey was carried out at sample plots, each of them set within a micro-scale geomorphic units. The *Quercus serrata* seminatural forest was prominent throughout the area studied near Sendai. All stands examined at the sample plots were ordered on an axis based on stand-to-stand floristic simila-

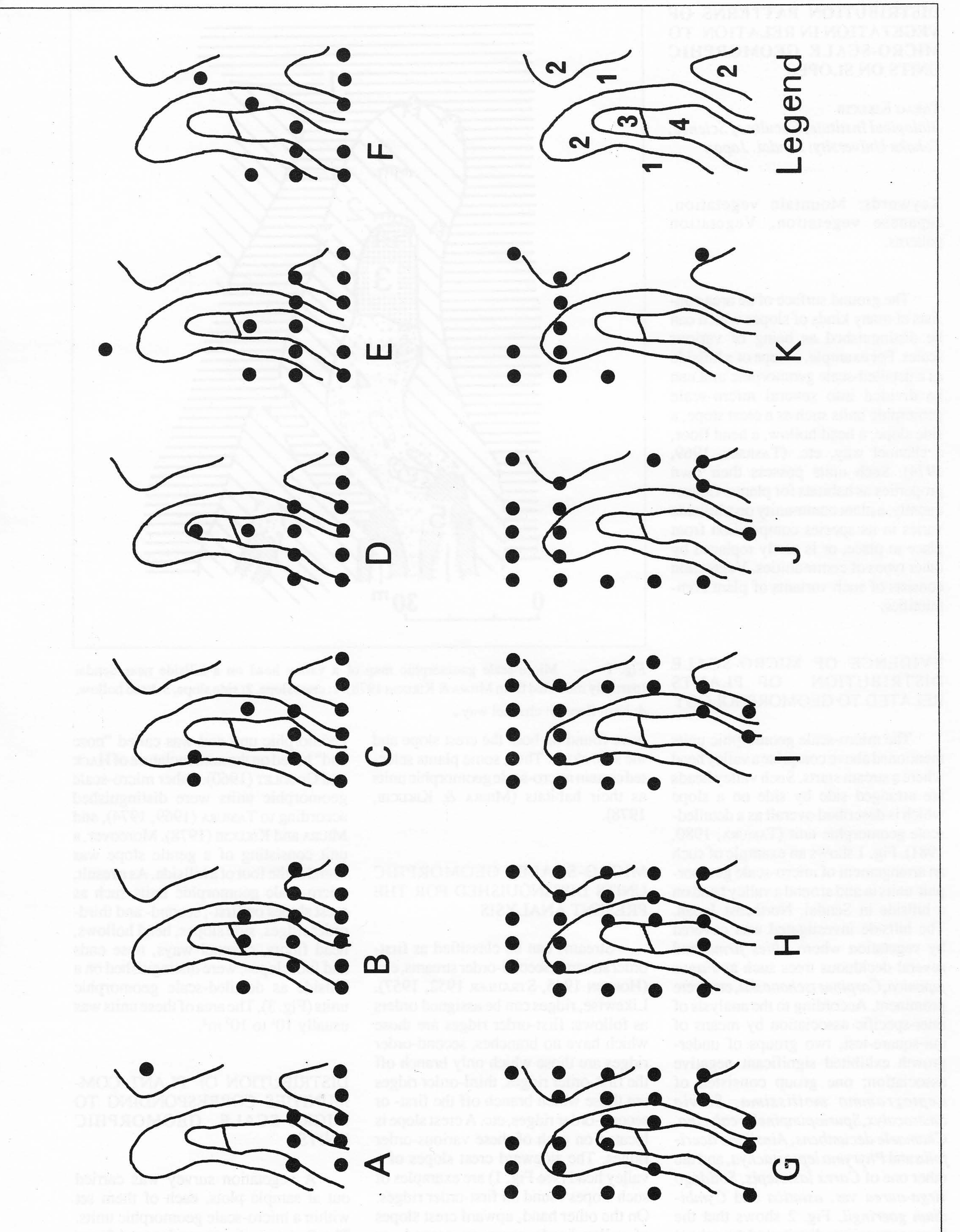

Fig. 2 — Distribution patterns of some undergrowth of an *Abies firma-Fagus japonica* forest in relation to micro-scale geomorphic units. A: *Leptogramma mollissima*, B: *Salvia omerocalyx*, C: *Spuriopimpinella calycina*, D: *Chamaele decumbens*, E: *Ainsliaea acerifolia*, F: *Phryma leptostachya*, G: *Carex conica*, H: *Ainsliaea apiculata*, I: *Carex lasiolepis*, J: *Solidago virga-aurea* var. *asiatica*, K: *Cymbidium goeringii*. 1: crest slope, 2: side slope, 3: head hollow, 4: head floor.

rity (BRAY and CURTIS 1957) measured by means of Jaccard's coefficient. The stands ordered on the axis progressively varied in their floristic composition along the axis. Fig. 4 shows the floristic variation corresponding to a sequence of micro-scale geomorphic units. The stands on third-order crest slopes were located near an end point of the axis. These stands were characterized by *Pinus densiflora* which at times dominated the sites. On the other hand, the stands on the head floor were located near the other end point of the axis. They were characterized by a lack of crown layer. Subtrees and many of the common shrubs were also lacking there except for *Aucuba japonica*, *Pleioblastus chino*, *Viburnum dilatatum*, and some others. All other stands dominated by *Quercus serrata* were located between the positions of these stand groups on the axis. Among those *Quercus serrata* stands, the range of stands on the foot slope partially overlapped the range of the head floor stands on the axis. They possessed no luxuriant subtree layer.

Thus, a hillside as detailed-scale geomorphic units was divided into four habitats; each of them was characterized by micro-scale geomorphic units and vegetation of its own. As a result, there was a micro-scale distribution pattern of plant communities corresponding to the miro-scale geomorphic composition on a slope.

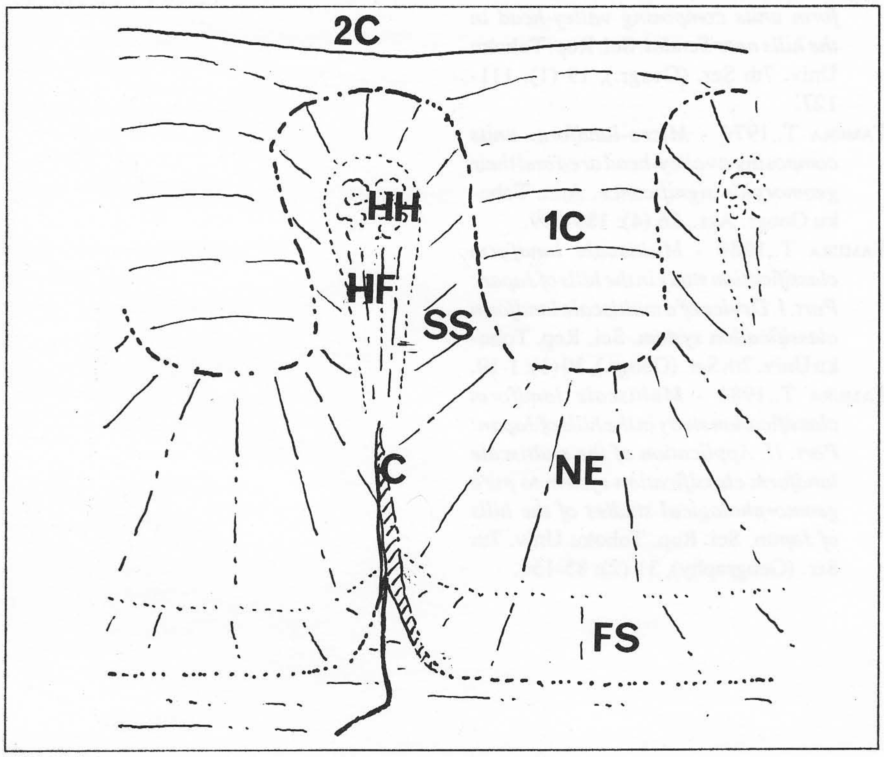

Fig. 3 — Block diagram showing micro-scale geomorphic units comprising a hillside as a detailed-scale geomorphic unit. 1C: first-order crest slope, 2C: second-order crest slope, SS: side slope, HH: head hollow, HF: head floor, C: channel way, NE: nose end, FS: foot slope.

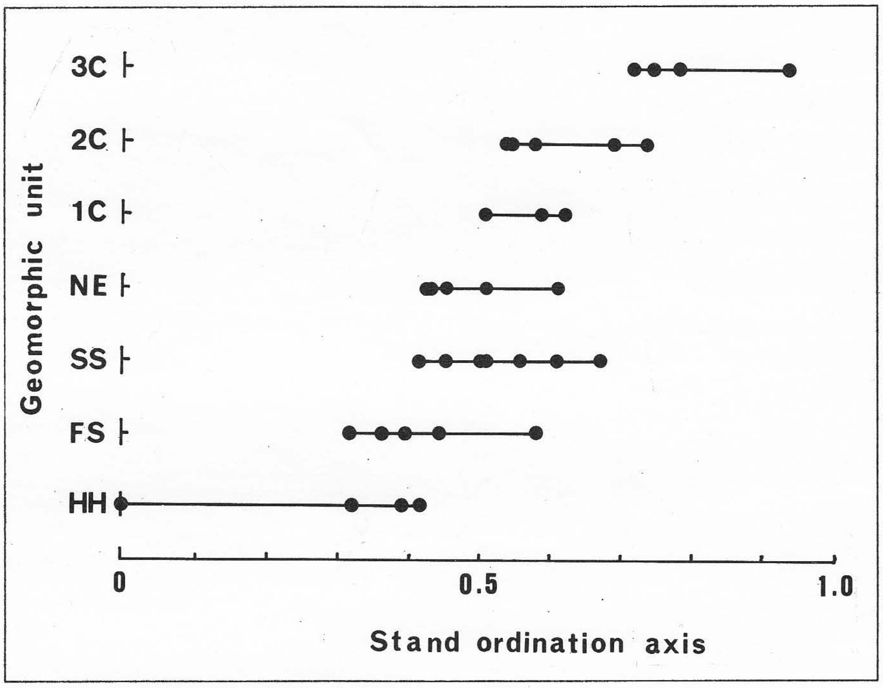

Fig. 4 — Sequence of micro-scale geomorphic units changing along with sequence of stands ordered on the axis in accordance with their floristic similarity

SUMMARY

The micro-scale distribution pattern of vegetation was examined on slopes of hillsides. A hillside as a detailed-scale geomorphic unit was divided into seven different micro-scale geomorphic units but into four habitats, each of them being characterized by certain micro-scale geomorphic units and vegetation as follows: 1) crest slopes on third-order ridges covered by *Pinus densiflora* forest, 2) crest slopes on lower-order ridges, side slopes and nose ends covered by luxuriant seminatural forest of *Quercus serrata*, 3) foot slopes coverd by *Quercus serrata* seminatural forest without the distinct subtree layer and 4) head floors covered by scrubs.

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SEED BANKS IN CLIMAX FORESTS OF JAPAN

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Keywords: Mountain vegetation, Seed banks, Forests of Japan.

ABSTRACT

Generally, the buried viable seeds in the climax forests of Japan decrease in number in proportion to the degree of latitude and elevation. The seed density of woody species clearly decrease from the warm-temperate forest to the subalpine forest. High density of seeds of woody species and rich flora of seed banks in the temperate broad-leaved forests function in the recovery of plant biomass, the rapid reculutement of seedling population, and the maintenance of community diversity. On the other hand, the poor seed bank of the subalpine conifer forest causes slow recovery after forest disturbances.

INTRODUCTION

In Japan, the climax forests still remain in mountain areas. These forests are quite valuable in East Asia where the human population is so large and man's impact on forests is intensive.

A seed bank is defined as seeds buried alive in soil in the plant growth season, producing seedlings when conditions are suitable for germination. It is contrasted with the growing plant population, and is regarded as the potential plant cenopopulation. Studing the seed banks in climax forests is quite important for understanding how many seeds are in soils as the successors of climax forests. Also, it become posible to estimate the species composition and structure of the initial plant community following a disturbance of climax forest. There are papers on the buried seeds in climax forests in which the full data of seed density on every species are listed as follows: OOSTING and HUMPHREYS (1940), OLMSTED and CURTIS (1947), KARPOV (1960), KELLMAN (1970, 1974), GUEVARA and GÓMEZ-POMPA (1972), STRICKLER and EDGERTON (1976), HAYASHI (1977), WHIPPLE (1978), NAKAGOSHI (1981, 1984a, 1984b, 1985b), PETROV (1981), PETROV and PALKINA (1983), GRANSTRÖM (1982), and NAKA and YODA (1984).

The present study deals with the ecological features of the seed banks in several types of climax forests in Japan and their comparisons along an eco-geographical zonation. The papers on seed banks in climax forests in other regions were referred to discuss the altitudinal and latitudinal gradients of buried seed populations.

STUDY SITES

Principally, three climatic climax forest zones can be distinguished in the mainland Japan. They are warm-temperate evergreen broad-leaved forest zone (*Camellietea japonicae* MIYAWAKI et OHBA 1963), temperate deciduous broad-leaved forest zone (*Fagetea crenatae* MIYAWAKI *et alii* 1964) and subarctic or subalpine evergreen coniferous forest zone (*Vaccinio-Piceetea* BR.-BL. 1939). In addition, there are climax conifer forests on the steep slopes of mountains between the warm-temperate zone and the temperate zone. Following 8 stands of climax forests in Japan were selected for study the buried seed populations in soils (Fig. 1).

1. *Castanopsis cuspidata* forest (*Ardisio-Castanopsietum sieboldii* Suz.-Tok. 1952) located at Moto-ujina in Hiroshima City (40 m in altitude, 34°19'N lat., 132°29'E long.) surrounded by Hiroshima Bay.

2. *Castanopsis cuspidata* var. *sieboldii* forest (*Photinio-Castanopsietum cuspidatae* NAKANISHI *et alii* 1977) on Mt. Futatabi in Kobe City (350 m alt., 34° 43' N lat., 135° 11' E long.) as the protected forest of the Tairyu-ji temple surrounded by the old-growth *Pinus densiflora* forest.

3. *Abies firma* forest (*Ilicio-Abietum firmae* Suz.-Tok. 1961) on the foot of Mt. Misen in Miyajima Island (20, 90 m alts., 34° 16' N lat., 132° 19' E long.). Two plots investigated locate in the Forest Reserve as the Misen primary forest and in the *Camellietea japonicae* zone.

4. *Tsuga sieboldii* forest (*Ilici-Tsugetum sieboldii* HORIKAWA et SASAKI 1959) near the top of Mt. Misen in Miyajima Island (430, 470 m alts., 34° 16' N lat., 132° 20' E long.). Two plots also locate in the same area as the *Abies firma* forest and were identified an association in the *Fagetea crenatae*.

5. *Fagus crenata* forest (*Lindero umbellatae-Fagetum crenatae* SASAKI 1970) subordinated as the typical type (NAKAGOSHI, 1984b) on the slope of Mt. Hiba in Chugoku district of SW Japan (1,180 m alt., 35° 04' N lat., 133° 04' E long.). This site is in the the wide forest reserve.

6. *Fagus crenata* forest (*Lindero umbellatae-Fagetum crenatae*) subordinated as the *Dryopteris austriaca* type (NAKAGOSHI, 1984b) in the humid hol-

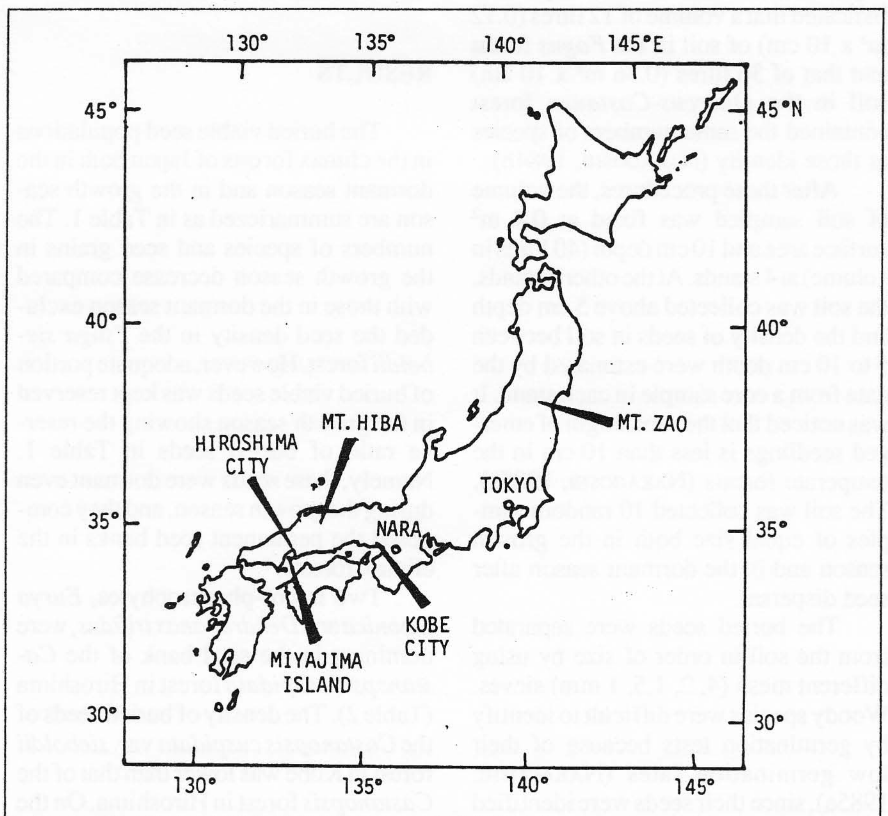

Fig. 1 — Map showing the study sites in this paper and two sites of the other reports on the seed banks in the *Castanopsis* forests (Nara and Tokyo).

low on Mt. Hiba (1,250 m alt., 35° 04' N, 133° 04' E long.) continuously covered with forest vegetation.

7. *Abies mariesii* forest (*Abietum mariesii* Suz.-Tok. 1954) with moss type floor on the middle part of long slope of Mt. Zao in Tohoku district of NE Japan (1,380 m alt., 38° 08 'N lat., 140° 29' E long.). This forest locates in the primary conifer forest.

8. *Abies mariesii* forest (*Abietum mariesii*) with floor covered by *Sasa kuriensis* near a flat ridge on Mt. Zao (1,540 m alt., 38° 07' N lat., 140° 28' E long.).

The phytosociological identification of the investigated forests was referred to Miyawaki (1983, 1984).

METHODS

A large number of seeds were seen between 0 and 10 cm depth in the soil of the temperate broad-leaved forests of Japan (Nakagoshi, 1981, 1984b). A soil volume of 80 litres (0.8 m² surface area x10 cm depth) was collected from a *Fagus* forest and from a *Quercus-Castanea* forest respectively after the seed dispersal season. Curves relating the number of species retrieved to soil volume were constructed from increasing the number of this 80 litre sample. Comparisons of numbers of species of buried seed found and the number of species reproducing seeds in the aboveground vegetation (15 m x 15 m size quadrat) indicated that a volume of 12 litres (0.12 m² x 10 cm) of soil in the *Fagus* forest and that of 36 litres (0.36 m² x 10 cm) soil in the *Quercus-Castanea* forest contained the same numbers of species as those identity (Nakagoshi, 1984b).

After these procedures, the volume of soil sampled was fixed at 0.4 m² surface area and 10 cm depth (40 litres in volume) at 4 stands. At the other 4 stands, the soil was collected above 5 cm depth and the density of seeds in soil between 5 to 10 cm depth were estimated by the data from a core sample in each stand. It was noticed that the root length of emerged seedlings is less than 10 cm in the temperate forests (Nakagoshi, 1985a). The soil was collected 10 random samples of equal size both in the growth season and in the dormant season after seed dispersal.

The buried seeds were separated from the soil in order of size by using different mesh (4, 2, 1.5, 1 mm) sieves. Woody species were difficult to identify by germination tests because of their low germination rates (Nakagoshi, 1985a), since their seeds were identified by external morphology and their viability by the existence of an embryo or an endosperm. But some seeds were not able to identify. Tetrazolium chloride staining (TTC test) was also used with seeds whose viability was difficult to check.

In the greenhouse, germination tests were made with those seeds which went through the 1.5 or 1 mm mesh sieve. The germination tests were carried on for a period about 100 days. This is sufficient to detect almost all the buried viable seeds in a forest soil (Naka and Yoda, 1984). Although the seedlings emerged from soil, several of them were could not identify due to their immediate death.

The species occurred in seed banks were classified into 3 categories reflecting the reproductive aspects in each forest as follows:

1. seeds of the fruiting species in the forest
2. seeds of the vegetative species in the forest
3. seeds of species not presently growing in the forest.

Nomenclature follows Ohwi and Kitagawa (1983). The life (dormancy) forms of species were mainly applied for Raunkiaer's system (1934) as following abbreviation:

MM:	meso- and mega-phanerophytes
ML:	micro-phanerophytes liana
N:	nano-phanerophytes
Ch:	chamaephytes
H:	hemicryptophytes
G:	geophytes (cryptophytes)
Th:	therophytes

RESULTS

The buried viable seed populations in the climax forests of Japan both in the dormant season and in the growth season are summariezed as in Table 1. The numbers of species and seed grains in the growth season decrease compared with those in the dormant season excluded the seed density in the *Tsuga sieboldii* forest. However, adequate portion of buried viable seeds was kept reserved in the growth season showing the reserve ratio of buried seeds in Table 1. Namely, these seeds were dormant even during the growth season, and they composed the permanent seed banks in the climax forests.

Two micro-phanerophytes, *Eurya japonica* and *Dendropanax trifidus*, were dominant in the seed bank of the *Castanopsis cuspidata* forest in Hiroshima (Table 2). The density of buried seeds of the *Castanopsis cuspidata* var. *sieboldii* forest in Kobe was lower than that of the *Castanopsis* forest in Hiroshima. On the contrary, the number of species in seed bank of the forest in Kobe was larger than that of the forest in Hiroshima. In Kobe, the seeds of *Eurya japonica* was solely dominat in the seed bank of the *Castanopsis* forest (Table 3). The seeds of phanerophytes, *Mallotus japonicus*, *Rhus succedanea*, *Rh. trichocarpa*, *Clerodendron trichotomum*, and *Zanthoxylum schinifolium*, were reserved in soils of the *Castanopsis* forests. These species emerge from the seed deposited and grow in the substitutional community following disturbances of forests together with *Aralia elata*, *Rhus javanica*, *Rubus microphyllus* and *R. palmatus*. If there are no disturbances such as wind damage, clear cut and wildfire, these seeds are in dormant stage and never germinate. No nuts of *Castanopsis cuspidata*, *C. cuspidata* var. *sieboldii* and the evergreen *Quercus* could be observed in these climax *Castanopsis* forests in the growth season.

Totally, 11 species and 258 seeds per m² were occurred as the buried viable seeds in soil of the *Abies firma* forest situated in the warm-temperate slope of Miyajima Island (Table 4). The viable seeds of *Abies firma*, the dominant tree, could not be found in soils of either season. This might be caused by low seed production of *Abies firma* and the unsuitable environment of forest floor including browing by deer to its dispersed seeds (Nakagoshi, 1985b). On the other hand, *Cryptomeria japonica* produce seeds despite low dominance of the aboveground vegetation. *Mallotus japonicus* and *Vitis flexuosa* were detected in the seed bank, and they grow in disturbed sites, chiefly felling and fire sites. *Symplocos glauca*, *Cinnamomum camphora* and *Cleyera japonica* probably maintain their population reproducing by seeds in this *Abies firma* forest.

An annual weed, *Crassocephalum crepidioides*, widely disperses its anemochoric seeds into the climax forests of warm-temperate zone. This weed is a character species of the *Crassocephalo crepidioidis-Erechitetum hieracifoliae* Miyawaki 1967 at the open sites such as clear cut or post-fire stand.

Excluding the buried seeds of *Trochodendron aralioides*, the seed bank of the *Tsuga sieboldii* forest was quite poor in the density of seeds (Table 5). Originally, this forest grows steep slopes of a mountain, therefore, the seeds are not able to accumulate in soil such a topographic condition. *Cryptomeria japonica* and *Pieris japonica* are common species in the *Tsuga* forest and they had the permanent seed banks in soil. Although *Trochodendron aralioides* and *Chamaecyparis obtusa* are coexsistence species in the *Tsuga* forest, their seeds were accidentally classified into the species group 3 due to the location of quadrats.

Table 1 — Buried viable seed populations in soils of climax forests in Japan.

Climatic zone / Formation / Forest type	Buried viable seed populations in soil: number of species per 0.4 m² x 10cm — Dormant season	Growth season	Density of seeds per m² x 10cm — Dormant season	Growth season	Reserve ratio of buried seeds in the growt season (%)
Warm-temperate zone					
Evergreen broad-leaved forest					
1. *Castanopsis cuspidata* forest	31	15	119	591	49.7
2. *Castanopsis cuspidata* var. *sieboldii* forest	33	19	926	417	45.0
Mountanious conifer forest					
3. *Abies firma* forest*	19	11	425	258	60.6
Temperate zone					
Montanious conifer forest					
4. *Tsuga sieboldii* forest* #	24(23)	11(10)	643(623)	683 (98)	106.2 (15.7)
Deciduous broad leaved forest					
5. *Fagus crenata forest*:: typical type	26	17	940	218	23.2
6. Fagus crenata forest: *Dryopteris* type	27	13	898	350	39.0
Subartic/subalpine zone					
Evergreen conifer forest					
7 *Abies mariesii* forest: moss type	31	15	1206	358	29.7
8. *Abies mariesii* forest: Sasa type	24	11	603	257	42.6

* total of two polts
\# Figures excluded *Trochodendron aralioides* are shown in parenthesies. Location: 1. Hiroshima City (altitude 40m), 2. Kobe City (350 m), 3. and 4. Miyajima Island (20, 90 m/ 430, 470), 5 and 6. Mt. Hiba, SW Japan (1180, 1250 m), 7 and 8. Mt. Zao, NE Japan (1380, 1540 m).

Table 2 — The seed bank in soil of a *Castanopsis cuspidata* forest in Hiroshima City in the plant growth season of 1981. Explanations of species groups and life forms are shown in text.

Species group	Life form	Species	Density of buried viable seeds per m² x 10 cm depth
1	M	*Eurya japonica*	378.4
	M	*Dendropanax trifidus*	111.6
	M	*Symplocos lucida*	27.2
2	MM	*Ilex integra*	5.4
3	MM	*Rhus succedanea*	19.1
	M	*Rhus trichocarpa*	10.9
	N	*Zanthoxylum schinifolium*	8.2
	NL	*Smilax china*	8.2
	M	*Mallotus japonicus*	5.4
	M	*Aralia elata*	2.7
	ML	*Hedera rhombea*	2.7
	ML	*Akebia trifoliata*	2.7
	N	*Clerodendron trichotomum*	2.7
	N	*Pittosporum tobira*	2.7
	-	Unidentified species 1	2.7
		Total	590.7

Table 3 — The seed bank in soil of a *Castanopsis cuspidata* var. *sieboldii* forest in Kobe City in the plant growth season of 1980.

Species group	Life form	Species	Density of buried viable seeds per m² x 10 cm depth
1	M	Eurya japonica	204.2
2	MM	Prunus jamasakura	10.9
	M	Ilex pedunculosa	5.4
	M	Rhus trichocarpa	2.7
	M	Acer palmatum var. matusumurae	2.7
3	MM	Carpinus tschonoskii	46.3
	M	Mallotus japonicus	27.2
	Th	Crassocephalum crepidioides	21.8
	N	Zanthoxylum schinifoium	16.3
	N	Rubus microphyllus	13.6
	G	Phytolacca americana	13.6
	MM	Rhus succedanea	10.9
	ML	Vitis saccarifera	10.9
	H	Viola grypoceras	8.2
	M	Rhus javanica	5.4
	N	Rubus palmatus	5.4
	-	Monocotyledoneae sp.	5.4
	N	Clerodendron trichotomum	2.7
	H	Miscanthus sinensis	2.7
		Total	416.5

Table 4 — The seed bank in soil of an *Abies firma* forest (total two plots) in Miyaajima Island in the plant growt season of 1973.

Species group	Life form	Species	Density of buried viable seeds per m² x 10 cm depth
1	M	Symplocos glauca	50
	MM	Cryptomeria japonica	47.5
	MM	Cinnamonum camphora	30
	MM	Cleyera japonica	10
2	M	Ilex pedunculosa	2.5
3	Th	Crassocephalum crepidioides	70
	M	Mallotus japonicus	35
	H	Gramineae sp.	5
	M	Acer palmatum var. matsumurae	2.5
	ML	Vitis flexuosa	2.5
	-	Unidentified species 2	2.5
		Total	257.5

Table 5 — The seed bank in soil of a *Tsuga sieboldii* forest (total two plots) in Miyajima Island in the plant growth season of 1973.

Species group	Life form	Species	Density of buried viableseeds per m² x 10 cm dept
1	M	Pieris japonica	32.5
	MM	Cryptomeria japonica	10
	M	Eurya japonica	2.5
3	MM	Trochodendron aralioides	585
	MM	Chamaecyparis obtusa	17.5
	M	Rhus trichocarpa	12.5
	ML	Vitis flexuosa	7.5
	MM	Neolitsea sericea	5
	-	Unidentified species 3	5
	MM	Acer rufinerve	2.5
	-	Unidentified species 4	2.
		Total	682.5

In early spring, seedlings emerge on the floor of the *Fagus crenata* forest owing to the good thermal conditions under the open canopy. Resultingly, the reserve seeds decrease and the reserve ratio of buried seeds in the *Fagus* forests indicates lower value compared with those of the climax forests of evergreen trees (Table 1). The seeds of phanerophytes such as *Aralia elata*, *Rhus ambigua*, *Rh. javanica*, *Rh. trichocarpa*, *Rubus crataegifolius*, *R. palmatus*, germinate in low rates (NAKAGOSHI, 1985a), therefore, they composed the permanent seed banks in the growth season (Table 6). The seeds of *Cacalia nikomontana*, introduced from outside the plots under the *Fagus* canopy, were most numerous but never established seedlings. They were constantly buried in soil throughout a year. The nuts of *Fagus crenata* and *Quercus mongolica* var. *grosseserrata* were seldom buried alive in soils of the growth season.

For the density of seeds, the *Dryopteris* type forest had richer number than that of the typical type, while the seed bank in the latter type showed higher diversity in the floristic composition and in the relative seed density compared with that of the former type. But, the features of seed banks of these two types had not large difference in species diversity and in seed density in the other years (NAKAGOSHI, 1984b).

In the subalpine *Abies mariesii* forest, the viable seeds of *Abies mariesii* also did not find from soil in the growth season. The seeds of hemicryptophytes such as *Deschampsia flexuosa*, *Anaphalis margaritacea* var. *angustior*, and *Epilobium* sp. dominated in the seed bank (Table 7). The seeds of phanerophytes constituted 35% of the seed bank in the moss type forest and only 15% of that in *Sasa* type. However, *Betula ermanii* which is only a tall tree of successional species reserved its viable seeds in the climax *Abies* forests. The moss type forest in lower altitude apparently had rich seed bank compared with that of the *Sasa* type in higher altitude.

There were several species whose buried viable seeds distibuted transzonally. They were *Aralia elata*, *Rhus javanica*, *Rh. trichocarpa* and *Rubus palmatus* both in the warm-temperate zone and in the temperate zone. All of these species are the component species of the successional community at disturbed sites. The seeds of a micro-phanerophyte liana, *Rhus ambigua*, were buried in the temperate soil and in the subalpine soil.

DISCUSSION

In the same site , the buried seed contents of the secondary forests are always richer than those of the climax broad-leaved forest in the temperate zones of Japan (HAYASHI, 1977, NAKAGOSHI, 1981, 1984b). This may be caused by the large number of seeds produced by the component species in the successional communities, and the low seed production of the species under the shade stress and the unfavorable floor environments in the climax forests. Similar phenomena were reported by OOSTING and HUMPHREYS (1940) and by OLMSTED and CURTIS (1947) in the temperate forests of the United States, and by GUEVARA and GÒMEZ-POMPA (1972) in the tropical forests in Mexico. But the high density of buried seeds in the seral forest did not exist in the boreal forests of Sweden (GRANSTRÖM, 1981).

Even in the tropical rain forest, the density of buried viable seeds in soil fluctuated showing seasonality. Namely, higher (689 - 862 seeds per m²) and lower (175 - 344 seeds) densities of seed banks were observed in the period from January to May and in June to November respectively. GUEVARA and GÓMEZ-POMPA (1972) estimated that the meteorological factor such as soil temperature possibly roles this seasonal changes.

A distinct seasonal decrease in the number of species in the buried seed populations in the climax forests of Japan (Table 1). This decrease in the growth season may be ascribed to short lived seeds, damage by birds, rodents and soil animals, rotting by fungi and bacteria, chilling in the cold winter, and unsuitable conditions at the soil surface. A comparison of the densities of buried viable seeds between dormant season and the next growth season, and the emerged seedlings in the next growth season, has also proved that most of the seeds die without germination in the climax forest (NAKAGOSHI, 1985a). It must be discuss on the buried seed population in the dormant season and in the growth season separately.

For the buried seeds in the dormant season, average 1,058 seeds per m² in the *Castanopsis* forests, 919 seeds in the *Fagus* forests and 905 seeds in the subalpine *Abies* forests were counted in the climax forest soils of Japan. The mountainious conifer forests had 425 to 643 seeds per m². These densities are similar order compared with those in the climax forest of the United States: 1,181 seeds per m² in the Oak-hickory forest in North Carolina (OOSTING and HUMPHREYS, 1940), 121 and 990 seeds in the maple forests in Maine (OLMSTED and CURTIS, 1947), and 421, 1,863 and 3,447 seeds in the Pacific conifer forests in Oregon (STRICKLER and EDGERTON, 1976).

Among the seed banks of the *Castanopsis* forests in the growth season, 591 seeds per m² in the forest of Hiroshima, 417 seeds in Kobe, 2,750 seeds in Nara (NAKA and YODA, 1984) and 5,575 seeds in Tokyo (HAYASHI, 1977) were extracted as the viable seeds in soils. In the seed population of Nara, *Eurya japonica* occupied largely 1,688 seeds per m². In Tokyo, the study forest is in the urbanized area as a forest island, and the seeds of *Idesia polycarpa* (2,725 seeds per m²) were probably dispersed by birds and accumulated richly in soil. Thus, the small seeds in sap fruits of these two species play a large contribution to the density of seed banks in these *Castanopsis* forests.

The densities of seed banks in the climax forests decrease from the *Castanopsis* forests to the subalpine *Abies* forests: average 1,253 seeds per m² in the *Castanopsis* forests excluded the forest in Tokyo, 471 seeds in the mountanious conifer forests, 285 seeds in the *Fagus* forests and 308 seeds in the subalpine *Abies* forests. This tendency is clear in the seeds of fruiting species (Fig. 2). The Pasific conifer forests in British Columbia, the densities of seed banks were 206 seeds per m² (KELLMAN, 1974) and 1,016 seeds (KELLMAN, 1970). The boreal *Picea* forests (two stands over 120 years old) in Sweden had 695 seeds on average (GRANSTRÖM, 1981). The subalpine conifer forests in Colorado (ca. 3,000 m in altitude) had only 28 seeds on average (WHIPPLE, 1978). In the subarctic conifer woodlands in Northwest Territories of Canada, seed banks were absent (JOHNSON, 1975). Johnson concluded that the lack of viable seeds was caused by the short growing period (ripening condition might not be good) and its effect on germination. These data suggest that the densities of seed banks decrease in number in proportion to the degree of latitude and elevation.

In Russia, the boreal *Picea* forests contained as many as 1,300 - 5,000 seeds per m² (KARPOV, 1960) and 2,799 seeds (PETROV, 1981) in the seed banks. Moreover, the *Quercus-Tilia* forest in southern Moskow region had 6,500 seeds in soil despite in the growth season (PETROV and PALKINA, 1983). However, the dominants in these seed banks were *Deschampsia caespitosa*, *Carex* sp., *Hypericum perforatum* and *Oxalis acetosella* of small herbaceous species similar to the species in the subalpine *Abies* forest of Japan. It is still remained the problem what kind vegetations surround the investigated stand.

The maximum size of plant growing from seeds is especially siginificant to discuss the plant biomass and vegetation structure of the early stage of

Table 6 — The seed banks in soils of *Fagus crenata* forests on Mt. Hiba in the plant growth season of 1978.

Species group	Life form	Species	Density of buried viable seeds per m² x 10 cm depth	
			Typical type	Dryopteris type
1	ML	Rhus ambigua	30	132.5
	Ch	Rubus pectinellus	-	35
	N	Lindera umbellata	10	5
	M	Acanthopanax sciadophylloides	5	-
	N	Symplocos coreana	2.5	-
2	MM	Taxus cuspidata	-	2.5
3	G	Cacalia nikomontana	77.5	152.5
	N	Rubus palmatus	57.5	-
	M	Prunus grayana	5	2.5
	N	Rubus crataegifolius	5	2.5
	M	Rhus trichocarpa	2.5	2.5
	M	Aralia elata	2.5	2.5
	M	Rhus javanica	5	-
	H	Viola grypoceras	-	5
	MM	Carpinus tschonoskii	2.5	-
	MM	Kalopanax pictus	2.5	-
	MM	Magnolia obovata	2.5	-
	M	Cornus kousa	2.5	-
	N	Meliosma tenuis	2.5	-
	N	Ligustrum tschonoskii	2.5	-
	M	Ilex macropoda	-	2.5
	ML	Actinidia arguta	-	2.5
	G	Viola vaginata	-	2.5
		Total	217.5	350

Table 7 — The seed banks in soils of *Abies mariesii* forests on Mt. Zao in the plant growth season of 1979.

Species group	Life form	Species	Density of buried viable seeds per m² x 10 cm depth	
			Moss type	Sasa type
1	N	Ilex sugerokii var. brevipedunculata	29.5	6.9
	H	Viola selkirkii	18.4	-
	N	Vaccinium sp.	11.1	-
	G	Streptopus streptopoides var. japonicus	11.1	-
	M	Sorbus commixta	7.4	-
	M	Viburnum furcatum	3.7	-
	N	Prunus nipponica	3.7	-
	G	Clintonia udensis	-	3.4
2	N	Hydrangea paniculata	22.1	20.6
	N	Alnus maximowiczii	14.7	-
	MM	Taxus cuspidata	3.7	-
3	H	Deschampsia flexuosa	92.2	140.5
	H	Anaphalis margaritacea var. augustior	73.7	-
	Ch	Empetrum nigrum var. Japonicum	25.8	30.8
	H	Epilobium sp.	-	34.3
	MM	Betula ermanii	25.8	3.4
	H	Solidago virga-aureo var. leiocarpa	14.7	-
	H	Polygonum cuspidatum	-	6.9
	ML	Rhus ambigua	-	3.4
	N	Vaccinium ovalifolium	-	3.4
	-	Dicotyledoneae sp.	-	3.4
		Total	357.6	257.0

succession. The life form of species whose seeds were buried in soil, therefore, should be considered in each seed bank (RABOTNOV, 1981, NAKAGOSHI, 1985a). Figures 3 and 4 show the compositions of seed banks accoding to life form analysis.

The *Castanopsis* forests and the mountanious conifer forests had rich seed banks of tree seeds which provide seedlings when the forest canopy is removed. These seedlings rapidly grow to reconstruct a substitutional scrub for a few years (NAKAGOSHI, 1981). The seeds of therophyte are characterized the seed banks of warm-temperate forests.

The *Fagus* forests kept the seed banks consisted in micro and nano-phanerophytes, chamaephyte and geophytes. Most of the woody species seen in these seed banks can regenerate quickly in forest gaps and felling sites, namely their dormant seeds germinate and establish after the former forest has been destroyed (NAKAGOSHI, 1984b, 1985a). MARQUIS (1975) reported the similar seed bank of woody species in the maple forest in Pennsylvania. Geophytes characterize both in the vegetation (RAUNKIAER, 1934) and in the seed bank at the temperate forest.

The seeds of hemicryptophytes were dominant in the seed banks of the subalpine *Abies* forests. These small seeds are difficult to establish in the dim floor with thick coniferous litter in the *Abies* forest. The seedlings originated small seeds can hardly survive on the floor in climax forest (NAKAGOSHI, 1985a). They need to germinate the high temperature and the thin organic litter. Such a condition appears only in the case of landslide or forest fire. In these cases, few seeds remain at the disturbed soil surface. Therefore, the herbaceous seeds in the seed banks of the subalpine forests are not so significant for regeneration of plant community. Thus, the poor seed bank of woody species together with the low temperature climate may retard the succession of subalpine forests after natural and man-made disturbances.

In conclusion, these specific features of seed banks of climax forests influence the rates of regeneration or succession of forests and diversity of forest communities.

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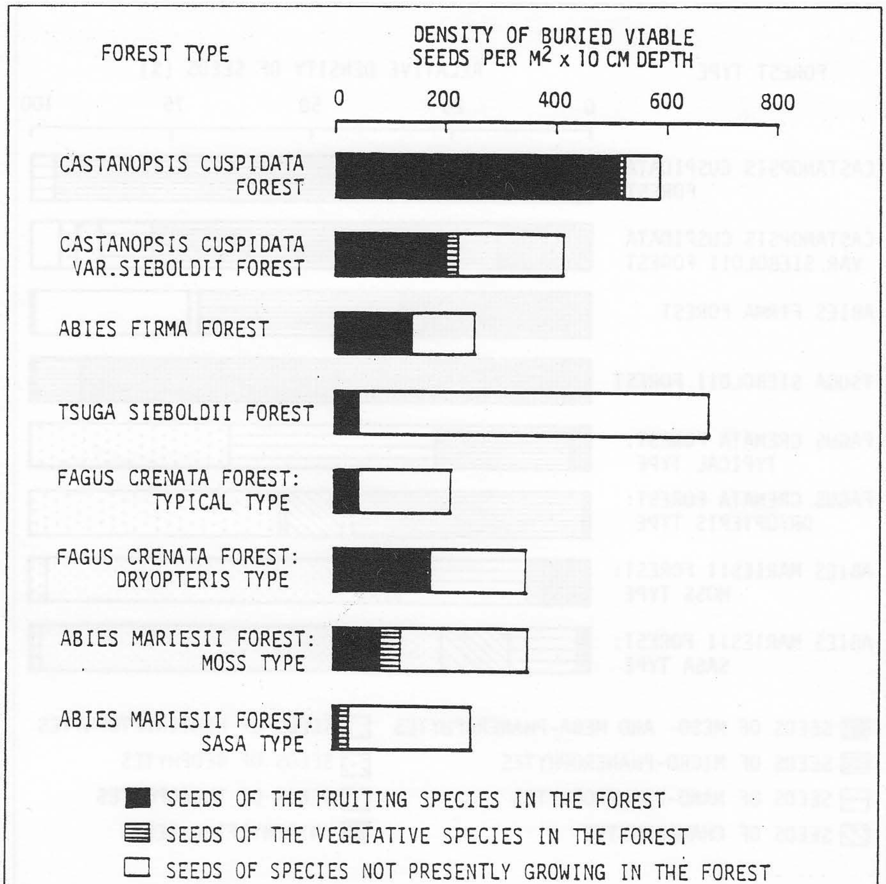

Fig. 2 — Densities of seed banks in soils of the climax forests in the plant growth season. Seeds were classified into three species group which reflect the reproductive aspect in the

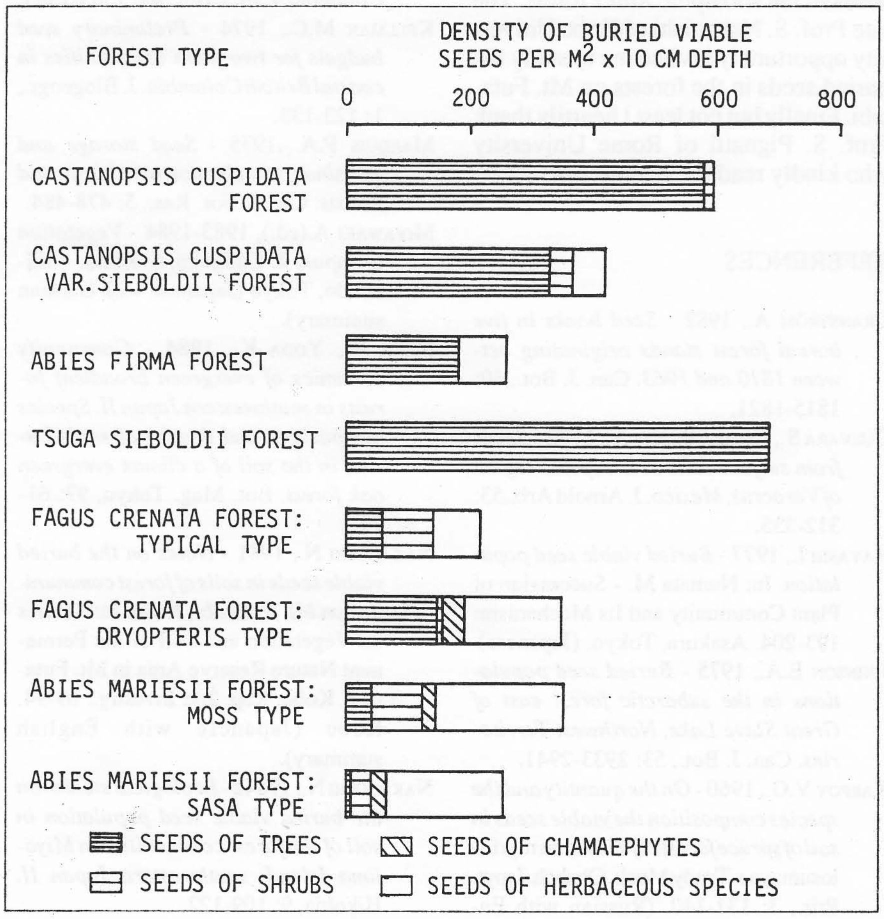

Fig. 3 — Densities of seed banks in soils of the climax forests in the plant growth season. Seeds were classified into four major life forms of parent plants.

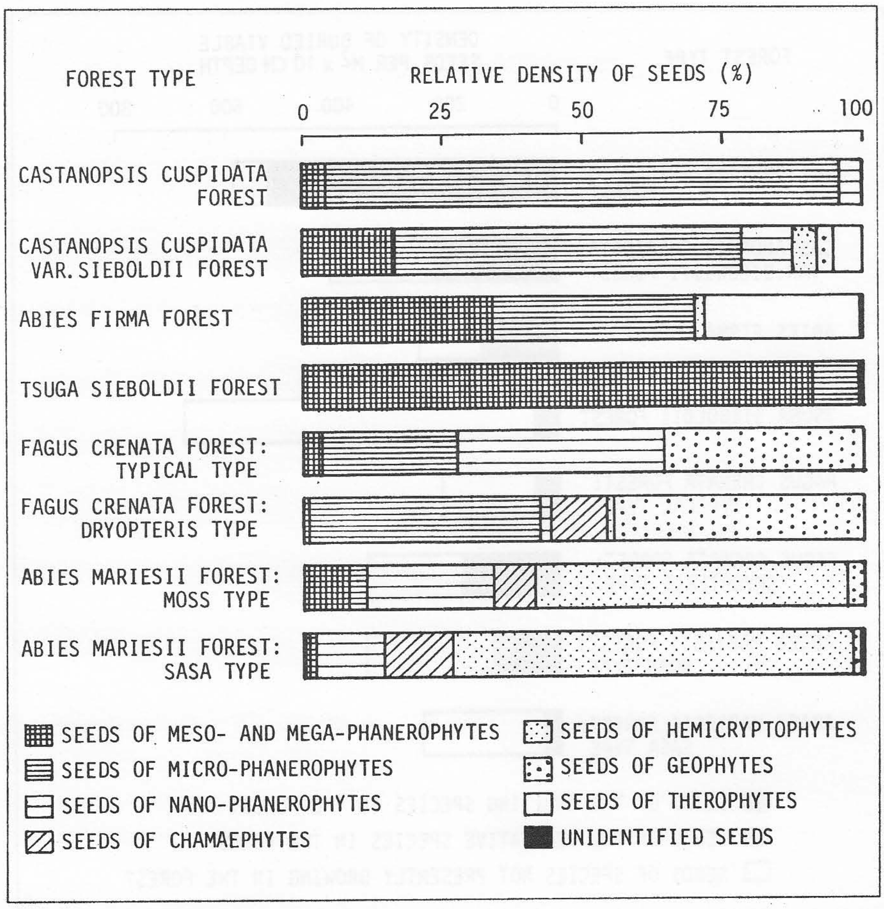

Fig. 4 — Composition of seed banks in the plant growth season according to Raunkiaer (1934)'s life form system

seeds in the subalpine *Abies* forest. The late Prof. S. Nakanishi of Kobe University opportunely invited me to study the buried seeds in the forests on Mt. Futatabi. Finally but not least I heartily thank Prof. S. Pignatti of Rome University who kindly read the manuscript.

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TRANSPLANTATION OF MOUNTAIN VEGETATION

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INTRODUCTION

Transplant.ation of plants is a common method to study impacts of the environment on various species, but is mostly used on single specimens. The "Experimental studies on the nature of species" carried out by Clausen and collaborators 30-50 years ago (for instance CLAUSEN, KECK and HIESEY, 1940) clearly showed the genetic variation between lowland and mountain races of several species. Mountain races were shown, for example, to be genetically more short-statured than lowland races of the same species.

Both morphological and ecophysiological ecotypic variations are also found within a single species at low alpine mountain regions at 62°N (in South Norway just above 1000 m a. s. l.) and close to the sea at 79°N (at Spitsbergen), probably partly because of the different day length. Transplantation between the two regions has shown, for instance, increased stomatal diffusion resistance in the mountain plants transplanted to the arctic (E. Espolin Johnson, pers. comm. 1986). One result of this is that the plants maintain a relatively high internal temperature in the harsh arctic climate (GAUSLAA, 1984). The dry matter percentage was up to 35% higher in arctic specimens than in lower latitude alpine specimens of the same species at similar phenological stages, regardless of where the plants were grown.

In ecophysiological studies like the ones mentioned, effects of competition are not studied, although these are normally very important in nature. It is, therefore, also of great interest to study transplantations of a whole vegetation mat. In old plant communities of woody plants, where the roots often penetrate large areas, such whole vegetation transplants are particularly difficult. Because of the methodological problems involved, only a few studies using this method have been carried out in mountain areas.

MATERIAL AND METHODS

The area of each vegetation mat has to be large enough to be representative for the vegetation. In a small mat the border effect is also normally very strong. The roots of many plants are cut in the transplantation. This, of course, affects growth of the. plants, particularly along the edges of the mat.

Life forms with creeping stolons and rhizomes (many singleshooted monocotyledons and matted dicotyledons with long, prostrate stems, particularly woody species), will be more disturbed than life forms with fibrous roots or tap roots. The vegetation mat transplantation method is impossible to use in forested areas with many large trees and shrubs, but may be used in alpine and polar regions.

The size to be used for the mat depends very much on the equipment available. In our studies we used 75 x 35 cm styrofoam boxes for transport and found this size practical. With an excluded border of 10 cm the research area was 55 x 15 cm in the centre of each transplanted mat. All plots were chosen at random within various vegetation types, but if large rocks were present in the upper 10 cm of the soil, the plot was rejected. In the various alpine vegetation types studied most of the roots were concentrated in the upper 10 cm of soil. This soil depth was therefore used in the present transplantation studies.

Mats from an exposed lichen heath with shallow snow cover in winter (less than 50 cm) and a dry, coarse sandy soil, poor in nutrients and humus, were transplanted to a nearby depression with more snow and a higher nutrient and humus content in the soil, but with a shorter growing seasonxthan the lichen hecith due to later snow melt. The vegetation is also quite different from the lichen heath, having only sparse lichen vegetation but a good moss cover and blueberries (*Vaccinium myrtillus*) and dwarf Salices. The "blueberry" vegetation was also transplanted to the lichen heath. To study the transplant effect itself, vegetation mats were also transplanted within each of the plant communities. In all cases strips of plastic were placed vertically along the edges of the transplanted mats to restrict plant growth across the border to the original vegetation. Good contact was achieved with the soil beneath the transplanted mats and the neighbouring vegetation.

Late in the growing season, mats from the two vegetation types mentioned above and from a wet low alpine meadow were taken to the University of Oslo, where they were maintained in green-houses and controlled climate rooms. The temperature was 10-17°C, with peaks up to 25°C in the greenhouses. In late fall after a 4-5 week period at 6 - 14°C in growth chambers, mats of the first two types were frozen at about -30°C for 4 weeks at short day (6 h) and low light intensity. After freezing, the vegetation mats were placed in growth chambers again at 6-14°C with additional artificial light for 12 hours. The plant cover was analyzed before and about 3 months after the end of the freezing treatment.

RESULTS AND DISCUSSION

The studies with vegetation mats from a wet alpine meadow in Southern Norway show the importance of temperature to the competition between plant species. This is demonstrated by the relative growth of the sedge *Carex nigra* and the grass *Festuca rubra* in a low alpine wet meadow of Southern Norway, both in s itu and in mats grown in a greenhouse in the lowlands. Mean daily temperature in the mountain sj te for July-August over 4 years was 7.2°C, while the mean temperature was about 16°C in the greenhouse. In the field, plant cover was 28% for *Carex nigra* as an average of 10 replicates and 10% for *Festuca rubra* (LYE, 1972). After a late summer growth period of approximately 4 weeks in the greenhouse, green material of *Carex nigra* covered only slightly more than in the field, about 30% cover. *Festuca rubra*, however, had increased to a cover of about 200a. Similar variation was also observed for the dry weight of green material of the two species. When harvested in the field in July and August, biomass of *Carex nigra* was on the average 3.2 times higher than *Festuca rubra* biomass (31.9 g/m² and 9.8 g/m², respectively). In September this ratio was reduced to 1.8 (18.6 g/m² versus 10.3 g/m²) (WIELGOLASKI and KJELVIK, 1975). After 4 weeks in the greenhouse, the two species had nearly the same biomass (25.0 g/m² and 21.5 g/m²). It is obvious that *Carex nigra* is not favoured by the higher temperatures in the greenhouse. This species also seems to be better adapted to the short growing season in the mountains as shown by the I ower amount of green biomass in September than in July and August. On the other hand, biomass of *Festuca rubra* increased somewhat in the fall. compared to early summer. This species probably needs a longer growing season and higher temperatures than *Carex nigra* to obtain maximal growth. *Festuca rubra* plants in mountains obviously are depressed by low temperature, producing weak, narrow-leaved, mostly sterile plants, which nevertheless have the potential to grow considerably better at

Table 1 — Relative cover (%) of the main plant groups in two alpine vegetation type. Observed before freezing for 4 weeks at 30°C and at about 12 weeks after the end of cold treatment, grown at 6-14° C and 12 hour day legth in the phytotron.

Plant groups	Lichen heath Before freezing	Lichen heath 12 weeks after trt.	"Blueberry community" Before freezing	"Blueberry community" 12 weeks after tr
Carex bielowii	1.1	1.7	2.0	0.7
Grasses	2.9	0.1	6.2	0.1
Dwarf Salix	0	0	2.7	1.2
Vaccinium	11.1	0.1	7.2	0
Bryophytes	0.8	3.1	19.3	35.1
Lichens	59.9	53.7	14.3	11.4
Dead plants and bare soil	24.5	41.3	47.7	51.3
Total	100.3	100.0	99.4	99.8

higher temperatures. Both species are well known in wet habitats both in the lowland and low alpine regions in Norway, but *Festuca rubra* also grows in drier meadows. This may as well have influenced growth of the vegetation mats in the boxes in the greenhouse where soil moisture generally was somewhat lower than in the wet meadow in the field.

In the experiments with lichen heath and "blueberry" vegetation, the tolerance of *Carex* to extremely low temperatures was shown by its response to freezing in the phytotron. Table 1 gives the relative percentage of green plant cover in the lichen heath and "blueberry" vegetation mats before freezing and about 12 weeks after the end of this treatment and growth at 6-14° C (which simulates the growth regime in the alpine area at the time of maximum biomass). *Carex bigelowii* is the only vascular plant with an increase in relative cover (in the lichen heath vegetation) after freezing. The grasses (*Festuca ovina* at the lichen heath and *Deschampsia flexuosa* in the "blueberry" vegetation mats) were strongly reduced in green biomass cover by the freezing treatment. This may again indicate that many grasses are not very well adapted to extreme mountain conditions.

The woody species, a dwarf willow, *Salix herbacea*, in both communities and an evergreen *Vaccinium* (*V. vitis-idaea*) in the lichen heath were also reduced in relative cover of green biomas s by the freezing treatment. The only vascular plant that showed no green material at all even 12 weeks after the extreme cold conditions was the blueberry shrub *Vaccinium myrtillus*, which covered more than 70a of the "blueberry" vegetation mats before freezing. This strongly suggests that cold is the reason that blueberries are missing on windswept ridges having shal low snow cover.

Cryptogams were clearly less influenced by the freezing than higher plants, as shown by the increase in their relative cover percent. This does not necessarily mean that they had increased their growth after the cold treatment. But when the phanerogams were reduced, more cryptogams were visible by inspection from above. On dry ridges lichens normally dominate in the field, also indicating that this plant group tolerates low temperatures well, while there are fewer bryophytes due to the dry soil cover. In the phytotron experiments, however, bryophytes seemed to increase more than lichens after freezing, also in the lichen heath vegetation. This was somewhat surprising, but may be explained by a better moisture regime in the phytotron than in the field. The better growth increment of bryophytes compared to lichens was also clear in the "blueberry" vegetation.

In the field, transplantation of vegetation from the wind swept lichen heath ridge to the sheltered "blueberry" community and vice versa, increased the cover of dead plant material and bare soil (Table 2), much more than in the freezing experiments and growth in phytotron.

As expected, most of the *Vaccinium myrtillus* was dead 3-4 years after transplantation from the "blueberry" community to the extreme conditions at the lichen heath (less than 20 alive) . To a large extent this is also true for the grass *Deschamnsia flexuosa*. The vascular plant species, *Trientalis europaea*, however, tended to increase when transplanted from the sheltered to the wind swept plots. This might be seen as a result of competition. The species probably has problems to establish well in the relatively dense vegetation of the "blueberry" community, but may germinate and grow well in the bare soil exposed after death of other species by transplantation to the lichen heath. Cold due to the shallow snow cover at the lichen heath may limit the occurance of most of the vascular plants, but is only of small importance to Trientalis. This species is scarce, however, in the normal lichen heath, probably because of the dense lichen cover in this vegetation type. In 1986 *Carex bigelowii* and maybe the dwarf *Salix* (*S. herbacea*) also increased in the mat transplanted from the "blueberry" community to the lichen heath, again due to the lower competi-

Table 2 — Relative cover (%) of the main plant groups in two alpine vegetation types. Average of six replicates observed 11.7.86, 4 years after transplantation between a lichen heath and a blueberry community and within the two communities.

Plant groups	Lichen heath Transpl. within community	Lichen heath Transpl. to "Blueberry" community	"Blueberry community" Transpl. within community	"Blueberry community" Transpl. to lichen heath
Carex bielowii	2.5	5.3	1.4	4.6
Grasses	4.3	2.1	11.3	2.7
Dwarf Salix	-	0.2	1.9	2.3
Vaccinium	15.0	3.1	16.7	3.1
Other phanerogams	0.8	0.3	3.6	3.3
Bryophytes	1.7	5.2	28.5	12.5
Lichens	66.5	19.7	26.8	30.7
Dead plants and bare soil	9.2	64.2	10.0	40.8
Total	100.0	100.1	100.2	100.0

tion. Similar tendencies may as well be observed by transplantation the other way round. The evergreen *Vaccinium vitis-idaea* was the most strongly depressed vascular plant by transplantation from the lichen heath to the more sheltered "blueberry" community.

The cryptogam cover shows interesting changes by transplantation of the vegetation from the lichen heath to the "blueberry" community and vice versa. The bryophytes are not common at the lichen heath and increased slightly by transplantation to the "blueberry" community due to less competition. However, by transplantation from the "blueberry" community to the lichen heath the cover of bryophytes is strongly reduced although resistant tofreezing as seen in the phytotron studies. The reason must be the drought at the lichen heath. *Dicranum furcescens* was the most strongly depressed bryophyte.

Lichens, on the other hand, are well known to stand drought, and probably for that reason, increased somewhat when transplanted from the "blueberry" community to the lichen heath. Even more interesting are the lichens in the vegetation transplanted from the lichen heath to the "blueberry" community. Already during the first summer after transplantation the transplanted lichen mat had an uncommon colour at the "blueberry" community. There seemed to be less green pigments in the thalli. This was clearest in *Cetraria nivalis* which was quite yellow. After four years the total lichen cover was reduced to less than one third of the cover at the lichen heath. The lichen death at the "blueberry" community might be caused by the higher water content or by ice crusts during winter. In both cases the reason probably is lack of oxygen. Most strongly influenced was the lichen species favouring the most extreme cold and nearly snowfree areas, *Cetraria nivalis*, of which only 1/30 (3.37%) was left four years after transplantation from the top lichen heath to the sheltered "blueberry" community.

The use of vegetation transplantation is an interesting addition to species transplantation. Each plant is less disturbed when the whole mat is transplanted than with single-specimen transplants, and it is possible to study effects of changes in within community competition in the transplanted plots.

ACKNOWLEDGEMENT

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THE ECOLOGICAL CONDITIONS AND THE LAW OF GEOGRAPHICAL DISTRIBUTION FOR CULTIVED TEA PLANTS IN CHINA

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Key words: Tea Plant, Ecological conditions, Geographical Distribution

ABSTRACT

The tea plant (*Camellia sinensis*) is a typical subtropical plant. It is an artificial vegetation. This paper discusses the character of ecological condition and the law of geographical distribution for tea plant in China. In the hilly lands, yield of the tea plant decreases with the elevation increases, and quality of the tea plant increases with the elevation increase in a given elevation range.

INTRODUCTION

Tea is one of the three main beverages in the world. It is also traditional export commodity of our country. According to 1983 statistics, there has been 1.138 million hectares in area of tea plantation, 424.7 million kg in tea output in China. The output of tea places the second of the world. Tea plant is a kind of cultived vegetation. As a natural vegetation, its geographical distribution is affected and limited by the ecological environment around it. But it is also strongly influenced by the economic conditions of the society. This is the essential distinction between cultivated and natural vegetation. The distribution of tea plant in our country not only possesses distribution law of the horizontal zonality, but also of the vertical one (LIU JIA-KUN *et alii*, 1981). There is no report on the distribution law of the zonality or non-zonality of the tea plant in our country so far. A discussion about the question is presented in this paper.

Table 1 — Requirement for ecological environment by tea plant

	Economic culture suitable for tea plant	Tea growth possible
Annual mean temperature (°C)	>14	>11
Mean temperature in coldest month (°C)	>3	>0
Absolute minimum temperature (°C)	>-13	>-20
Active accumulated temperature of mean daily temperature ≥10°C (°C day)	>4500	>3000
Mean annual precipitation (mm)	>1000	>750
Monthly aridity index in mean daily temperature≥ 10°C	<0.7	<1.0
Mean monthly humidity (%)	>80	>60
Soil acidity (pH)	4.5-5.5	>5.5or<4.5
Depth of soil (cm)	>100	>60

Table 2 — The heat conditions of sub-zone and tea plant varieties suitable for cultivation in the subtropical zone in China.

	North subtropical belt	Middle subtropical belt	South subtropical belt
Active accumulated temperature of mean daily temperature ≥10°C (°C day)	4250-5300	5300-6500	6500-8000
Mean temperature in coldest month (°C)	0-4	4-10	10-15
Absolute minimum temperature (°C)	-20 - -10	-10 - -2	-2-2
Tea plant varieties suitable for cultivation	Shrub type of middle leaf & small leaf	A small arbor type of shrub type	Type of a large leaf & an arbor
Tea type suitable to manufacture	Green tea	Wu-long tea, green tea and black tea	Black tea

THE ECOLOGICAL CONDITIONS REQUIREMENT OF TEA PLANT

The tea plant originated from Yun-Gui plateau in China. It lies to 25° N or so, with typical climate of the subtropics. It has a temperate climate all year round, with abundent precipitation, high humidity, cloudy and foggy weather, and overcast sky (CARR, M.K., 1972; HUANG SHOU-BO, 1981). Under this condition, tea plant has gradually evolved the special characteristics of being inclined to warm, moist weather, acid soil, diffused light, against hot, freezing, dry weather and alkali soil (Table 1).

THE CHARACTERISTICS OF ECOLOGICAL ENVIRONMENT OF TEA PLANT AND ITS DISTRIBUTION IN CHINA

1. The Characteristics of Ecological Environment in Base Belt of the Subtropics of China

Tea plant is a subtropical plant and is mainly distributed in subtropical zone. The subtropical region in China lies from about 22° N to 34° N to 98° E eastward, with an area of 2.4 million square kilometres, and belongs to humid monsoon climate of east coast type. According to the difference in the condition of heat quantity this region can be further divided into three sub-regions (Table 2).

In the subtropics of China, there is no such dry climate as being influenced by the general subtropics high-pressure zone, but moist and much precipitation, high temperature in summer. The dominant natural vegetation is evergreen broadleaved forest, with types of the soil consisted of red and yellow soil. They provide the favourable condition for tea to grow normally. The arid weather in summer and autumn affect the output and quality of tea in most areas, freezing injury is the chief limiting factor of tea plant distribution, and the northern boundary to cultivate tea plant in China in much lower than any other areas at the same latitude in the world.

2. The Characteristics of Vertical Distribution of Ecological Environment in the Subtropical Hilly and Mountainous Land of China.

At the mountainous region, with increase in elevation each natural geographical factor changes. Most of the heat resources in the mountain areas show linear decreasing tendency but not at the same lapse rate in different areas (Table 3). Generally the lapse rate of temperature in the highest in summer and the lowest in winter (SENG GUOZUAN *et alii*, 1985).

Generally, there is much precipitation on the windward side of the small hilly land and little on the windshadow side. Under a given elevation range, the precipitation in the mountain areas increases with the rise in elevation. The elevation for the maximum precipitation changes with different areas and seasons. The absolute humidity decreases with the elevation, but the relative humidity changes sightly. Generally, the hours of illumination decrease with the elevation, especially in the rainy season from April to October (the period for picking tea). Under a given elevation range, foggy days increase with the elevation of mountain.

Table 3 — Lapse rate of temperature (°C/100 m) in the subtropical hilly land of China.

	Mean value	Maximum value	Minimum value
Annual mean temperature	0.49	0.67	0.30
Mean temperature in coldest month	0.43	0.62	0.24
Mean temperature in hottest month	0.45	0.81	0.40
Active accumulated temperature of mean daily temperature≥10°C	187.4	240.0	117.0

THE LAW OF GEOGRAPHICAL DISTRIBUTION OF TEA PLANT IN CHINA

1. The Horizontal Zonality Distribution of Tea Plant

The tea plant in our country is distributed with horizontal zonality. It shows chiefly as follows: The areas northwards the line of Qing Ridge to Wai River in China belong to the temperate zone in climate. Restricted by low temperature, the tea plant can not safely grow through the winter. Except individual coastal areas, no tea plant is ditribited in these areas. In the areas westwards from Dadu River having low temperature, little precipitation, the ecological condition can not meet essential requirement for tea growing. There fore, no tea plant is cultivated except in individual areas. At present, tea plant in China is distributed from 94° E to 122° E longitude, from 18° N to 37° N latitude. But the areas for economic cultivation area concentrate in the region from 102°E eastwards and 32°N southwards. Most of the output is in the middle subtropic areas (Table 4). In 1983, Zhejiang province located in subtropics has the most output, according for 24 percent of the total output of China. Hunan province comes in the second, accounting for 17 percent of the total. Other provinces such as Sichuan, Anhui, Fujian make up 9.9, 9.5 and 7.8 percent of the total output respectively. The total output of the above provinces is about 70 percent of the whole (Fig. 1).

2. The Vertical Distribution Characteristics of tea Plant in China

Though the tea plant is widely distributed on the hillocks, hills and low mountains, it is also cultivated in many mountain slopes, and high quality tea with nice color, sweet-smelling, superb flavor and good appearence (Table 5). The range of vertical distribution in the tea area of China is vast from the mountain slopes at elevation of 2600 m to low hillock at elevation of only several meters. For example, according to the growth condition of tea plant, degree of freezing output, recovering speed after freezing, the tea plant in Tainmu mountain (elevation 1479 m) and Guacang mountain (elevation 1374 m) in Zhejiang province can be divided into five zones (Table 6). The vertical zonality of tea plant in the mountain especially shows in the aspect of the tea quality, for example, the content of amino acid which effects the quality of tea increases with the elevation below 850 m (different slightly with differ mountain), and decreases when the mountain elevation (Fig. 2). The amino acids are one of the mian components in determining the quality of green tea (WANG ZHUO-CHENG, 1983; ZHOU ZHI-KANG, 1985).

In the subtropics mountain of China, the higher the mountain, the lower the output, but within definite elevation range the better the natural quality of tea. To get the best economic benefit, a suitable range in height must be chosen, this range is called the relative superiority layer for tea plant cultivation (Fig.3).

CONCLUSIONS

1. Tea plant is a typical subtropic perennial evergreen plant. It has a natural inclination for warm humid climate and acid soil.
2. The area of subtropics in China has the characters of warm humid climate, weak ecological balance (with frequent natural calamities). This provides the favourable condition for tea planting, but at the same time has some inadequancy as well.
3. Tea plant is a cultivated vegetation. Its geographical distribution is restricted by natural and social economic conditions.

Nevertheless, tea plant has its distribution law of horizontal and vertical zonality.

Ninety five percent of the tea plant

Table 4 — The distribution of tea plant in China (1983).

Name of climatic zone	Tea production	
	million kg	%
Warm temperate zone	1.20	0.3
North-subtropical zone	55.00	13.0
Middle-subtropical zone	293.45	69.1
South-subtropical zone	60.50	14.2
Tropical zone	14.55	3.4

Table 5 — Elevation of major mountain peak and famous tea name of producing in tea production regions of China.

Name of mountain peak	Elevation hilltop (m)	Name of province	Tea name of producing
Huangshan	1841	Anhui	"Huangshan Maofeng tea"
Tianmushan	1507	Zhejing	"Tianmu qingding tea"
Wuyishan	2120	Fujian	"Wuyi-yan tea"
Lushan	1426	Jiang Xi	"Lushan Yunwu tea"
Emeishan	3092	Sichshan	"Emei Eyui tea"

Table 6 — Heat conditions and elevation of perpendicular heat zone for tea planting at Mount Tian-Mu area and Mount Gua-Cang area in Zhjiang.

		Most suitable zone	Suitable zone	Sub-Suitable zone	Possible for tea planting	Not possible for tea planting
Active accumulated temperature of mean daily temperature ≥ 10° C		>4800	>4500	>4200	≥3700	<3700
Annual mean temperature (°C)		>15.2	>14.3	>13.4	≥12.0	<12.0
Mean temperature in coldest month (°C)		>2.6	>1.9	>1.2	≥0.0	<0.0
Mean annual absolute minimum temperature (°C)		>-8.3	>-9.3	>-10.4	≥-12.0	<-12.0
Range of elevation (m)	Mt. Tian-Mu area	<142	142-320	321-499	5000-796	≥796
	Mt. Gua-Cang area	<373	374-529	530-684	685-943	≥943

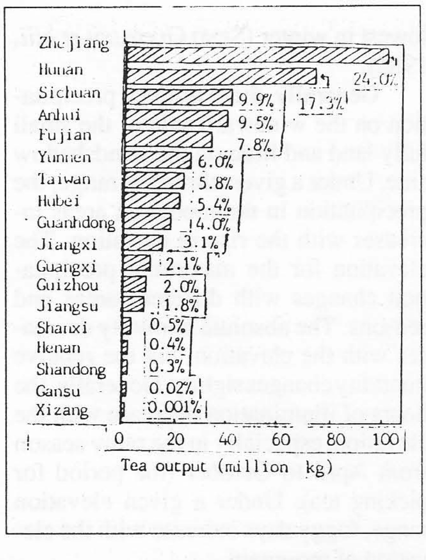

Fig. 1 — Tea output of every province in China and its percentage in the whole of China (1983).

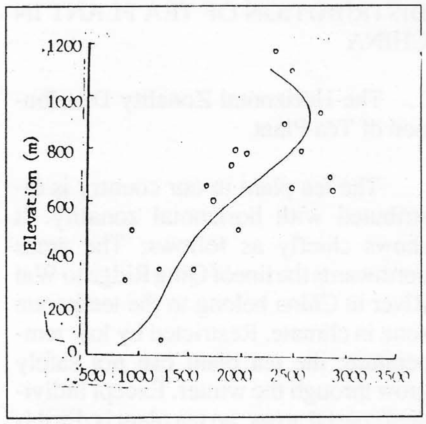

Fig. 2 — The content of aminoacid of tea changes with the elevation.

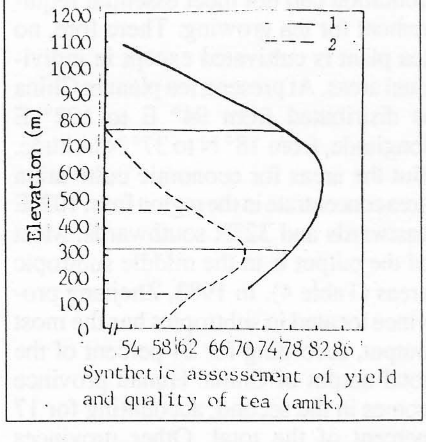

Fig. 3 — Relative superiority and layer area of tea growing in Longchuan (1) and Tianmu (2) Mountain.

in China concentrate in the middle subtropic areas. The output of tea decreases with the elevation of the mountain, but the natural quality improves with the elevation at a definite range.

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EFFECT OF SNOW ACCUMULATION TO THE VEGETATION IN THE REGION OF MT. NAMJAGBARWA

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Key words: Snow accumulation, Vegetation, Mt. Namjagbarwa

Mt. Namjagbarwa (7782 m) is the highest peak in the eastern Himalayas. The Yarlungzangbo River makes a peculiar U-shaped curve near the foot of Mt. Namjagbarwa, crosses the mountain range located in the southern part of the Tibetan Plateau, and flows down southward along the eastern side of Mt. Namjagbarwa. From there, the Yarlungzangbo River begins to flow from north to south, and the valley formed by the river here has become the most important passway of the warm and moist airflow, which enters the Tibetan Plateau from the Indian Ocean (GAO DENGYI, ZOU HAN, WANG WEI, 1985). Influenced by this airflows, the southern part of the Namjagbarwa region is the moistest area of the Himalayas with an annual rainfall of over 1500-5000 mm. At least from the end of October to April of the next year, the precipitation falls in form of snow in the alpine and subalpine belts. The total thickness of the snowfall as at least 50 cm. So the effects of snowfall to the vegetation in these belts are quite evident in the region. But the northern part of Mt. Namjagbarwa region is less moist and its precipitation is only 500-1000 m as the result of the rain shadow effect of Mt. Namjagbarwa and Mt. Kangrigarbo to the moist airflow from the Indian Ocean. So there are less effects of snowfall to the subalpine and alpine vegetations in this semi-humid area than the southern part. From 1982 to 1983 I spent 13 months investigating Mt. Namjagbarwa's vegetation, especially the effects of snow accumulation to the subalpine and alpine vegetation. The conclusion of the observation is that the snow accumulation is a very important factor in distribution, composition, and growing of the subalpine and alpine vegetation in the humid southern part of Mt. Namjagbarwa region.

Snow accumulation in the region

Because of the strong influence of the airflow of the Indian Ocean and the high mountain topography, the snow depth starting and ending time of snowfall, and duration of snow accumulation closely related to the orientation of slopes, altitude, and landforms. Except the lower montane evergreen and semi-evergreen both belts and middle montane evergreen broadleaf forest belt located below 1800 m, all vegetations above this elevation are affected by snow accumulation, in varying degrees, among them the subalpine vegetations are strongest affected by it.

The Table 1 shows the relationship between snowfall and the vertical vegetation belts in the Mt. Namjagbarwa region.

The snowfall is not only bound to the altitude of the mountain but also to the topography as well. There is far more snowfall in many southern passes than the valleys of the Yarlungzangbo River with the same altitude.

EFFECTS OF SNOW ACCUMULATION TO THE VEGETATION

1. Hydro-regulation effects of snow accumulation into vegetation

Snow is an important water source for the vegetation, but only in spring and summer when snow is melting. Snow accumulation can regulate the humidity of the soil. In this case, the snow accumultaion changes the synchronic rhythm between soil water content and atmospheric precipitation.

Mt. Namjagbarwa region is moistened by the monsoon from the Indian Ocean and have typical monsoon climate, a rainy season befalls from May to October inclusive with up to about 80% rain fallin the year, and a dry season from September to April in the nextyear, the signs of drought are evident. In spring, before rainy season when plants come to grow, the dry weather in the region plays a very important role in the local condition. The regional plant community and the divisional lines of the vertical belts of the subalpine and alpine vegetation are totally determined by the snow accumulation, and the snow depth in the region.

There takes the vertical spectra of vegetation as the example: in Table 1 there is both prominent differences in vertical spectra of vegetation above subalpine belt between the southern part and the northern part in the region of Mt. Namjagbarwa.

Firstly, the lower subbelt of the subalpine evergreen coniferous forest is composed of *Tsuga dumosa*; in northern part, the *Picea likiangensis* var. *linzhiensis* is the dominant species covers all over the subbelt. Because of that during winter and spring, soil moisture is prominent difference between the southern part and the northern part. When the late autumn with the end of the rainy season arrives, the lower subbelt of the subalpine forest in the southern part is covered by heavy snow, during all winter, the tickness of the snow accumulation is more than 25 cm. In spring, snow accumulation completely melts until middle April, the humidity of the soil can last until the raining season. That can satisfy with *Tsuga dumosa* which requires the moist weather (CHANG KINGWAI, CHIANG SHU, 1973), so in there hemlock grew very well and formed continuous belt of the forest. However, during winter the subbelt in the northern part is only short-term continuous cover of the snow, in earlier spring, when the snow has melted, the soil becomes quickly dry, the *Picea likiangensis* var *linzhiensis* adapts that drier site, so in there the lower subbelt of the subalpine is composed of the spruce forest.

Secondly, the lower half belt of the alpine belt in the southern part of the region is the alpine scrub and meadow belt, which is composed of the evergreen azalea scrub and the dicotyledon meadow; but in the northern part, the belt is divided into the following both belts: the alpine belt is composed of the evergreen azalea, which is growing on the northward slopes and the evergreen Juniper, which is growing on the southern slopes. The alpine meadow belt is composed of the monocotyledon. This kind of difference is created by causes similar to the subalpine belt. In the humid southern part, the alpine scrub and meadow are mainly formed by the mesophytic communities, such as, the Com. *Rhododendron wardii*, *Rh. neriiflorum*, *Rh. forrestii*, *Salix annulifera* etc., the meadow Com. *Caltha sinogracilis* f. *rubriflora*, *Potentilla stenophylla*, *Bertgenia purpurascens* etc. In the semi-humid northern part, the alpine scrub and meadow are mainly formed by xero-mesophytic communities, such as, the scrub Com. *Rhododendron nivale*, *Sabina pingii* var. *wilsonii*, *S. saltuaria* etc., the meadow Com. *Kobresia pygmaea*, *K. prattii* etc.

On the aspect of the limit of the vegetation belt, the effects of snow accumulation are same evident. For example, the lower limit of the forest is composed of the fir, spruce and hemlock tends to extend downward several hundred metres in altitude along the branch valley of the Yarlungzangbo Riverand makes a jigsaw-like lower forest line there. That is because the snow accumulation on the slopes of the branch valley is thicker than that of the main-stream at the identical altitude.

Table 1 — Snowfall on the vertical vegetation belts in the Namjagbarwa region

Vertical belt of the vegetation	elevation (m)	mean annual temperature* (C)	starting and ending time of snowfall	starting and ending time of snow accumulation	average depth of snow accumulation (cm)
Southern part of the Namiagbarwa region					
alpine subnival vegetation belt	4400-4900	-2.1-0.4	early Sept.-end June next year	mid Sept.-end June next year	100
alpine scrub and meadow	4000-4400	0.4-2.4	mid Sept.-mid June next year	end Sept.-mid June next year	100
subalpine fir forest belt	2800-4000	2.4-8.4	early Nov.-mid May next year	mid Nov.-early May next year	75
subalpine hemlock forest	2400-2800	5.4-10.4	end Nov.-end Apr. next year	end Nov.-early Apr. next year	25
middle montane evergreen broadleaf forest belt	1800-2400	10.4-13.4	early Jan.-early next year	mid Jan.-end Jan.	10
Northern part of the Namiagbarwa region					
alpine subnival vegetation belt	4800-5200	-3.6-1.6	end Aug.-end June next year	early Sept.-end May next year	20
alpine meadow belt	4400-4800	-1.6-0.4	early Sept.-end June next year	mid Sept.-mid May next year	20
alpine scrub belt	4200-4400	0.4-1.4	mid Sept.-mid June next year	end Sept.-mid May next yea	25
subalpine fir forest belt	3600-4200	1.4-4.4	end Sept.-mid May next year	mid Nov.-early May next year	15
subalpine spruce forest belt	3200-3600	4.4-4.6	early Nov.-early May next year	early Dec.-end Mar. next year	7
middle evergreen broadleaf sclerophyllous forest belt	2500-3200	6.4-9.9	mid Nov.-early Apr. next year	end Dec.-early Mar. next year	3

* Lin Zhenyao, Wu Xiangding, 1985: A preliminary analysis of the climate in the Mt. Namiagbarwa region. Mountain Research, 3

2. The snow accumulation as a cover

Besides its regulation effect in soil water , another important role of snow accumulation is as a cover. It is clear that in the dry and cold winter, the continuous snow accumulation is indispensable for the survival of the subalpine fir and hemlock forest, the alpine evergreen large-leaf azalea scrub, and the alpine dicotyledon meadow in the part of the region, conversely in only the spruce, another kind of fir forests and alpine monocotyledon meadow, which is adaptable to this habitat, are growing very well.

However, if the snow accumulation is too heavy and it melts too late, that will be greatly shorten the plants growth times, and will cause tha change of the character with the communities. This effect is very evident in the southern part of the Mt. Namjagbarwa region. For example, the *Abies delavayi* var. *motuoensis* forest growing above 4000 m is generally covered by a 150-200 cm snow accumulation. But in branch valleys, the snow accumulationis even thicker and can't melt completely in early July. As the result, many saplings of this kind of fir can't survive, making the forest regeneration very difficult there, lowing down the forest line to 3700 m in altitude, and making the upper forest line jigsow-like. In the northern part, the forest line is formed by the Com. *Abies georgei* var. *smithii* is same jigsow-like, but the range of the line is narrower.

The aforesaid effect is present same in the alpine belt, especially for the community's composition of the alpine vegetation in the southern part of the region (see Chart 1).

The climax community in the lower half of the alpine belt will be azalea shrub, if there have not the strong effects of snow accumulation. However, the thickness of the snow accumulation is uneven because of the landform and redistribution by wind. The azalea shrub needs comparatively long time to complete its annual growing cycle, so only the hilltop and mountain ridges, where snow melts in early spring, are suitable for its growth. On the other hand, the alpine dicotyledon meadow and creeping deciduous shrub are mainly growing in the place with heavy snow accumulation and there snow melts slowly in spring, such as, the mountain valley, depression and col etc.

Because in there the distribution of the alpine scrub and alpine dicotyledon meadow make a mosaic-like, a spécial mixed vegetation belt of alpine scrub and meadow is formed in the southern part of the region. As the plant of the some communities, such as, the Com. dicotyledon meadow and the Com. creeping deciduous shrub, have a ability to survive under heavy snow drift and need a short annual growing cycle. it was found recently the *Caltha sinogracilis* f. *rubriflora* and *Salix acuminatomicrophylla* begin flowering at September when snow has just begun to melt. Sometimes, when snow drift lasts the whole year round, they can still survive. For adaption to this kind of environment, the majority of those perennial dicotyledon have fat store-root, the willow is cushion-like and they creep on the ground surface to reduce the pressure of heavy snow drift.

In addition, as in the southern part of the region, the starting time of the snow accumulation is earlier than the decreasing in soil temperature to 0°C, the heavy snow accumulation can prevent the soil temperature from continuing dropping and protect the plants from low temperature and winter drought. Thus, the snow accumulation is ecological important for the growth of plants even after the snow melted in spring. According to some of the soil profile taken during a research trip, the soil in this area is not frozen when the snow is melting.

3. The gravity effect of snow drift.

The gravity effects of snow drift are shown in two aspects: the static one and the dynamic one.

There is a very heavy snowfall in the southern part of the Namjagbarwa region and the tree branches and needles of the subalpine coniferous forests are covered with heavy snow, so a lot of withered branches are fractured, and some withered trees are broken down. In this way, the light condition of the forests have been improved, helping the rejuvenescence of the subalpine coniferous forest in the area. The gravity effects of snow drift in static aspect are seen mainly in the form of the alpine elfinwood near the upper timberline. Because of the pressure of heavysnow drift, the communities of *Rhododendron laudandum*, *Rh. wardii*, and *Betula utilis* are inclined towards the ground surface and become a low bush form, which is rarely seen in the northern part of the region.

When heavy snow drift is formed on precipitous mountain slopes, the snowslide is onevitable. This is closely related to the amount of snow accumulation and the topographyof the area. The sight of snowslide is frequently seen in the southern part of the Namjagbarwa region; the soil of the subalpine forest is eroded; many deep gulleys are formed; sometimes the snowslide could reach to the middle mountain semi-evergreen broadleaf forest belt at 2000 m in altitude. Under the action of snowslide year after year, a series of successive plant communities are formed in the gulley from inside to outside, they are perennial dicotyledon herbaceous communities, willow scrub communities, and birch communities successively. Besides, in the northern part of the region, many of the meadow plants are uprooted by the snowslide, and a special snow-erosion community type is generally composed by plants belong to some genera, such as, *Oxygraphis*, *Ranunculus*, *Lagotis*, *Cremanthodium*, etc. is found.

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LONGTERM-INFLUENCE OF FERTILIZATION ON THE NARDETUM AT THE SCHYNIGE PLATTE ABOVE INTERLAKEN (SWISS ALPS)

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Keywords: Mountain vegetation of Switzerland, Fertilization of pastures, Alpine successions

INTRODUCTION

In 1930, Lüdi started an experiment in the *Sieversio-Nardetum*, a pasture of the alps with low productivity. In many cases it stands on places of former spruce-forests, but it can exist as well above the potential timberline. The typical association has developed by overgrazing of a normally productive pasture, the *Crepidi-Festucetum rubrae*. In larger distances from the alpine cottages cattle came for feeding, but no manure was brought there. The soil was overused, the vegetation changed into the *Sieversio-Nardetum*. This produces very little organic matter, of which a great part is not eaten by cattle: the dominant *Nardus stricta* has thin and hard grassleaves. The animals are not able to bite it. The few forbs have mostly dense rosettes near the ground and are no food as well.

In certain parts of the alps this community covers great surfaces, and it was of economic interest in 1930 to improve its food production.

METHODS AND MATERIAL

For Lüdi, the improvement of this alpine pasture was the main purpose, when he started his experiment in the thirties. He postulated the change from the nardetum to the *Crepidi-Festucetum rubrae* with its good food by fertilization. To prove this , he installed an experimental field on Schynige Platte, with more than 300 test surfaces of 1 m^2 each, with five squares of identical treatment out of the following:

- leave the natural sward
- dig the soil, leave to natural colonization
- dig and sow plants indigenous to productive pastures
- leave the natural sward, tear off the "weeds"

The surfaces were fertilized with:
- N, P, K, NK, PK, NPK, ground lime (Ca), NPKCa, Thomas scoria and manure.

For every square many observations were made; for the present paper only the detailed list of the species in the square is of importance, which was made three to four times, with estimation of the cover of the species in percents.

Unfortunately Lüdi himself never published any detailed report of this experiment. The most important paper was LÜDI 1959.

RESULTS

The squares of different fertilizer-treatments show very different combinations of species, and this after more than 25 years of identical treatment for all surfaces: no more fertilizer, no more pasture and no other human influence has been applied since 1956. Fig. 1 shows some squares in their order in the slope. Two species groups are shown that Lüdi had defined: good and bad fodder plants and acidophilous plants. The differences between the squares are evident after fertilization from 1930 to 1936 and 1946 to 1952. Afterwards the squares stayed undisturbed.

An improvement of the *Nardetum* is possible by fertilizing.

The best sward with good food and high production is reached with PK, NPK, NPKCa or Ca. Fig. 2 shows as an example the change of one group of squares without fertilizer and another treated with NPKCa. Phytosociologically the fertilized squares look very much like the *Crepidi-Festucetum rubrae*, the untreated squares remained *Sieversio-Nardetum.*

One fertilizer alone and the combination NK have only very little influence, as is to be seen in Fig. 3. NP and PK give some improvement, but not as much as NPK, NPKCa or Ca. The influence of lime is based on neutralization of the acid raw humus, which leads to a speeding up of the mineralization of the organic matter and to free nutrients for the plants.

The reaction of some species on the fertilizations is shown in Fig. 4. A few species react already with one fertilizer, others show changes only after use of NPK or Ca. Some species need a long time for their reaction, while others show changes very soon; the duration of the influence is different too.

Surfaces that had been digged at the beginning for the destruction of the nardetum usually show more bare parts

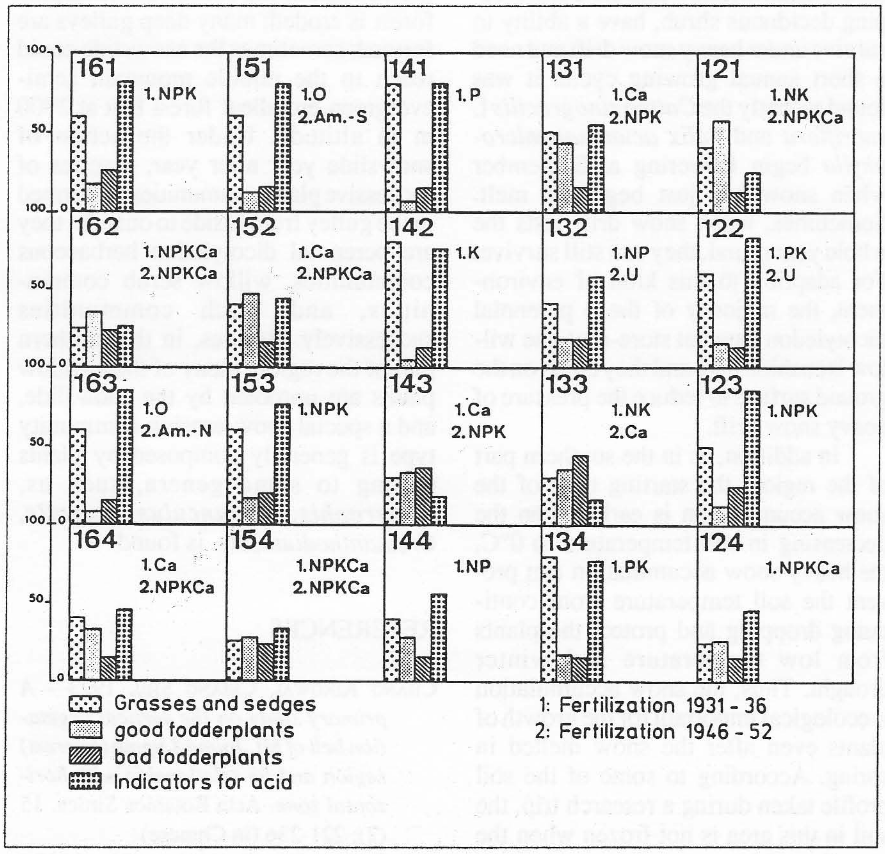

Fig. 1 — Part of the experimental plots in natural sward in 1982 influenced by different fertilization. The figure shows the percentage cover of the following, nonexcluding groups of species: grassy plants, good food plants, bad food plants and acidophilous plants. The first line of fertilizer shows the nutrients applied in a first period from 1930 to 1936, the second the same for 1946 to 1952.

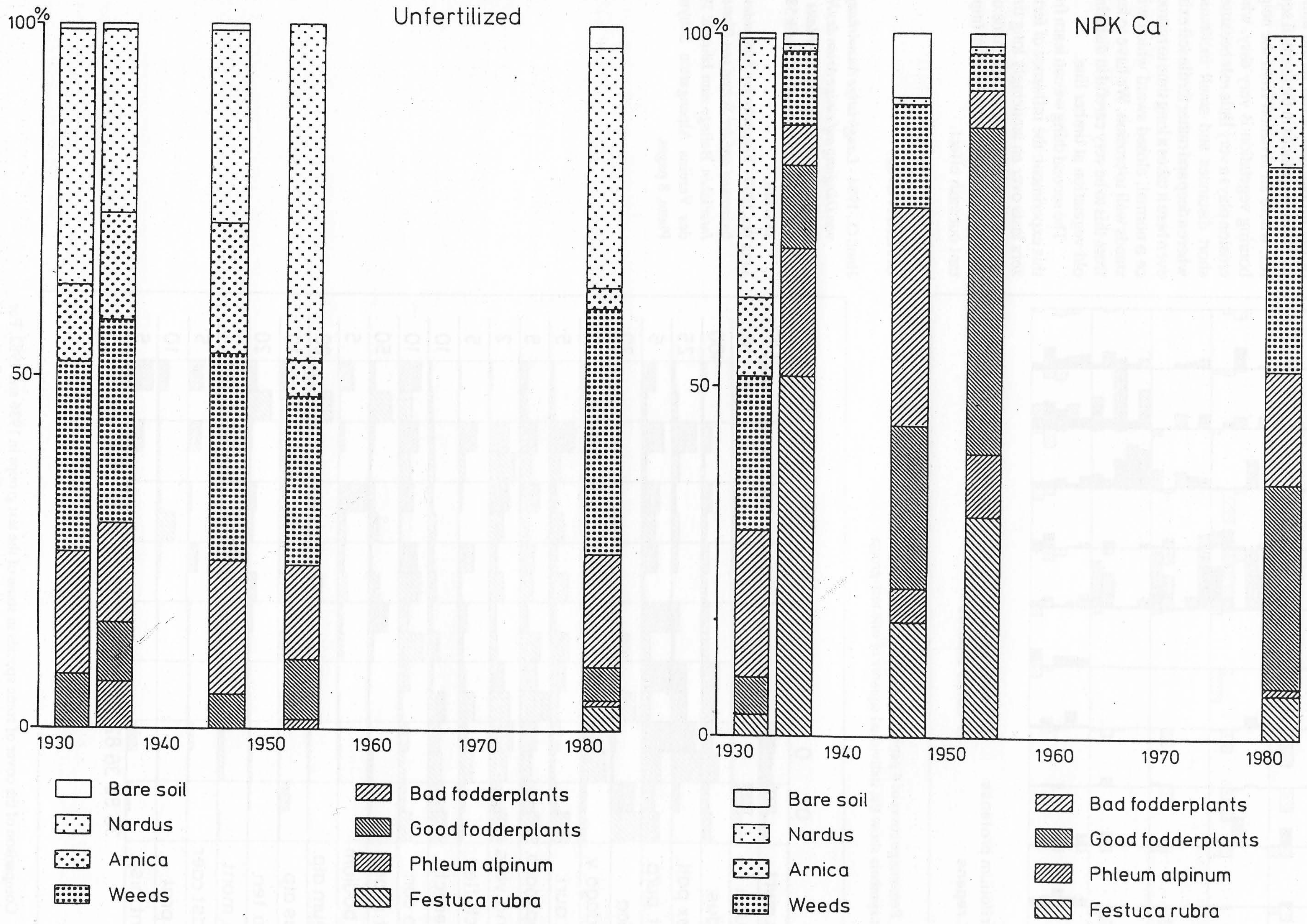

Fig. 2 — Longterm influence of fertilizer on natural sward. Application in 1930 to 1936 and 1946 to 1952.

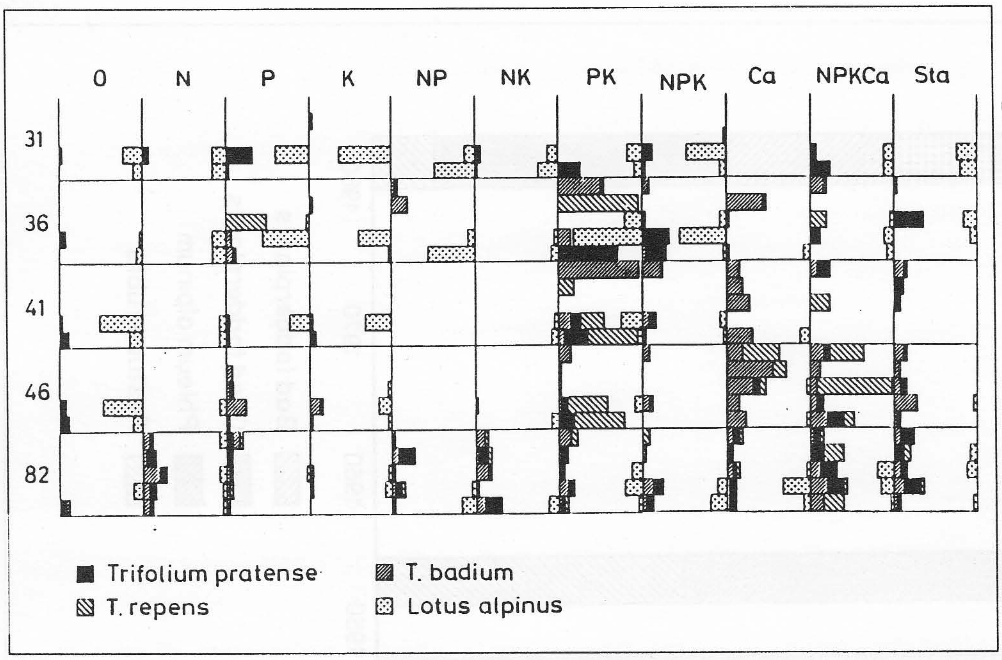

Fig. 3 — Percentage cover of 4 papilionaceae species for the years 1931, 36, 41, 46, 54 and 82. The five different symbols show the individual squares of one test-group.

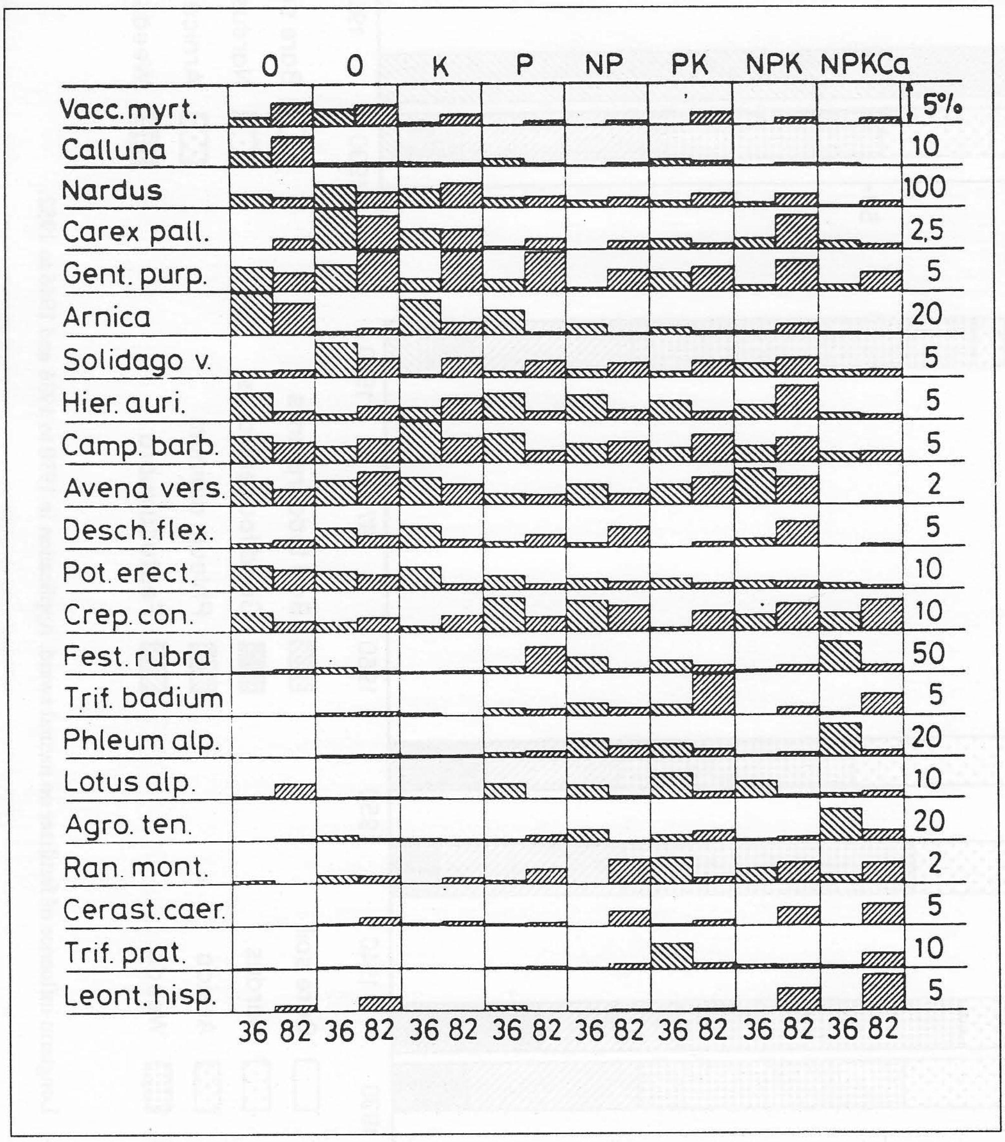

Fig. 4 — Comparison of the cover of some species in some of the test groups in 1936 and 1982. For some species, it is clear that they did recover within the testtime, while for others the influence of fertilizers is visible, still today. Numbers at the right show the percentages, to which the with of the line corresponds.

in the sward than those in the natural sward. This demonstrates the danger of destroying the vegetation in the vicinity of the timber line. Even in the almost ideal circumstances in these small squares, where an invasion from the neighbouring vegetation is very easy, where erosion plays a very little role because of short distances and small inclination, where a deep and rather fertile soil exists, even here it takes a long time to reproduce a normal, closed sward which withstands well to erosion. We have to learn from this to be very careful in disturbing old vegetation at timber line.

The second thing we can learn from this experiment: the influence of fertilizers lasts over an amazingly long time, although the experiment was made on a slope, where we would expect an important outwash effect.

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THE RELATION BETWEEN VERTICAL VEGETATION STRUCTURE AND AGRICULTURE PRODUCTION SYSTEMS IN THE MOUNTAIN REGION OF BEIJING

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Key words: Complex agro-ecosystem, Mountain region Beijing, Productivity.

ABSTRACT

The relatioship between the vegetation of mountain regions of Beijing suburbs and agricolture production system discussed in this paper, in addition the overall construction of the complex agro-ecosystem also being put forward which is composed of natural vegetation and artificial vegetation.

BACKGROUND CONDITION

Beijing city is surounded by the mountains from north, west and east, and the mountainous region at 39° 12' to 41° 05' N, 115° 25' to 117° 30' E covers about 61% of the total area of Beijing. the mountainous region extends from south to north about 167 km, from east to west about 177 km. According to the taxonomy of chinese vegetation, this region belongs to the sub-belt of deciduous oak forest, the north part of deciduous broad leaved forest district of temperate zone.

On the piedmont belt of the Ying mountain which is connected with the plain, the elevation is no more than 100 m, the topography is gradually rising to the west and north and reaches above 2000 m. The highest peak of Donglin mountain is 2303 m Haitu mountain 2234 m and other peaks vary from 1000 to 2000 m, the relative heigh is about 2000 m.

THE VERTICAL DISTRIBUTION OF THE VEGETATION

In Beijing city area, its main part is plain, the climate is uniform. Howeever because of topographic relief in mountain area, an obvious vertical climatic belt in suburb happens (see Table 1) (SHEN YUANCUN 1985).

The vertical climatic difference causes a corresponding vertical change of the natural geographic components such as vegetation etc. The plain in front of the mountains is a warm temperate type of deciduous broadleaf forest belt, from 800 to 1800 m is a mid-temperate type of deciduous broad-leaved forest belt. Above it comes into mountainous region with cold temperature type of coniferous forest, birch forest, and scrub belts. Above 1800 to 1900 the top of mid-mountain region, is meadow belt.

The hights of the vertical vegetation belt are not the same on the shadow side and the sunny side of mountain, generally speaking, the vegetation distribution on sunny side will raise about 200 m comparing with the former. In addition, the lithological character has a remarkable influence on the vegetation distribution of mountainous region. The soil developed from the limestone is more infertile and arid than from the granite.

THE PRESENT SITUATION OF UTILIZATION

The vegetation differences reflect the comprehensive natural conditions and decide the utilization direction of natural resources? Therefore, the different agricultural production systems or types of agro-ecosystem have been formed on different vertical belts and soils, and it also reflects the superior agrotechnical level of chinese peasants. The basical ways of utilization now are intercroping fruit-trees with crops, comprehensively developing vegetables, cow, hennery, fishery planting flowers and some other medical plants on hills; on lower mountain the natural forest is protected, a larger proportion of the intermont basin is used for planting crops, on the other part have been mainly developed fruit-trees and animal husbandry; on the mid-mountain in the vegetation is basically natural, only part of scrub-grassland is a very good pasture in summer.

It should be pointed out that, this area has been the cultural centre and economically developed region of China with more than 2000 years history of development, the density of population is rather high and the activities of the human strongly changed the original character of vegetation, so in this area appear a series of secondary vegetations. In early history the deciduous broad-leaf forest represented by *Quercus liaotungensis* and *Pinus tabulaeformis* widely distributed on the low-mountain hill even plain; on upper part of mid-mountain distributed coniferous forests consisting of *Picea asperata*, *Abies fabri* and *Larix qmelinii*. But now, except some natural forests such as *Quercus liaotungensis*, *Betula dahurica*, *Tilia mongolica*; *Larix principis-rupprechtii*, *Pinus tabulaeformis*, *Populus-Betala*, *Populus davidiana*, *Betula platyphylla*, the plantations of *Pinus tabulaeformis*, *Morus alba*, *Sophora japonica*, *Platycladus orientalis* have been cultivated. The scrub is widely distributed, which is a secondary vegetation after the forest was destroyed, the scrub together with a grass-scrub which distributes on sunny-side under an altitude of 350 m cover over 55% of the mountain area. Meso-scrubs are mainly *Lespedeza bicolor*, *Spiraea trilobata*, *Spiraea pubescens*, *Corylus heterophylla*, *Deutzia grandiflora*, *Myripnois dioica*, they form various scrub formations: xero-meso-scrub mainly consists of *Vitex chinensis*, *Prunus armeniaca* var. *anus*, *Ziziphus jujuba*. Among them often appear grasses such as *Bothriochloa ischaemum*, *Melica scabrosa* etc. Therefore, the pattern of land use corresponding with local conditions has been planned, including the succession and restoration of the natural vegetation under human acceleration and control. So, this pattern possesses the character of recombination of the natural vegetation with cultivated vegetation. Generally speaking, the ecological efficiency of the complex agro-ecosystem consisted of artificial ecosystem and natural ecosystem is high, it indicates that, the chinese peasants have a variety of superior techniques and creative ability. For example, intercroping persimmon with cereal crops is common pattern of farmland population on the cultivated land of cinnamon soil with an elevation of 100-350 m where also present the grass-scrub consisted of *Vitex chinensis*, *Ziziphus jujuba*, *Bothriochloa ischaemum* preserved on grit carbonate cinnamon soil and used as a pasture and *Pinus tabulaeformis* plantation on the shade side all these natural and cultivated vegetations form a mosaic structure. On the low-mountain of 350-800 m in the eluvial cinnamon soil is developing, the broad-leaved forests and scrubs dominated by *Lespedeza bicolor* and *Corylus heterophylla* remain on the sunny side, on the shade side appear mainly the plantations of *Pinus tabulaeformis* which are often mixed with survivingbroadleaf forest, sometimes we can see *Quercus liaotungensis*. In this area except protecting natural vegetation, the big blat apricot, haw, walnut, chestnut have been mainly developed, among these trees the planting elevation on the mountain of the big flat apriat is under 900 m, the haw under 800 m, chestnut under 500 m, and parsimmon between 200-300 m. The walnut, apricot and persimmon adapts to alkaline soil they usually grow on limestone soil and chestnut adapts to acid soil and grows on granite soil.

Table 1 — The vertical climatic belt of north mountain system of Bejing

elevation	mean annual temperature (°C)	≥ 10° C accumulated temperature (°C)	frost-free season (day)	mean annual rainfall (mm)
80-150 m	11.5-12.3	4150-4200	over 200	600 or so
150-350 m	10-11	3800-3900	200-192	620
350-800 m	8-10	3900-3150	192-155	650
800-1800 m	8-2	3150-3120	155-130	700
over 1800 m	2-0.5	<3120	<130	over 700

The main types of vegetation of Haitu mountain

1.Forest

- i. Form. *Pinus tatulaeformis* Carr., distributed at 850-1000 m, sunny side, shadow side
- ii. Form. *Quercus liaotungensis* Koidz, shadow side, 800-1300 m
- iii. Form. *Quercus liatungensis* Koidz, *Tilia mongolica* Maxim, shadow side, 800-1300 m
- iv. Form. *Betula platyphylla* Suk., shadow side, 1250-2000 m, secondary forest
- v. Form. *Betula dahurica* Pall., shadow side, 1000-1800 m
- vi. Form. *Populus davidiana* Dode, shadow side, 700-1500 m, secondary forest

2.Bush

- i. Form. *Syringa villosa* vabl., *Spiraea pubescens* Turcz., sunny side, mid-mountain, 1700-1900 m.
- ii. Form. *Lespedeza bicolor* Turcz., sunny side, mid-mountain, 1700-1900 m.
- iii. Form. *Corylus heterophylla* Fish. ex Bess., *Lespedeza bicolor* Turcz., shadow side, mid-mountain, 1200-1800 m.
- iv. Form. *Syringa pekinensis* Rupr, *Celtis bungeana* Bl. (e), shadow side, low mountain, 800-1000 m or sunny side, mid mountain, 100-1600 m
- v. Form. *Spiraea trilobata* L., sunny side, 750-1000 m
- vi. Form. *Prunus sibirica* L. distributed widely on sunny side of hills
- vii. Form. *Deutzia grandiflora* Bunge, shadow side, 600-800 m
- viii. Form. *Vitex negundo* L. var. *heterophylla* (Franch.) Rehd., sunny side, 600-800 m

3.Shrub-erb

- i. Form. *Vitex negundo* L. var. *heterophylla* (Franch.) Rehd. *Ziziphus jujuba* Mill., *Bathriochoa ischaemum* (L.) keng, 600-700 m, low mountain, secondary shrub-herb

4.Meadow

- i. Form. *Carex lanceolata* Boott *Chrysanthemum lavendulaefolium* (Fisch) Makino *Hemerocallis minor* over 2000 m, hilltop
- ii. Form. *Abelia biflora* Turcz., *Salix caprea* L., mixed wet meadow, 1900-2000 m
- iii. Form. *Potentilla fruticosa* L., mixed wet meadow, sunny side, 1800-2000

5.Grassland

- i. Form. *Bathriochloa ischaemum* (L.) Keng. *Themeda triandra* Forsk var. *japonica* (wiud) Makino, sunny side in fornt of mountain, 550-650 m.

THE PROSPECTIVE DIRECTION FOR THE DEVELOPMENT OF THE MOUNTAIN AREA IN BEIJING

1. Combining agricultural production with the restoration of natural vegetation and plantation not only should the production system be created according to the differ vertical belts, but also the natural resources should be transformed and utilized in accordance with the vegetation types in the specific site. The artificial ecosystem and natural ecosystem ought to be formed a correlated complex agro-ecosystem, and to link up the transport channel of energy flow and substance flow between these two ecosystem and finally to raise the total productivity of the region (SUN HONGLIANG etc., 1984).

So that the utilization for different regions is suggeste as follows (see Table 2):

1) The natural forest region in mid-mountains should be classified into the ecoprotective region of conserving water forest. This region covers 29.2% of the area of mountainous region, its topography is high (800-2200 m); the thermal is not sufficient (the accumulated temperature ≥ 10°C being 3200-3600 °C), the main vegetation type is forest. At present the proportion of land used for agriculture, forestry, animal husbandry is 1: 9: 4.5, it seems that the forest ratio is higher. Because of felling tress repeatly in history and serious soil erosion, the land area with forest only makes up 56.7% of the land suitable to afforest, the land area with a soil depth of 25 cm accounts for 40% of the total area, thus the main attention should be paid to the afforestation and protection of conserving water forest. The total rainfull per year in the mountain region of Beijing-Tianjin is 7,120 million cubic metre; the surface run off is 1,861 million cubic metre, equal to 47.5% of the total surface water of this region, which is closely related to people's life and economic construction of Beijing-Tainjin region, so the conserving water forest plays a very important role here. The attention should also be paid to afforest the scrub forest snd construct in part the artificial grassland for developing livestock husbandry in region of farren hill with thin soil which accounts for 22.9% of the total area of this region, the cultivated land has covered 4.8% of the total area, it should not be enlarged again.

2) The basin among mountains should be classified into eco-renovating region of food crop, fruit and animal husbandry, it covers an area of 4.7% of the mountain region with an elevation of 400 m more. The air temperature and precipitation of the basin is more supe-

Table 2 — The agro-ecosystem types of the different vertical belts in the mountain area of Beijing

vertical vegetation belts	agro-region	elevation (m)	land structure* (%)	area percentage (%)	main planting patterns**	economical productivity kg/ha.yr	complex pattern of agro-ecosystem
the temperate type of deciduous broad-leaved forest belt	land type used for interplanting fruit trees with crops at foothills	below 350-500	S 27.8 C 7.6 F 15.5 G 27.4 E 21.7	22.4	wheat-corn-soybean wheat-corn-corn persimmon + corn apple + soybean peach orchard grape orchard	10000 11000 persimmon 3100 + corn 3000 18000-22500	the interplating of fruits &food crops as the major, a comprehensive development type of cow chicken, fish, vegetable, flowers and plants
	land type used for planting trees and fruit trees pasture, agriculture on the lower mountains and hills	350-800	S 5.6 C 0.7 F 32.3 G 43.6 E 17.8	45.3	chestnut walnut + corn hawthorn apricot	3000-4500 walnut (2250-9300) + corn (750-1120) 12000-22000 22500-45000	the artificial afforestation as the major, a comprehensive development type of forage livestock, fruit, agricolture
	land type used for agricolture pasture and planting fruit trees on the intermontane	basin 500-800 (900)	S 45.3 C 2.6 F 8.5 G 15.7 E 27.9	4.7	wheat-corn wheat-sorghum wheat-sweet-potato sesame potato soyboan	5200	the agricolture as the major, a comprehensive development type of agriculture animal husbandry, fishery
the mid-temperate type of deciduous broad-leaved forest belt the cold-temperate type of coniferous forest belt	land type used for protective natural forest and grassland	800-1600 1600-1900	S 4.1 C 1.3 F 57.6 G 29.2 E 6.8	29.2	potato flat apricot	15000	the conservation of natural forest as the major, a type of combination of forest and animal husbandry

* S: the land used for agriculture
C: the land used for interplanting fruit trees with crops
F: the forest land
G: grass scrub
E: the others

** Continuous cropping: + interplanting

rior than that of plain because of its more coordinate habitat and water & thermal conditions, especially there is a temperate region in front of mountain east of the basin. This region is headed by planting, the proportion of land used for agriculture, forestry and animal husbandry is about 1: 0.24: 0.35. In future in addition to be the main foodstuff base of the mountain region, the basin also serves as an important vegetable base of the urban districts in slack season, which will relax the vegetable deficiency during period of September and October. At present the forest ratio is too low and there is also a problem of soil erosion to some extent, so agriculture and forest should be combined and the fruit, livestock, fishery and processing economy should be developed comprehensively.

3) The region of low mountains & hills should be classified into ecorenovating region headed by conserving soil & water forest. The elevation of this region is 350-800 m, with a land proportion of agriculture, forestry and animal husbandry being 1: 1.28: 1.87. Also the ratio of land used for forest is too low, the practice has demonstrated that the land proportion should be regulated to the proper proportion of 1: 4: 3.5. The soil erosion in this region is rather serious, natural ecosystem has generated, the land with forest only accounts for 36.3% of the land area suitable to afforest, the land area with a soil depth of <25 cm accounts for 53% of the barren hill area. Therefore the afforestation of conserving soil & water forest should be put in the first position, in addition a portion of cultivated land should be returned to forest and the forest, fruit,

agriculture and animal husbandry should be combined with developing the processing and tour economies.

4) The hill platform in front of mountain should be classified into eco-renovating region of food-crop and fruit. The elevation of this region is 50-400 m, including the hill platform in front of mountain and of flood accumulation, which covers 22.4% of the mountain area. The proportion of land used for agricolture, forest and animal husbandry is 1: 0.43: 0.77. The interference from mankind here is serious, the vegetation here is mainly the secondary bush and shrubherb, most artificial plantations are fruit forests. There is a long history here of interplanting between ftruits and food crops, which should be the main part of the agriculture in this region and with developing the animal husbandry, fishery, processing & tour economies. The barren hill accounting for 13.9% of the total area of this region shoul be accelerated to afforest. The land of agriculture, forest and animal husbandry should be developed into a proper proportion of 1: 1: 1. The topography superiority of the moderate region in front of mountain (its mean year temperature is higher than that of plain by 0.5° C) and the advantageous geographical superiority of technique, labor and communication resulting from shorter distance to urban districts should be brought into full play and thus to construct this region into a producting base of modernized agriculture and a model of eco-farm, the region should establish a direct close contact with the supply and marketing organizations, serve to the capital and make a greater contribution to Beijing.

2. Establishing the natural protective regions. The flora of mountain area of Beijing is situated on the transition zone of the northeast and north China floras, and on the transition zone from humid district to semi-umid district, so establushing natural productive regions will greatly benefit both the study of regional change of natural environment and the protection of resources of animal and plant population. At present the mountains of Bongling, Baihua, Shanffang, Haituo, Yunmeng, Wuling have been included in the natural protective region.

3. Meeting the needs of the urban districts and capital. Taking the superiority of the suburb of the capital city, the mountain area can provide the city with more fresh fruits, livestock and fishy products all year round. Particularly, low mountain basins enjoy condition for farming, because of low mean temperature and their great amplitude tuber and root tuber vegetable can be produced, especially some fresh vegetables can be supplied in the late season.

4. Developing eco-farming, setting up eco-farm. since the peasants in mountain area of Beijng have ligher level of agrotechnique, they have used relatively little chemical fertilizers and pesticide, so the environment pollution has not been caused. This will make it easy to manage ecofarming economy efficiency, but also can improve the quality of environment. The eco-engineering is the main part of the eco-farm technical system with modern scientific techniques, a more perfect situation could be realized.

BUILDING UP THE HEALTHFUL ECOLOGICAL REGION AROUND TOURING SITES

It is well known that Beijing has a famous both at home and abroad place of historical interest - Ming Tombs, they spread all over the place on foot of the mountain, golden buildings emerge in green trees, they are enchanting sights of Beijing. The Great Wall built in Qin Dynasty about 2000 years ago. It meandres and spreads on ridges of low-mountain and is very magnificient. The Great Wall is a chinese civilization heritage, it reflects the specific nation style of different periods in history of China. In addition to these places, there are many other places of historic interest which are being developed successively as new touring places and will become the most attractive ones to chinese and foreign visitators, but more attention should be paid to healthful ecological regions around touring sites.

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THE CHARACTERISTIC OF THE SCRUB-GRASS COMMUNITY ON THE MOUNTAINOUS REGION IN JI COUNTY OF TIANJIN

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Key words: Ji County, Scrub-Grass community, Mountain vegetation

The scrub-grass communities with an area of 535.7 km² distribute on the lower montain with an elevation of 200-800 m and hills below 200 m in the southern part of Yan mountain at 39° 56' - 40° 15' N and 117° 47' E. These are secondary scrub-grass communities in the deciduous broad-leaved forest region of the warm-temperate zone in China, most of them are mixed with farmland on the hills. Only some patches of deciduous broadleaved forest appear on the top of medium mountain at 800 m in altitude.

In this region the annual mean temperature is 11.9°C, the annual precipitation is 697.2 mm and evaporation is about 1987 mm it is dry and windy in spring, rainy and hot in summer, warm and clear in autumn and cold with frost but a little snow in winter on the mountains.

There are various soil types in the montane region. The drab soil occurs on hills below 50 m in altitude, the leaching drab soil appearing on the lower mountains is very poor and infertility. The brown earth or brown forest soil distributes on the mid-mountains.

The main vegetation in the region is deciduous broad-leaved forest represented by *Quercus aliena* community etc. (WU, 1980). The major physical and chemical properties of the soil are as follows (Table 1).

Under the influences of human activities including denudation, cutting for fuel, reclamation, over grazing, conflagtation and warfare on the montane vegetation. The primitive forests were destroyed, it causes serious water loss and soil erosion (loss of soil is about 265 t/km²/yr), thus scrub-grass communities may appear and scatter on the mid-mountains (YANG 1985).

The scrub-class community is a drought resistant type, it can tolerate the dry and infertile soil on the slopes of 20-40 degrees. The community comprised 60 species, its dominants are the *Vitex negundo* var. *heterophylla*, *Zizyphus jujuba*, *Themeda triandra* var. *japonica* and *Bothriochloa ischaemum*. The frequent spicies, such as *Spodiopogon sibiricus*, *Cassia nomane*, *Arundinella hirta*, *Siphonostegia chinensis* and *Scutellaris baicalensis*, etc. more or less scatter in the community, the main floristic composition in the floral element of Hebei, with some tropical and subtropical element. The structure of community is very simple. It may be divided into strata the *Bothriochloa ischaemum* and *Themeda triandra* var. *japonica* consisting a herbaceous layer grow densely, various deciduous broad-leaved shrubs, such as the *Vitex negundo* var. *heterophylla*, *Zizyphus jujuba*, etc. are scattered on the grass mountain slopes. The plants in the communities are short and sparse, only 70 cm - 100 cm in height, about 40-60% in coverage. The productivity of community is low. The mean fresh and dry weight are 0.52 kg/m² and 0.22 kg/m² (TANG 1985), respectively. The structure feature of community is as follows (Table 2).

According to sample plots investigation (100 sample plots, 1 m² sample area), there are about 61 species including 11 shrub species, and some of them are the exotics. 83% of the total species are in Frequency class A; 10% in Frequency class B; 5% in Frequency class C none of them in Frequency class D and E, it seems inconsistant with the "Law of frequency" especially the species with 1% frequency occupy 37% of the total species but the frequency of the dominant species is below 50%. It demonstrates that the distribution of species in the scrub-grass communities is uneven (RAUNKIAER 1934).

Table 1 – The main physical and chemical properties of the soil in mountainous region

name of soil	pH matter	organic N (%)	whole P (%)	whole K (%)	vhole (%)	C/N	$CaCO_3$
Brown earth	6.38	12.41	0.513	0.168	2.3	14.1	
Leaching drab	7.9	1.19	0.052	0.073	2.54	13.4	0.37
Drab soil	8.1	1.54	0.052	0.164	2.00	10.4	

CONCLUSIONS

1. In the mountainous region the schrub-grass community is a result of human economic activities in a long-term, which degraded from the forest vegetation.

2. In the vegetation successional process the external disturbance repeatedly happened to be. The scrub-grass community becomes a relatively stable stage in the successional series.

3. There are two successional directions for scrub-grass communities under the human continous disturbance, it would probably speed up its becoming the poorest or most extreme sites and cause the vegetation extermination. On the other hand if the vegetation resources are used rationally and protected, it would gradually restore the zonal deciduous broad-leaver forest community.

4. Under the undue stress on the use of the mountain area, the regeneration of the natural resources had been neglected. Owing to lumbering, overgrazing, overcutting the twigs of the vitex (used for weaving baskets, etc.), and overgather medicinal herbs, etc., it leads to the exhaustion of resources waterlosing and soil erosion.

SUGGESTIONS

In view of the facts mentioned above, the following proposals suggested.

1. In order to recover the production of vegetation and the soil fertility, a rational utilization of the resources must be adapted and the protection for the scrub-grass community must be emphasized. The effetive methods are closing the mountain to avoid human disturbance and cultivating shrub and grass. Under rigorous protection, it is possible to recover the vegetation from scrub-grass community succeeding to the zonal deciduous broad-leaved forest (ZHOU 1986).

2. The reconstruction of artificial forest and including fuel forest will speed up the vegetation development. The forest system for water conservation and scenary must be developed. Then the forest community may play an important role on the ecological balance.

3. The regeneration of the natural resources for perpetual use of vegetation must be ensured. To plunder the vegetation resources in the mountainous region must be avoided. How to exploit and protect the natural resources mus t be planned.

4. Grazing in the scrub-grass communities on the slopes of this montane region must be prohibited strictly and advocate feeding livestock in pens.

Table 2 — The structure of the *Vitex negundo* var. *heterophylla,Zizyphus jujuba,Themeda triandra* var. *japonica* and *Bothriochloa ischaemum* community (date: Aug. 1983).

Species	strata	abundance (Drude)	cover (%)	height average (m)	life form	presence
Shrub layer						
Vitex negundo var. heterophylla	I	Cop^2	20	0.8	Ch	V
Zizymus jujuba	I	Cop^1	10	0.9	Ch	V
Indigofera kirilowii	I	SP	5	0.4	Ch	III
Spiraea trilobata	I	Sol	1	0.3	Ch	II
Lespedeza davurica	I	Sol	1	0.3	Ch	I
Herbaceous layer						
Bothriochloa ischaemum	I	Cop^2	30	0.7	H	V
Themeda triandra var. japonica	I	Cop^1	20	1.0	H	V
Arundinella hirta	I	Sp	5	0.7	H	II
Cassia nomane	II	Sol	2	0.3	H	I
Potentilla chinensis	II	Sol	2	0.2	T	II
Platycodon grandiflorum	II	Sol	1	0.3	H	II
Arthaxon hispidus	II	Sp	2	0.2	T	II
Allium sp.	II	Sol	1	0.4	G	I

Because the scrub-grass vegetationin this area not only gives poor production, but also has a low value for food of the livestock. Over grazing irresistibly destroyes the vegetation and accelerates water loss and soil erosions.

5. Conservation of vegetation must be taken in consideration first whenever the natural resource in the monuntain region is developed and utilized. The main purpos of these activities is developing forestry. This is the foundation of the development of the montane region, only having luxuriant forests, can we develop a diversified economy, can we gain great ecological efficiency and economical efficiency as well. If the vegetation is destroyed, water loss and soil erosion will take place ana make this region naked and sanded.

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PRODUCTIVITY STATUS OF A HILLY GRASSLAND IN HAINAN ISLAND

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Key words: Artificial grassland, Productivity, Hainan Island.

ABSTRACT

The present paper compares the productivity of cultivated vegetation with the natural one on the Lipo Grassland in the mid-west of Hainan Island. Normally, the annual fresh weight of the artificial pastures are 6-33 tons/ha, 0.5-7 times higher than the natural ones.

INTRODUCTION

There is a total of 750,000 hectars of secondary tropical grassland in Hainan Island, accounting for nearly 20% of the total area of the island. The most of the grassland are located is hilly area and undulating. The Lipo Grassland is situated in the hilly area of Baisha County, Hainan Island, with a total area of around 3,700 hectares at an elevation of 300-500 meters.

Climate: According to local meteorological data recorded over a long period of time, the annual mean temperature on Lipo Grassland is 22.7° C, the minimum is 3.4°C, and the annual accumulation of ≥ 10°C, is 8,271°C. The annual rain fall is around 2,000 mm. There are distinct dry and wet seasons in this area with 85% of annual rain fall during the period between May and October followed by a November to April dry season of about 165 days.

Soil: The soil of the grassland is mostly yellow laterite formed from granite and sandstone. Due to the damage of the vegetation by human activities and the effect of soil erosion, the ground surface is gravelly with less than 2% organic matter.

Vegetation: The primitive vegetation of this area was tropical semi-deciduous monsoon forest dominating by *Lannea grandis*, *Garcinia oblongifolia*, *Albizzia procera*, *Liquidambar formosana* and *Quercus acutissima*. But the wanton cutting, burning, shifting cultivation and animal grazing in the past have almost destroyed all of the original forest. As a result, the vegetation has degraded into a secondary tropical grassland or savanna, 75% of which consists of *Imperata savanna*, 20% is shrub savanna dominated by *Gossampinus malabaria*, *Phyllanthus emblica*, *Eupatorium odoratum*, *Melastoma sanguineum*, and tall grasses *Saccharum spontaneum*, *Imperata cylindrica* and *Themeda villosa*. Some of the grassland is covered by short grasses dominated by *Digitaria longiflora*, *Panicum repens* and other creeping herbs, such as *Desmodium triflorum* and *Centella asiatica*.

Land use: This area was once cleared for *Pinus ikedai* planting in the period of 1958-1968 but was unsuccessful. It was again heawily exploited for rubber (*Hevea brassiliensis*) cultivation in the 1970s but that project also ended up in failure. Then, it has become pasture since 1980. An experiment with the introduction of some fine grasses, such as, *Stylosanthes guianensis* cv. Graham, *Stylosanthes scabra* cv. Seca, *Macroptilium atropurpureum*, *Brachiaria decumbens*, *Melinis multiflora*, *Panicum maximum* and *Tripsacum laxum* into the area has been carried out.

MEASUREMENT OF PRODUCTIVITY

The measurement was taken on ten quadrats of 1 x 1 m randomly distributing in the community. The above ground part of the plant was cut and weighted. The average fresh weight for each sample was taken as the standing crop (or annual above ground phytomass) to compare with the other. The results are given in Table 1.

RESULTS AND DISCUSSION

Productivity of Artificial Grassland Is Higher Than That of The Natural Grassland

1) The productivity of better grown native *Imperata cylindrica* community as in simple 1 was 18 tons per hectare. That is quite close to the potential maximum yield of 20 tons/ha/yr estimatied by Alferez in the Philippines in 1974 (UNESCO, 1979).

2) The annual productivity ofciltivated grass *Melinis minutiflora* (in sample 9) is 3.3 kg/m²/yr, 78.3% higher than that of sample 1. Besides, the measurement of *Melinis minutiflora* on the grassland in larger area and in the fixed quadrats of 100 m² showed an average yield of 6 tons/ha/yr, identical to that measured by Adegbola in Nigeria in 1964 (UNESCO, 1979).

3) Among various communities given in Table 1, sample 3 (natural community of *Digitaria longiflora* + *Desmodium triflorum*) gave the minimum yield (only 0.4 kg/m²), while samples 6, 9, and 10 (artificial communities) gave higher yelds than sample 1, 2 and 3. If the phytomass of sample 3 is taken as 100%, the yields of samples 6, 9, and 10 are 5, 7, and 6 times higher respectively; if the annual fresh weight of the all natural grassland (i.e. 7.5 tons/ha/yr) is taken as 100%, the yelds of samples 6, 9, and 10 are 3.3, 4.4, and 3.8 times higher respectively.

4) The artificial communities of 4, 5, 7 and 8 gave lower yields due to the over growth of weeds or the failure of the planted grasses to dominate. Nevertheless, Seca in sample 8 giving a yield of 2.6 kg/m²/yr is similar to that of sample 6.

5) The annual phytomass of sample 2 was 2.35 kgm², of which 61.7% or 1.45 kg/m² was *Eupatorium odoratum* that had not been eaten by animals.

6) *Imperata cylindrica* predominated in the Lipo Grassland. Sample 1 was almost a pure population of *Imperata*. In this sample, the fresh weight of Imperata was 1.7 kg/m²/yr, while those of samples 6,9 and 10 were 0.47, 0.94 and 0.70 times higher than that of sample 1 respectively. *Imperata* palatable to cattle and goats, but is not as nourishing as *Stylosanthes*, *Macroptilium*, *Melinis* and *Brachiaria*.

7) Among the cultivated pasture, the annual net primary production of *Stylosanthes scabra* cv. Seca and *Melinis minutiflora* topped others and that of *Brachiaria decumbens* ranked second.

Broad Prospects On Artificial Grassland

In the past 30 years, the Lipo Grassland has seen degeneration of its vegetation and deterioration of its environment resulting from more and more activities of human beings there. Pines and rubber trees were tried to establish on the Grassland but ended with a failure. In reality, the vegetation of this area has changed from primitive semi-deciduous tropical monsoon forest into a savanna, and the aveeage yields of the wild pastures is less than 7.5 tons/ha/yr with a minimum of 4 tons/ha/yr. In contrast, artificial grassland could be yielded 6-33 tons of forage per hectare per year, 0.5-7 times higher than that of matural grassland. The higher production of cultivated forage has ensured higher carrying capacity and contributed to the improvement of environment. The experiment has indeed thrown light on the importance of establishing a new agroecosystem on the grassland.

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Table 1 — Productivity of Lipo Grassland at Baisha County, Hainan Island

Sample No.	Plant community	Height (m)	Coverage (%)	Main species composition	Fresh weight of aboveground (kg/m²)	
					Total	Main plant
1	Imperata cylindrica	1.30	100	I. cylindrica; Desmodium velutinum; D. triquetrum; Hedyotis ampliflora	1.85	Imperata: 1.70
2	Eupatorium odoratum + Imperata cylindrica	1.50	100	E. ororatum; I. cylindrica; Urena procumbens; Sida rhombifolia	2.35	Eupatorium 1.45 Imperata: 0.30
3	Digitaria longiflora + Desmodium triflorum	0.05	80	D. longiflora; D. triflorum; Centella asiatica	0.40	
4	Macroptilium atropurpureum	0.35	100	mixed weeds Eragrostis pilosa; Cyperus rotundus	2.70	Macroptilium: 0.20
5	Stylosanthes guianensis cv. Graham	0.40	75	mixed weeds: Setaria glauca; Paspalum commersonii	0.80	Graham: 0.45
6	Stylosanthes scabra cv. Seca	0.70	100		2.50	Seca: 2.50
7	Macroptilium atropurpureum + Stylosanthes guinensis cv. Graham	0.46	85	mixed weeds: Setaria glauca; Digitaria violascens	1.50	Macroptilium: 0.60 Graham: 0.50
8	Stylosanthes scabra cv. Seca	1.10	100	Mixed weeds: Imperata cylindrica Desmodium triquetrum; Urena procumbens; Eupatorium odoratum	3.60	Seca: 2.60 Imperata: 0.60
9	Melinis minutiflora	0.70	100		3.30	Melinis: 3.30
10	Macroptilium atropurpureum + Stylosanthes guianensis cv. Graham + Brachiaria decumbens	0.80	100		2.90	Macroptilium: 0.40 Graham: 0.70 Brachiaria: 1.80

Note: The measurement was carried out in April, 1985. Samples 1-3 were natural communities; samples 4-10 were one-year-old cultivated communities.

VEGETATION OF THE YEHE VALLEY AND ITS UTILIZATION IN THE CENTRAL SECTION OF THE TAIHANG MOUNTAINS

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Key words: Taihang Mountains; Yehe Valley; Vegetation; Utilization.

The Yehe Valley is located at 37°22'-38°18' N and 113°12'-114°12' E. From south to north the valley is about 90 km long and its maximum width is more than 80 km. The total area is 6,333 square km.

The topography of the region is higher in the southwest and lower in northeast. The height of mountains is more than 1,500 m. Among them Mt. Baiyang, Higher than 1,836 m, is the highest one. The mountains in the eastern part of the valley are midheight. Most of the mountains in the western part of the valley have gentle slopes and are hill-lake. Loess widely spreads over the area and takes important in geomorphy of the area. For example, flattopped loessridge and loess replat. The continental climate dominates the region (GUAN-SHU-KUEI, 1979).

The soils are main drab soil and meadow soil. 321 vascular plant species (67 families) have been found in the region, in which, there are 53 species from Compositae (19 percent of the total species), from Gramineae 26 species, from Leguminosae 25 species and from Rosaceae 24 species. The above four families have totally 128 species and 39 percent of the total species.

BASIC FEATURES OF THE VEGETATION

The ecological feature of the vegetation and the dominant species are as follows:

1. There are a few spring short-living plants forming the major composition of the plant community in the region.

This can be related to the aridity, long winter, and short spring.

2. The present herbaceous community has a smaller saturation of species, there are only 5-8 species per square metre. Obviously this is due to human activity and natural characteristics.

3. The plant cover in the region is about 20-30 percent and the structure of the vegetation is simple. The plants consisting the communities are short.

4. The plants belong to various life forms, most of them are perennial plants therophytes are seldom seen in the region. The major plant community contains species of Compositae, Gramineae, Leguminosae, and some other grasses. These species can be divided into xeromesophytes and mesophytes ecological groups.

5. The plant leaves are narrow and lobeshaped to reduce the traspiration, such as, *Artemisia sacorum*. Usually the surface of the plant is covered with thick hairs.

6. The root system of the plant is distributed widely. They have strong ability to grow indefinite, such as, vegetation propagations. For instance, *Hippophae rhamnoides*, *Zizyphus jujuba*, and *Vitex negundo* var. *heterophylla* propagate by sprouting from their roots; *Artemisia sacorum* propagate by tillering and so does *Bothriochloa*. All of these are the result of adapting to xeric condition.

MAIN PLANT COMMUNITIES

Most of the land in the region is used for cultivation. Valleys are the only places where the natural vegetation is preserved. The various vegetations distributes in accordance to the topographical variations.

1. Plant communities of flat-topped ridge, replat and slopes.

Most of the land on flat-topped ridge, replat and slopes are cultivated. Natural plants including weeds could be found in the graveyard, cliffs, and farmlan margins.

1) Graveyard plant.

In graveyard the earth is substantial and abundant with humus. The main plant are *Artemisia sacorum*, *Bothriochloa*, *Heteropoppus altaicus*, etc. Their cover is about 20 percent.

2) Plant communities and communities on the precipices.

Because of steep slopes, they could not be used as farmland, but he thick loess is favourable for plant growth. Natural vegetation distributes there are droughtenduring, deep-rosted shrubs, and small trees, such as *Ulmus pumila*, *Ailanthus altissima* and *Periplosa sepium*, etc.

3) Plants on ridges.

Trampled by people and livestock.

The earth is too hard for the plants. In general, the plants are short, the cover is low. *Artemisia capillaris*, *Chenopodium album* and *Cynanchum chinensis* are common species there.

4) Weeds in the field

Among weed species, the perennial herbs whose roots and stems are strong at propagation are dominat, such as, *Cirsium segetum* and *Calystegia arvensis*.

2. Plant communities in valleys.

The disatribution of plant communities in valleys is influenced by slope aspect and soil moisture:

1) The main plant communities on southern slopes include *Bothriochloa ischaemum* association, *Vitex negundo* var. *heterophylla* - *Bothriochloa ischaemum* association, *Artemisia sacorum*-*Bothriochloa ischaemum* association, *Cledits heterophylla* + *Vitex negundo* var. *heterophylla*-*Bothriochloa ischaemum* association and *Biota orientalis* association.

2) The main plant communities on northern slopes include *Themeda japonica* + *Bothriochloa ischaemum* association, *Spiraea trilobata*-*Carex* sp. association, *Hippophae rhamnoides* association, *Cotinus coggygria* var. *cinerea* + *Spiraea pubescens*-*Carex* sp. *association*, *Rosa xanthina* + *Vitex negundo* var. *heterophylla* + *Bothriochloa ischaemum* association, and *Pinus tabulaeformis* + *Quercus liatungensis*-*Cotinus coggygria* var. *cinerea* + *Ostryopsis* association. Deciduous broad-leaved forests are the zonal vegetation type in the region. The drab soil distributes inaccordingly. The forest of the area posses xeric characteristics. The conifer species can often be found in deciduous broadleaved forest. The common broadleaved tree species in *Quercus* spp. including *Quercus liaotungensis*, *Q. variabilis*, etc. The representative species of the coniferous forest is *Pinus tabulaeformis*. This forest type will be replaced by the secondary community after placed by the secondary community after destroyed by human activities. This sort of secondary communities could be called semixeric bush-herbosa.

Although it is classified and different as a secondary community, but, is the most stable plant community at the current stage.

UTILIZATION OF VEGETATION RESOURCES IN THE REGION

The following measures should be taken according to the local environmental condition the natural resource of agriculture, in the central section of agriculture, in the central section of the Taihang Mountains.

1. Basing on the pattern of the vegetation succession, some excesively used farmland in the forest region should be afforested and the plant resource should be used gradually (LIU LIAN, 1984).

It will undergo a series of stages of vegetation succession to restore the primary vegetation. The following phases should be produced: (see Fig. 1). There are a lot of Therophytes on the abandoned farmland after wasted for one or two years. The common plants are *Stearia viridis*, *Bothriochloa ischaemum*, etc.

They form dominant association.

After three or four years various plants, such as *Artemisia capillaris* and *Themeda triandra* var. *japonica* increase apparently. This is the period that bush-herbosa take the dominant position. The longer the farmland has been abandoned, the more the bush will be invading into the field. If there is no more disturbance the bush could be replaced gradually by forest stage. The forests are a relative stable phase in the succession series. The major type is the deciduous broad-leaved forest

The Taihang Mountains have complicated ecological conditions. After the forest has been destroyed, the retrogical succession of vegetation varies in according to different conditions (see Fig. 2) (LIU LIAN, 1984).

The utilization of the vegetation resources in the central section of the Taihang Mountains should be kept with the following measures:

1) Large scale exploitation and unreasonable utilization for forest resources should be inhibited.

2) The misused farmland should be recovered with forest vegetations, i.e. closing mountain region for establishing forests.

Under normal condition, grass slope on the Taihang Mountains can develop into bush-herbosa and bushes after "closing mountain" for 3-4 years, the forest coverage can reach to 70-80 percent. After more than 15 years those slopes will develop into young forest groves.

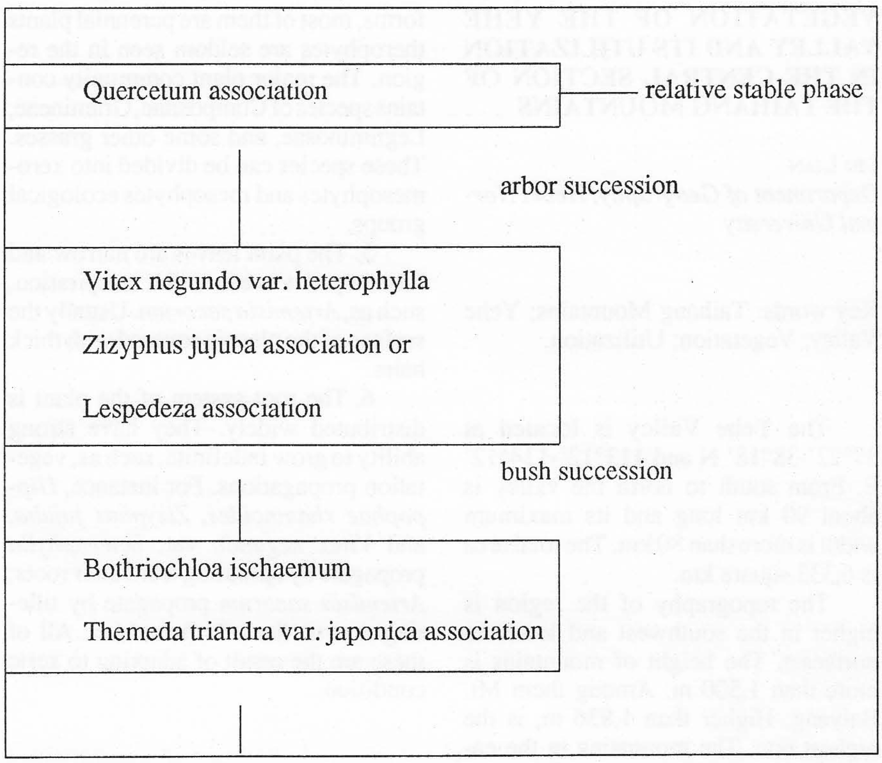

Fig. 1 — Vegetational succession stages.

2. Artificial grassland and forest should be developed to improve environment of the mountain area, prevent soil erosion, and regulate water supply.

Comparing herbage with trees, the latter is more effective in preserving soil moisture, but in earlier period they grow slowly and are sparse. They require more investment and have not economical interests at the beginning. Meanwhile the herbage grows fast and thick, it can make rapid profit in a short period. Sowing grass and planting trees can also increase the organic matter content in the soil and improve the physical properties of soils. The Taihang Mountains have dry and barren soils, so the grass species (Table 1) which posses droughtenduring, wide adaptability, fast growth and high economic value should be chosen as the slopecover plants on the mountains and hills where the forest have been seriously destroyed, afforestation (Table 2) should be taken into practice as soon as possible (YANG ZIN-FENG, 1982).

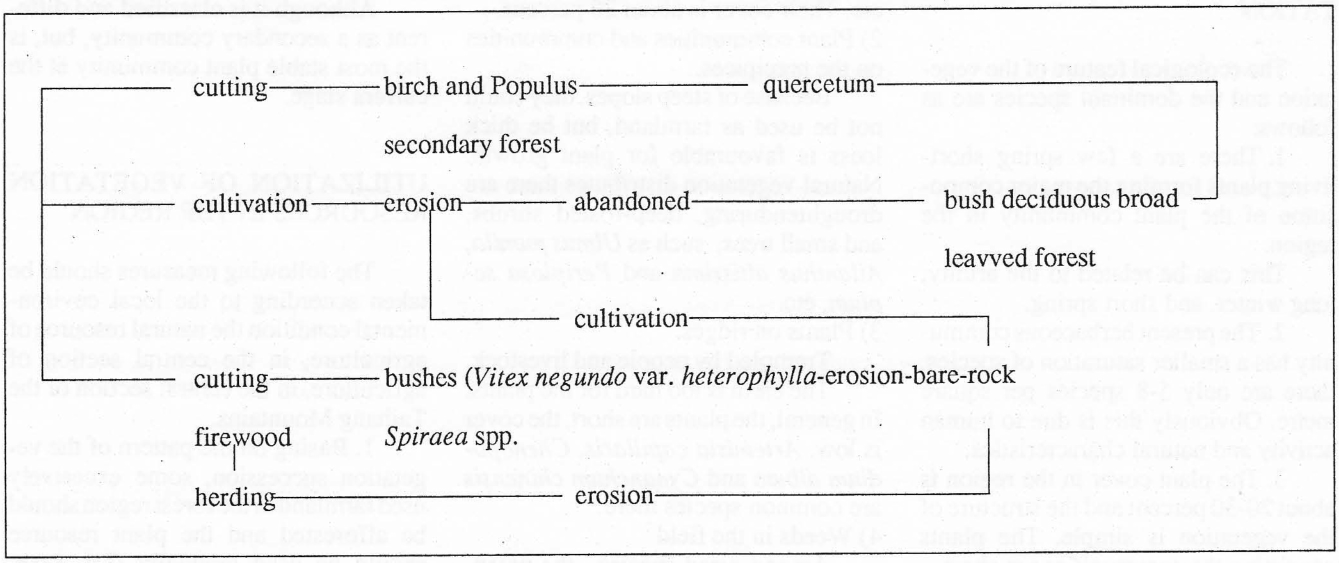

Fig. 2 — The vegetation succession after disturbance.

Table 1 - The plant species suitable for growing in mountainous area

Species	Families	Suitable conditions	Comments
Bothriochloa ischaemum	Gramineae	Slopes of mountains and hills with temperately warm, moderate moisture. For the formation of plant community, consisting of Artemisia, Lespedeza and Themeda triandra var. japonica.	Suitable for forage grass, livestostock like it before blossom. Being less delicious after blossom, livestock also like it, when withered.
Arundinella hirta	Gramineae	Damp environment. Suitable for neutral or acid soil, of widely-planted species.	Livestock like it before earing. Then it becomes less delicious. When withered, livestock don't eat them at all.
Lespedeza davurica	Leguminosae	Drought and barrenness-enduring with strong suitability. Growing on slopes hills and banks of ditches.	Containing highly of crude protein; delicious; livestock like its tender branches with leaves. After bloeeson, it becomes less delicious.
Caragana microphylla	Leguminosae	Growing on dry slopes.	Good for feeding sheep; goats. They like it very much. Tender braches and flowers have fertilizing effect.
Vicia unijuga	Leguminosae	Suitable for dampness and acid soil cold-resistant; growing more in subalpine meadow and among bushes.	Both green and withered are delicious for livestock.
Potentilla bifurca	Ranunculaceae	Growing on slopes, in mountain valley, and foothills with strong suitability.	Both the dried and the fresh are delicious for sheep and goats.
Sanguisorba officinalis	Rosaceae	Growing in mountain meadow.	Valuable plant for feeding; delicious for livestock before blossom; livestock likes inflore-scence after blossom and withered grass, too.
Pueraria lobata	Gramineae	Drought-enduring, cold-resistent, barrenness-enduring, growing in ditches and stony soil.	High in nutritive value. All livestock likes it. Pioneer plant for afforestation of mountains.
Amorpha fruticosa	Leguminosae	Drought-enduring; cold-resistant; barrenness-enduring. Comparatively waterlogging-enduring; anti-sandblowing and salinazation-enduring.	Green manure plant.
Lespedeza bicolor	Leguminosae	Drought-enduring; barreness-enduring. Growing on hill shopes with soil and moisture erosion.	Fine forage and green manure plant.
Ziziphus jujuba var. spinosa	Rhamnaceae	Strong in drought-resistance and strong in suitability. Growing on wasted slopes and steep cliffs.	Covering the surface by bushes effective in strengthening ditches and pretesting slopes and preser-ving moisture and soil.

Table 2 - The species of trees suitable to afforestation in mountains and hills

Species	Families	Suitable Conditions	Comments
Platycladus orientalis	Cupressaceae	Growing under the condition below: absolutely from 45°C, the highest temperature to -25°C, the lowest. Precipitation being less than 400 mm; elevation being lower than 500 mm soil: gowing thicker in soils with strong suitability, of slopes barren and dry and calcareous.	Deep-rooted; sun-love tree species growing slowly. Pioneer species for the afforestation of hills. Its wood quality being hard and rotenduring.
Ailanthus altissima	Simarubaceae	Suitable to climate high in temperature and low coldness, from 47°C, the highest to -25°C, the absolutely lowest, elevation below 400 mm; alble, such as neutral soil, calcareous hills and acid soil.	Deep-rooted, strong-sun-love tree species growing fast. Various uses Pioneer species for the afforestation of hills.
Robinia pseudoacacia	Leguminosae	Cool live, non damp-and-not-love, growing properly from 40° C, the absolutely highest to -20°C, the absolutely lowest, elevation being lower than 1500 m, annual precipitation about 400 m, growing in soils with strong suitability. Neutral soil-love growing also in acid soil and saline-alkali soil with salinity of 0.3 per cent more barrenness-enduring, growing also in hillslopes with surface soil of 15 cm, growing in soil weathered from gneissoild calcareous standstone, but slowly.	Strong sun-love tree species, shallow-rooted plant, growing fast to 10m, with 20 years. Its chest measurement being 18 cm. Its wood quality being hard and root-enduring.
Pistacia chinensis	Anacardiaceae	Warm-love, cold-fear, growing properly from 45°C the absolutely highest to -20°C, the absolutely lowest, elevation being lower than 600 m. Annual precipitation being 400 m. Drought-enduring, suitable to kinds of soils-neutral soil, minutely acid soil and light alkali soil.	Sun-love, deep-rooted tree species, species, timber forest, oil-bearing trees. Its seeds containing more oil, being eatable or useful in industry, fast growing as well.

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THE CHARACTER OF MOUNTAIN GRASSLAND AND ITS EFFECTS ON CHERNOZEM FORMATION PROCESS. XILIN RIVER VALLEY, INNER MONGOLIA.

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Key words: Mountain grassland, Vegetation of Mongolia, Chernozem.

THE NATURAL CONDITION OF THIS AREA

The types of vegetation, the structure of plant community and the chemical composition of plant make an important impact on the soil formation process, soil nature and profile shape. In this paper, we report the character of mountain grassland and its effects on chernozem formation process, Xilin River Valley, Inner Mongolia.

The chernozem of Inner Mongolia distributes at the east and northeast of Fulunbeier Plateau and the western part of Daxinanling Mountains (INNER MONGOLIA NINGHSIA INTEGRATION SURVEY TEAM, ACADEMIA SINICA, 1978). The chernozem of Inner Mongolia joins with the chernozem of Northeast China (NANJING INSTITUTE OF PEDOLOGY, 1978; INSTITUTE OF FOREST AND PEDOLOGY; ACADEMIA SINICA, 1980). The chernozem of Xilin River Valley is the western part of Inner Mongolia Chernozem. It distributes at the east of this area and it joins with the western steppe chestnut soil. The most part of Xilin River Valley belongs to Inner Mongolia fold zone. The upper reaches of Xilin River belongs to Daxinanling fold zone. The three structure movements from Mesozoic Era exercise a great influence on the topography of this area. The fault movement and Spurt and intrude of magma has arisen in the Yanshan movement, but the risefall movement and break of this area has arisen in new structure movement. The Ximulaya mountain building gives rise to break line of magma intrude and overflow in this area, so the basalt in a great range has arisen. These big structure movements of this area layed the groundwork of geomorphological type of this area. Since corrosion and accumulation process long time ago, so it formatives types of topography: mountain, downland, basin dane etc. But the chernozem mainly distributes at the mountain and downland.

This area was a low sea in Silurian period-Devonian period, so there are a lot of sand, clay and calcium deposit. Since early pleistocene epoch, there are a lot of loss deposit in this area. The above mentioned different types of basal rock and their sedentary product alluvial deposit are prevent material of chernozem.

The climate of this area belongs to the temperate-semiarid zone. According to Baiyinhahao climatological station data, its annual average temperature is -1.4°C, the average temperatures are 17.4°C (July) and -23.4°C (January), annual average precipiatation is 44.9 mm and 87.3% concentrate from May to August.

The types of vegetation are more complex. There are forest, grassland, meadow and bog in this area. The chernozem developments are beneath mountain meadow-grassland. Our study period extended from 1979 to 1985, and study program is about distribution of chernozem and its vegetation types, character of plant community and its product, the dynamic of biomass and their chemical composition of plant which contains aboveground and underground.

RESULTS

Community Character

The chernozem develop beneath mountain meadow-grassland which includes three types i. e. Arid-cluser-grass grassland, *Aneurolepidium* grassland and *Filifolium* grassland. They have different ecogeographic and community character.

First of all, arid-cluster-grass meadow-grassland distributes at higher downland slope and basalt volcanic Conp slope which is more than 3000m above sea level. Their area is small and mainly distributes among *Aneurolepidium* grassland or *Filifolium* grassland, so they often are complex of arid-cluster-grass-*Filifolium* or arid-cluster-grass-*Aneurolepidium* grassland. This type of meadow-grassland consists of plant species with fluctuation from 29 to 39 species plant in per square meter. Dominant species are arid grass as *Stipa baicalensis*, *Aneurolepidium chinense*, *Koeleria cristata*, *Artemisia eriopoda*, *Astragalus melilotoides*, *Bupleurum scorzonerifolium*, *Galium verum* etc. Among all species of plant. The Gramineae accounts for 17.78%. The Leguminosae is 11.11%. The Compositae is 11.11% too. Others are Liliaceae etc. Their coverage is 63% and community is 19 cm in height (Table 1).

The *Aneurolepidium* grassland distributes at higher downland, low ground and overcast slope of mountain. It consists of 28 species of plant. Their dominant species are *Aneurolepidium chinense*, *Bupleurum scorzonerifolium*, *Schizonepeta mutifida*, *Galium verum*, *Serratula centanloides*, *Carex lanceolata*, *Sanguisorba officinalis*, *Vicea unijuga*, etc. Among them, the mesophytes as *Sanguisorba officinalis*, *Carex lanceolata* etc. makes up 46.43% of all species of plant. Their total coverage are 70%, the height of the community is 30 cm.

The *Filifolium* grassland distributes at the top of downland and some basalt stands. The area of this type of grassland is small and distributes among other types of grassland. It consists of 30 species of plant which fluctuation from 20 to 22 species in each square meter. Among all species, the mesophytes as *Stipa baicalensis*, *Filifolium sibiricum*, *Serratula centauloides* etc. make up 30% of all species, the other species are xerophytes as *Koeleria cristata* etc. Their dominant species are *Filifolium sibiricum*, *Aneurolepidium chinense*, *Bupleurum scorzonerifolium*, *Allium tenuissimum* etc. The total coverage is 53% and it is 30 cm in height.

The above mentioned data show that this type of mountain meadow grasslands are different with typical grassland in species of plant, total coverage and height of plant community.

The biomass

The biomass of plant community makes an important impact on the soil organic matter, especially its underground biomass. The biomass of mountain meadow grassland is shown at Table 1 and Fig. 1-3.

The aboveground biomass (W_1) in arid-cluster-grass grassland is 179.84 g. m^{-2}, in which Gramineae makes up 67.73%, others are Compositae (12.81%) and Liliaceae (2.82%) etc.

The biomass of underground (W_2) from 0-100 cm soil horizon is 2266.99 g. m^{-2} with its amount in every soil horizon is different. The amount in 0-10 cm soil horizon in 1058.24 g. m^{-2} and it makes up 46.68% of total amount, but the less the deeper of soil horizon. For example, it is only 111. 52 g.m^{-2} in 40-50 cm soil horizon and makes up 4.92% of total amount (see Fig. 1). Their r (W_1/W_2) is 12.61.

The aboveground biomass in *Aneurolepidium* grassland gets to 96.22 g. m^{-2} and it is 73.68% of total amount. Others are Compositae (8.48%) and Liliaceae (4.55%) etc. The biomass of underground is 906.4 g. m^{-2}. Among them, the biomass weight at depth of 0-30 cm soil horizon is 59.40% of total underground biomass. Their r is 9.40 (Fig. 2).

The aboveground biomass in *Filifolium* grassland is the highest in the

Table 1 — The characteristics of different types of grassland.

Types of grassland	Arid-cluster-grass	Aneurolepidium	Filifolium
Height (cm)	19	30	23
Total overage (%)	63	50-70	53
Species of plant (1 m²)	45	22	30
Total yield (kg/ha)	1798.4	962.2	2364.8
Biomass of underground (g. m⁻², 0-100 cm)	2266.99	906.4	3245.02
r	12.61	9.42	13.76

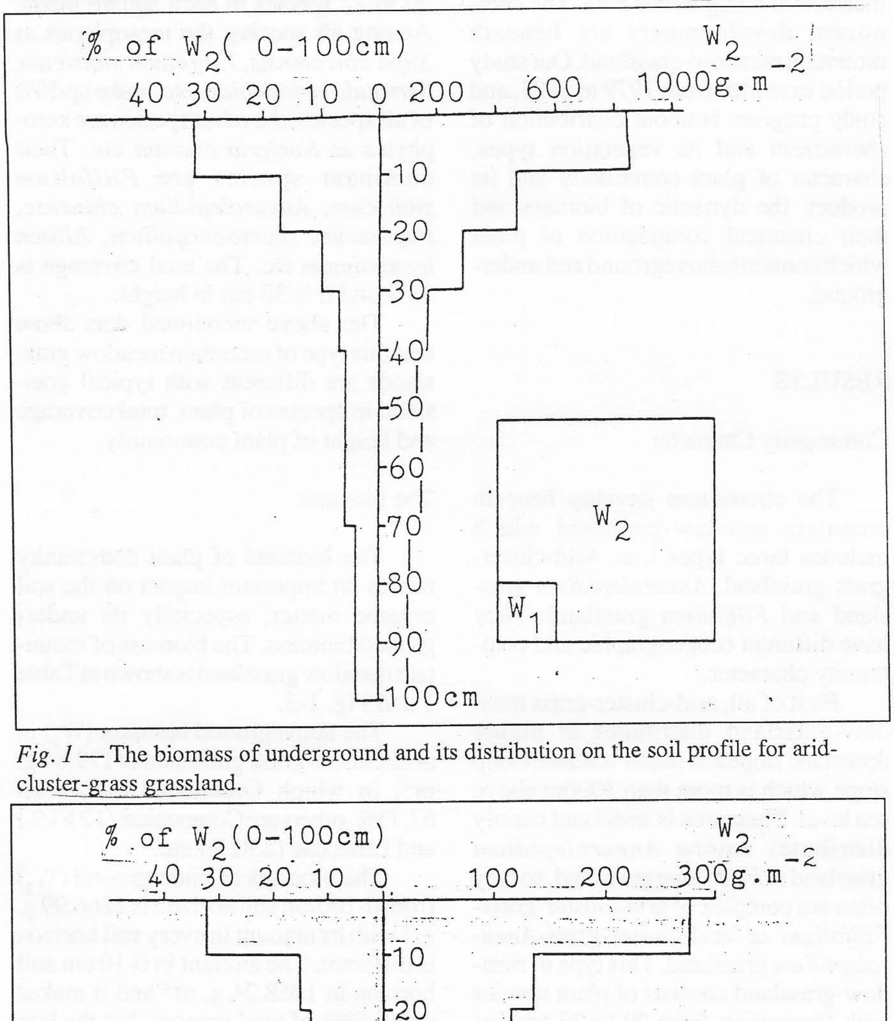

Fig. 1 — The biomass of underground and its distribution on the soil profile for arid-cluster-grass grassland.

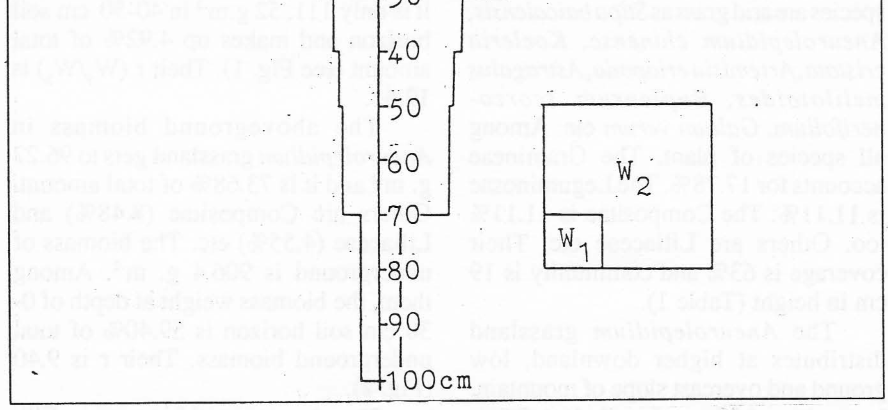

Fig.2 – The biomass of underground and its distribution on the soil profile for Aneurolepidium grassland.

three types of grassland, it gets to 236.48 g. m^{-2}. The biomass of the Compositae makes up 57.22% of total biomass. This is very interesting thing. Its underground biomass is more higher than those of *Stipa* and *Aneurolepidium* grassland too and it gets up 3254.02 g. m^{-2} at depth of 0-100 cm soil horizon. The biomass at depth 0-30 cm soil horizon makes up 66.35% of the total and its r gets to 13.76 (see Fig. 3).

Results from abovementioned indicate that above/underground of mountain meadow grassland are more higher than tropical grassland which formed castonozems and its r volue is more higher.

Chemical composition of above/underground biomass

The chemical composition of plants is an important element for soil formation and its nature. The chemical composition of *Aneurolepidium* grassland and their accumulation are tabulated in Table 2.

The nitrogen content of Compositae gets to 2.623%; it is the highest in all plants, but in the Gramineae is the highest, so its nitrogen accumulation is the highest, it gets to 1390.39 mg. m^{-2} and makes up 53.60% of all aboveground nitrogen accumulation.

The ash content of Leguminosae makes up 11.03%, but the ash content of *Stipa grandis* is only 4.998%. the ash accumulation of Gramineae is the highest too; its amount is 4.95 g. m^{-2} and makes up 47.28% of aboveground accumulation. Among Gramineae, the ash accumulation of *Aneurolepidium chinense* is 3.04 g. m^{-2} and it makes up 61.37% of all Gramineae ash accumulation. The potassium content and its accumulation is the highest in all ash elements. Though the potassium content of Legumineae is the highest (3.968%), its accumulation is lower, the potassium accumultaion of gramineae still is the highest, it is 1219 mg. m^{-2}, and makes up 46% of potassium saccumulation of aboveground.

The above-mentioned result shows that nitrogen and ash elements content and accumulation are dependent on the species of plant and their biomass.

The molecular ratio of silicon dioxide with ferric oxide effects the clay mineral formation. The molecular ratio of silicon dioxidewith ferric oxide in *Aneurolepidium* grassland is more wide. It varies from 13.68 to 148.23. This shows the character of higher SiO_2 content of plant.

The chemical element content and its accumulation play an important role for the accumulation and activity of nutrient elements of soil.

The chemical elements content and

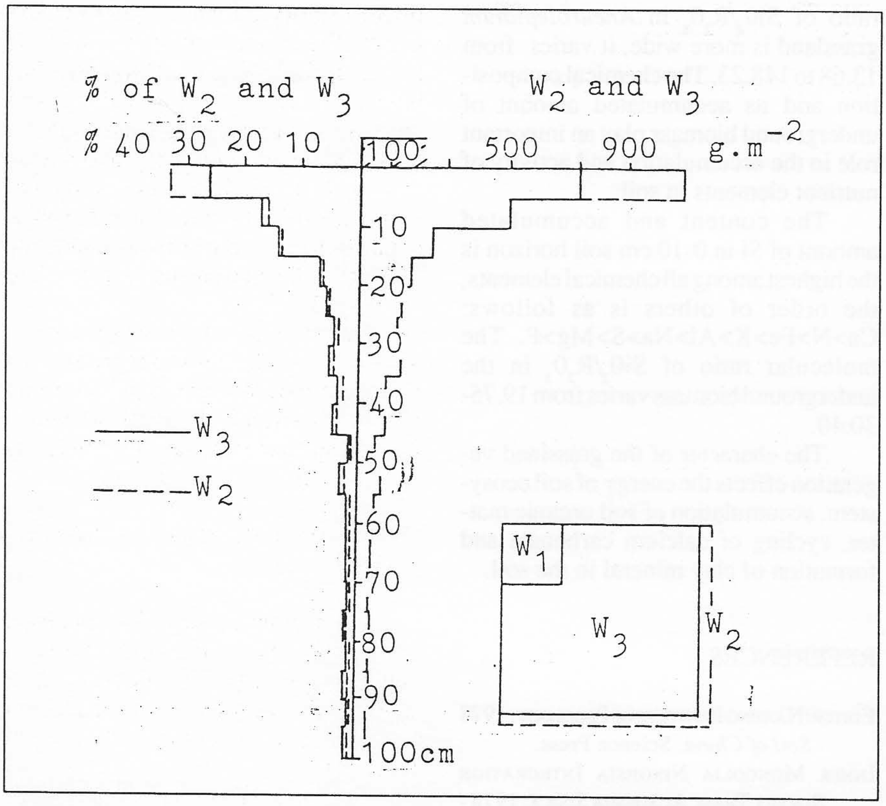

Fig. 3 — The biomass of underground and its distribution on the soil profile for *Filifolium* grassland.

its accumulation are different for the same soil horizon, for example, the silicon content and accumulation at 0-10 cm soil horizon is the highestin all ash elements. The order of other chemical element are Ca> N> Fe> K> Al> Na> S> Mg> P. The order of different soil horizon has similar trend. This shows that the chemical elements content of root system has similar trend. The chemical elements accumulation are different for different soil horizion.

The chernozem developed beneath the three types of mountain grassland vegetation has the same character at soil nature and profile shape, for example, their humus enriched horizion is about 50 cm, humic matter content of topsoil is about 4% and calcic horizon is unclear. The intermediate horizon among ABC horizon is unclear too. The types of clay mineral are montmorillonite and hydromicas. The profile shape of chernozem developed beneath the *Stipa baicalensis* and loess-like sediment was described as follows: 0-16 cm, 7.5 YR3/2, sandy loam, granulometric + lumpy structure, reaction to HC1 0, root system, moisture 16-22 cm, 7.5 YR3/2, sandy loam, lumpy

Table 2 — The chemical composition (dry weight, %) and accumulation (mg. m-2) of *Aneurolepidium* grassland.

Species	N	Ash	P	K	Ca	Mg	SiO_2/R_2O_3
Aneurolepidium	1.475	5.259	0.091	1.525	0.615	0.045	64.50
chinense	852.55	3039.70	52.60	881.45	335.45	26.01	
Stipa grandis	1.567	4.998	0.075	0.954	0.558	0.020	148.23
	357.28	1139.54	17.10	217.51	127.22	4.56	
Gramineae	1.464	6.279	0.090	1.219	0.942	0.020	99.70
	180.36	773.57	11.09	150.18	79.09	2.46	
Compositae	2.623	7.865	0.126	1.403	1.957	0.183	13.68
	442.04	1265.48	20.27	225.74	314.88	29.45	
Leguminae	2.03	11.037	0.155	3.968	1.651	0.182	87.67
	439.93	2389.51	33.56	859.07	357.44	39.40	
Other families	1.85	10.121	0.149	2.047	2.054	0.012	23.00
	341.33	1867.35	27.49	377.67	378.96	2.21	
Total (g. m-2)	2593.49	10475.12	162.11	2711.62	1613.03	104.12	
Soil layer (cm)							
0-10	1.233	21.404	0.016	0.179	2.441	0.079	
	11108.34	192832.92	144.15	1612.65	21991.46	711.73	27.46
10-20	1.193	23.373	0.016	0.192	2.398	0.163	
	4716.17	92398.14	63.25	759.01	9479.77	644.37	24.65
0-100							
Total (g. m-2)	32.40	672.05	0.42	5.34	75.59	3.84	

structure, reaction to HC1 0, root system, moisture 22-58 cm, 7.5 YR3/2, sandy loam, lumpy structure, reaction to HC1 0, root system, moisture 58-78 cm, 7.5 Yr4/2, sandy loam, lumpy structure, reaction to HC1, root system moisture 78-100 cm, 10YR5/1, reaction to HC1, root system, moisture

DISCUSSION

In type of vegetation, effect on not only every of soil ecosystem and organic matter, but also moving of chemical elements and forming of clay mineral. The relation between organic matter of soil and type of vegetation is more clear for us. We only discuss the effects of vegetation on moving of chemical elements and forming of clay mineral. According to above-mentioned results. the leaching and illuviating process of carbonate is an important process of soil formation. The character of carbonate leaching and illuviating, besides depends on parent waterial and climate condition, the types of vegetation take great effects. The effects of vegetation on carbonate moving lies in that plants absorbs calcium for soil in the first, and was illuviated in different soil horizion by decay matter of litter and root system. Calcium content of aboveground biomass at mountain meadow grassland fluctuates 0.558-2.054%, so calcium amount absorbed gets to 1.613 g.m^{-2}, their litter becomes calcium-fountainhead at topsoil horizon. Calcium content and accumulation of underground are more than aboveground. Calcium illuviated gets to 18.296 g. m^{-2} every year at 0-100 cm soil horizion, because decomposition of quarten root system.

Clay mineral is one of the most active solid part in soil formation. There are two types of clay mineral which are Aluminosilicate and oxide. Their formation all concern with plants. Among them, opal often accumulates on topsoil by biogenic accumulation. There are a lot of species of plant in *Aneurolepidium* grassland which Si content is more high, for example, Gramineae content Si 1.490%, i.e. SiO_2 3.19% and its underground content Si 5.64-9.32%, i.e. SiO_2 12.07-19.94%. The biogenic accumulation Si in 0-100 cm gets up soil horizion gets up 190690.63 mg. m^{-2}, i.e. SiO_2 408112.9 mg. m^{-2}. There are 102028 mg. m^{-2} every year transferred to soil if 25% of all root system were rejuvenated every year. This is great source of soil clay mineral opal. But a large number of calcium is favourable to illite formation. The underground contents Ca 3.013% i.e. CaO 3.218%, and then the Ca dissociated to soil gets up 1889.88 mg m^{-2} every year. In addition, the molecular ratio of SiO_2/R_2O_3 in *Aneurolepidium* grassland is more wide, it varies from 13.68 to 148.23. The chemical composition and its accumulated amount of underground biomass play an important role in the accumulation and activity of nutrient elements in soil.

The content and accumulated amount of Si in 0-10 cm soil horizon is the highest among all chemical elements, the order of others is as follows: Ca>N>Fe>K>Al>Na>S>Mg>P. The molecular ratio of SiO_2/R_2O_3 in the underground biomass varies from 19.75-30.40.

The character of the grassland vegetation effects the energy of soil ecosystem, accumulation of soil organic matter, cycling of calcium carbonate and formation of clay mineral in the soil.

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AN INVESTIGATION ON TRANSFORMATION OF HILLY SECONDARY VEGETATION IN SOUTH FUJIAN OF CHINA

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Key words: Secondary vegetation, Sundry fruits, Enclose the hill for natural afforestation.

INTRODUCTION

The hilly lands in both Jinjiang and Longxi Prefectures in South Fujian cover an area of about 1.5 million ha, amounting to 42% of total area, with an elevation of 100-400 m. According to the zonal vegetation regionalism, this area should belong to the zonal vegetation regionalism, this area should belong to the subtropical evergreen broad-leaved forest zone (EDITING COMMITEE OF VEGETATION OF CHINA, 1980). Because of long-term human disturbance, the existing vegetation includes secondary herb-shrub community and sparse *Pinus massoniana*. The herb-shrub community is composed of *Dicranopteris dichotoma*, *Rhodomyrtus tomentosa*, *Eriachne pallescens* etc., with a low biomass (Tab. 1). The investigation conducted in 1985 showed that the coverage of 20 year old *Pinus massoniana* at Pinghe Soil and Water Conservation Station was 15-20%, with 8.2 cm in diameter breast-high (DBH) and 4.83 m in height, incapable of forming a forest.

The destroy of vegetation and irrational cultivation caused the losses of water and soil as well as deposition of sand in the fields and river course, which was heavily detrimental. According to the observation by Pinghe Soil and Water Conservation Station, the surface soil erosion was up to 29 cm during 1916-1986, an average of 0.41 cm a year. As a result, the soil became lean and sandy, and in the soil layer of 0-30 cm the organic matter content was 1.8-4.16%, pH 4.2-4.7, the sand content was 40-54%. In order to conserve soil and water the shortage of rural fuel and develop the rural economy, the two Prefectures were ratedas the major controlling Prefectures, where a comprehensive controlling project was conducted by forestation, growing fruit trees and planting grasses to trandform the herb-shrub vegetation. The preliminary results of four-year investigations and trials wil be discussed in this paper.

Table 1 — Above-ground net biomass of herb-shrub communities (dried at 85°C) in Pinghe County.

Community types	A	B	C	D
Cover degree (%)	60	80	90	30
Sample plot (sq. m.)	4	2	4	3
Baeckea frutescens	836.0			
Rhodomyrtus tomentosa	210.1	1095.8	72.5	
Gardenia jasminoides	99.0	12.1		
Eriachne pallescens	216.6			4.5
Dicranopteris dichotoma			3505.3	
Morinda umbellata			12.5	
Ischaemum indicum				249.1
Digitaria sanguinalis				19.8
Cynodon dactylon				4.2
Chrysopogon aciculatus			4.0	
Total (g)	1406.7	1107.9	3590.3	281.6
Amount (Kg/ha)	3516.8	5539.5	8975.8	938.7

A Baeckea frutescens; B Rhodomyrtus tomentosa; C Dicranopteris dichotoma; D Ischaemum indicum

THE FORESTATION OF FAST GROWING FIRE-WOOD AND CONSERVATION OF SOIL AND WATER

The trial of forestation of fire wood on the eroded red hilly land was conducted in 1983 at Pinghe Soil and Water Conservation Station. The soil contained more than 50% of gravel and coarse sand in the surface soil of 0-5 cm and 0.04-0.142% of total nitrogen in 0-50 cm, pH 4.1-4.8. The main measures we adopted included reserving herbs and shrubs and digging pits and horizontal ditches around the hills. The pits were 40x40x40 cm, planting distance 1.5x1.5 m. The ditches were 0.7 m in width, 0.4 m in depth, spacing varied from 10-20 m, thus intercepting the pouring down of sand and water.

The pits were applied with adequate garbage soil and lime. In spring of 1983, over 20 species of plants were transplanted, including trees, shrubs and herbs, such as *Leucaena leucocephala* cv. *salvador* (PAN ZHI-GANG, 1982), *Acacia auriculaeformis*. At he same time, they were established on terraced fields in Xiamen. Under management, the results were investigated in December, 1986 (Tab. 2).

Table 2 showed the growth of *L. leucocephala* on strong acid soil in Pinghe County was depressed, 3-yr old plants hasn't formed close canopy, while in Xiamen where the soil pH is 5.2, the plant grew fast, the average heights of 3-yr old plants were 5.8 m and DBH 4.9 cm. According to the average of two sample trees (WANG TZE-TING *et alii*, 1984), above ground net biomass (dry weight) was 30.53 t/ha (stems 77.9%, branches 7.7% and leaves 14.6%); 8-yr old *L. leucocephala* was 9 m in height and 14 cm in DBH. Tested with a sample plant, the above ground net biomass (dry weight) was 92 Kg (stems 76%, branches 16% and leaves 8%). Calculated as 2500 plants:ha, it produced 211.6 tons of dry firewood and 18.4 tons of leaves. From the wood annual ring analysis (Fig. 1), the clear cutting period of *L. leucocephala* forest was 5-6 years and sprout forest in 2-3 years. Though the production was not so high as that in tropical zone and they were intolerant to strong acid soil, they were still regarded as fast growing species in coastal areas of South Fujian (SHI TIAN-XI, 1984). Over 340 ha of *L. leucocephala* have been cultivated throughout the province.

A. auriculaeformis were experimentally transplanted in Pinghe County. They showed strong adaptability (XU YAN-QIAN, HUO YING-QIANG, 1982), fast growing, and formed close canopy in two years. The coverage of 3-yr old plant was up to 90%, with average height of 7.6 m and DBH 5.4 cm. According to the tested production, above ground net biomass (air-dried) was 15.91 Kg/plant (stems and branches 74.2%, leaf-stalks 25.8%). Calculated as 4444 plants per ha, its biomass was 70.70 t/ha. The existing litter production (airdried) was 1.33 t/ha, which effectively reduced the soil surface run-off and increased soil organic matter, thus controlling the losses of soil and water. Because of the cover of *A. auriculaeformis*, the under herb-shrub community began to decline in the second year and tended to wither out in the third year, merely a few of shade tolerant trees left. Consequently the herb-

Table 2 — Growth in height and thickness of Acacia auriculaeformis and Leucaena leucocephala cv. salvador

Species	Planting sites	Planting density (m)	1-yr DB (cm)	1-yr H (m)	2-yr DBH (cm)	2-yr H (m)	3-yr DBH (cm)	3-yr H (m)	4-yr DBH (cm)	4-yr H (m)
Acacia auriculaeformis	Pinghe	1.5x1.5	2.7	2.1	4.1	4.5	5.4	6.7		
	Xiamen	2x2	2.0	1.8	3.1	3.4	5.2	4.4		
Leucaena leucocephala cv. salvador	Pinghe	1.5x1.5	1.7	1.6	2.1	2.6	2.4	3.4		
	Xiamen	1.5x1.5	2.6	2.1	3.7	4.3	4.9	5.8	7.3	7.5

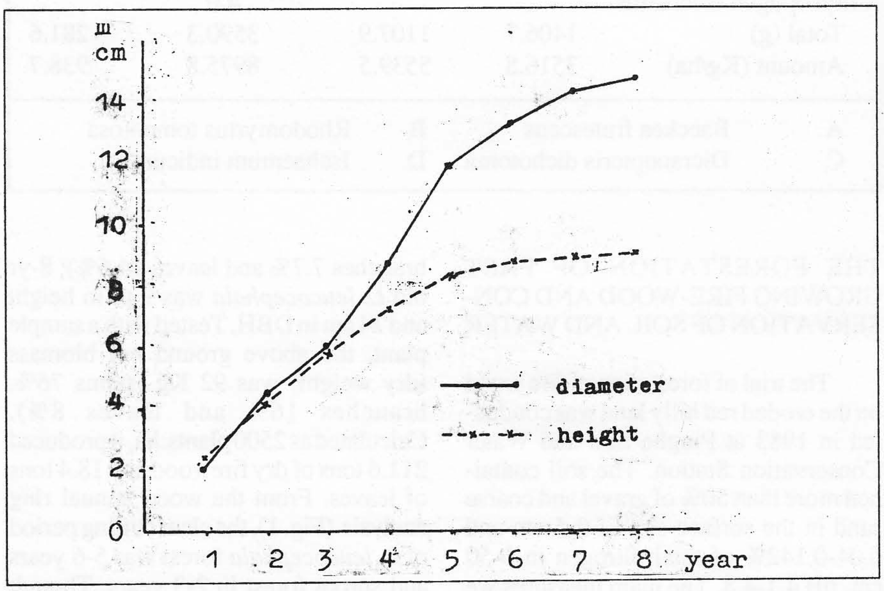

Fig. 1 — Growth curves in diameter and height of *L. leucephala* cv. salvador.

shrub community was replaced by *A. auriculaeformis*.

ENCLOSING THE HILL FOR NATURAL AFFORESTATION AND RECOVERING FOREST

In the vast area of hilly land, the all-round transformation of the existing herb-shrub community was impossible in recent years because of the limited fund and labour. Thus the measures either "Enclosing the hill for natural afforestation" or "Keeping trees and harvesting herbosa" should be taken to recover forest (HUANG SHENG-QUAN, 1983). It was observed that the selection of tree species and managing measures were the keys to be made sure. The species selected may include mixed forest of *Pinus massoniana* with *Schima superba*, *Acacia confusa*, *Eucalyptus robusta*, *Eucalyptus citriodora*. For management, the rule of "Keeping trees and harvesting herbosa" should be implemented, which means protecting young trees and cutting shrubs and herbs in rotation as fuel while aiding in afforestation for the purpose of recovering forest.

In Baoshan of Pinghe County, on the other hand, peasants have insisted in "Enclosing the hill for natural afforestation" for 20 years, where they reforested *P. massoniana* instead of herb-shrub community, *P. massoniana* + *S. superba*, *P. massoniana* + *A. confusa* and *Lemon eucalyptus*, etc. The coverage of hilly land forest was up to 50-60%, the species were complex, mainly *P. massoniana*, *S. superba*, *A. confusa*, *Liquidambar formosa*, *Castanopsis fissa*, *Ilex rotundra* and *Schefflera octopylla*, etc. Underbrush was cut in rotation in parts as fuel, in the meanwhile the wood land was tended. Now the peasants throughout the village have abundant fuel, even can provide to the residents in town. On the contrary, in the neighbouring Yuxi village where people did not take above measure, the land became bare. With doing so, the forest has been recovered for 20 years after trans forming secondary herb-shrub and sparse *P. massoniana*, and the investment made in which is little, with many species and high benefit. When all-round artificial afforestation was carried out on the secondary herb-shrub community, the forest forming period was about 10 years, and 25 year old trees were started to be put intermediate cutting production.

In Tingxi Station farm in Tongan County, for example, which was just set up for protecting Tingxi Reservoir, afforestation was started in 1958 and had completed planting 3000 ha of protecting trees by 1974. In 1986, the total wood accumulation was up to 120, 000 m3, annually 1000m3 wood in minor diameter. The main vegetation types include *P. massoniana*, *Cunninghamia lanceolata*, *P. massoniana* + *S. superba*, *A. confusa* + *P. massoniana*, etc. It was 8-12 m in height, 10-15 cm in DBH, with canopy density of 0.5-0.6, which belonged to intermediate and juvenile forests. It reduced effectively the reservoir deposition and ensured the safety in reservoir production since the forest covered the hilly land within the area of the reservoir. In the last few years the reservoir has become one of tour places in Xiamen.

THE TRANSFORMATION OF HILLY LAND AND DEVELOPMENT OF SUNDRY FRUITS.

In the gentle slope section on latosol hill, because of longterm cutting, the secondary vegetation was very sparse and soil erosion was seriously, which has become a conspicuous problem in South Fujian, especially in coastal areas. The method to reform the eroded hilly slopes was to plant sundry fruit trees, thus combining the production closely with controlling the land. The comprehensive measures taken included building up horizontalterraces and drainage systems, applying garbage compost and basal manure and planting sundry fruits, interplanting leguminous green manure in the field and planting grass on the side slope, etc. The sundry fruits planted include *Myrica rubra*, *Phyllanthus emblica*, *Ananas comosus*, etc. Consequently, we can attain better economical and ecological benefit.

M. rubra is a subtropical wild fruit which only a few were cultivated before. Being tolerant to poor and acid soil and adaptable, they are pioneer fruit trees for greening of hilly land (Shao Shao-hui *et alii*, 1984). In Jinjiang Prefecture, the fruit trees have been cultivated for a long time, and in the last fout years its cultivated area has covered about 870 ha. In Nana county, there have been cultural history of several decades. According to statistics in 1983, the cultivated area of *M. rubra* was over 4700 ha, yielding 7150 tons of fruits a year and its output value was 2.574 million yuan (RMB).

According to the investigation, in Nanjin Forest farm of Nanan County, 225-230 trees were planted per ha. They were put into production starting in the 4 th year and their ful fruit period in the 8th-10th year. 13-year old M. rubra plant was 4.5 m in height and 10-13 m in crown (Fig. 2, 3). At high yielding orchard, average yield was 125 Kg per plant and 75 Kg per plant at low yielding orchard, with the total average yield of 100 Kg per yielding orchard, with the total average yield of 100 Kg per plant. If calculated as sale price in 1986, the output value was 70 yuan and 15,750 yuan/ha. the fruits mature in mid-May. Except for using as flesh fruits, mostly are used for processing *M. rubra* has become pioneer fruit tree for greening of latosol hill, it is of great importance for villages with poor soil to develop economy.

P. emblica is one of the newly developed sundry fruits, suitable to be planted on latosol hill and well received by pesants. The fruits are an excellent material for preserved fruits.

It should be noted that terraced fields should be built for planting sundry fruits on eroded hilly land to prevent from further losses of soil and water. To fertilize the fields and interplant green manure are prerequisites for orchards with high and stable yelds.

Fig. 2 — The terraced orchard of *M. rubra* at Nanjin, Nanan County.

Fig. 3 — Fruits of *M. ru*

DISCUSSION

The way of transforming red soil hilly secondary vegetation is a problem involving many subjects and sectors. From the point of view of ecology, it is quite important to recover forest and promote an innocent ecological cycle.

Firstly, in the vast hilly land, the measures of "Enclosing the hill for natural afforestation" to recover forest vegetation should be taken in the near future, and from the real condition, the measure of "Preserving trres and harvesting herbosa" should be extended and applicated; artificila afforestation should be conducted year by year and hilly gradually realized. With these measures in mind, the work to transform the secondary vegetation could be completed.

Secondly, in real application; the introduction of tropical fast-growing tree species will achieved excepted results provided the trees adaptive to ecological condition are selected. For example, *L. leucocephala* cv. *salvador* is intolerant to strong acidic soil, while *A. auriculaeformis* is tolerant to it. The biomass of 3-year old trees were 30.53 tons and 70.70 tons, respectively, they were 5-10 times higher than that of herb-shrub community, but it is chilling injured at extremely low temperature of -2 C. In South Fujian the planting area of suitable hill is below 200 m above sea level.

Thirdly, in the area with favourable ecological environment, the development of subtropical fruits and other crops, such as *M. rubra*, *P. emblica*, etc. will bring us more economic benefict, but soil and water conservation project should be built.

The screening of acid tolerant type of *L. leucocephala* and its root nodule bacteria and the selection of upright stem type of *A. auriculaeformis* will be further studied.

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ON THE HUMAN INFLUENCE UPON HIGH MOUNTAIN FLORA AND VEGETATION. GENERAL REMARKS

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Keywords: Mountain vegetation, Vegetation belts, Human impacts in mountains.

Of course, this topic would be too complex for a single contribution. Since, in the end, similar evolution might have taken place in most high mountain regions, exemplarily a brief comment on the actual problems of the Eastern Alps may be discussed.

The Alps, the main high mountains of Europe, with an altitude up to 4810 m, extend over 1200 km from (south) west to (north) east. Their biggest width (250 km) lies in the Eastern Alps, which are characterized by an accentuated division into parallel mountain chains. They are divided into the mostly calcreous Northern and Southern Alps, and into the cristalline Central Alps (Fig. 1).

Climatically they belong to three main climatic regions: the oceanic (atlantic) climate in the north and northwest, the mediterranean climate in the south, the continental climate in the east and in the Central Alps.

In very early times the man might have hesitated to settle mountainous areas. Perhaps, we can assume, that for instance in Europe at first pressures of the situation (refuge) or chance for profit (food, mining etc.) might have stimulated the man to enter lacally and even temporarily the Alps. Later on, when he intensified his activities in mining of metals, salt etc., also he took up residence in (main) valleys and he started to construct trade roads across the mountains; he cultivated the valley bottoms and/or the adjacent mountain slopes. That means, he replaced the virgin forests by open secondary plant communities and areas of settlement.

After the intense medieval immigrations also alpine farming above the timber line has been intensified. Further the areas of alpine pastures have been enlarged by depressing the timber line at about 100 - 200 m.

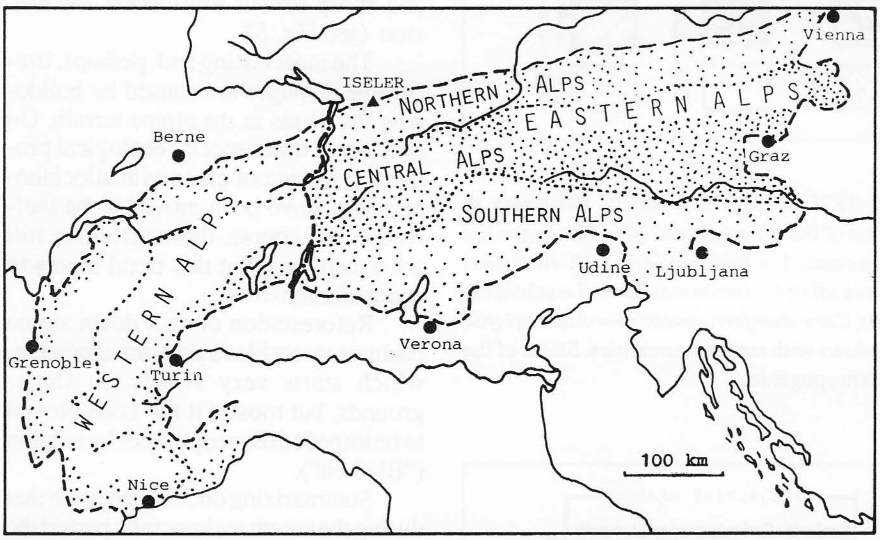

Fig. 1 — The position of the Alps in Central Europe; division according to geomorphologic, geologic, tectonic conditions (in part according to GLAUERT 1975).

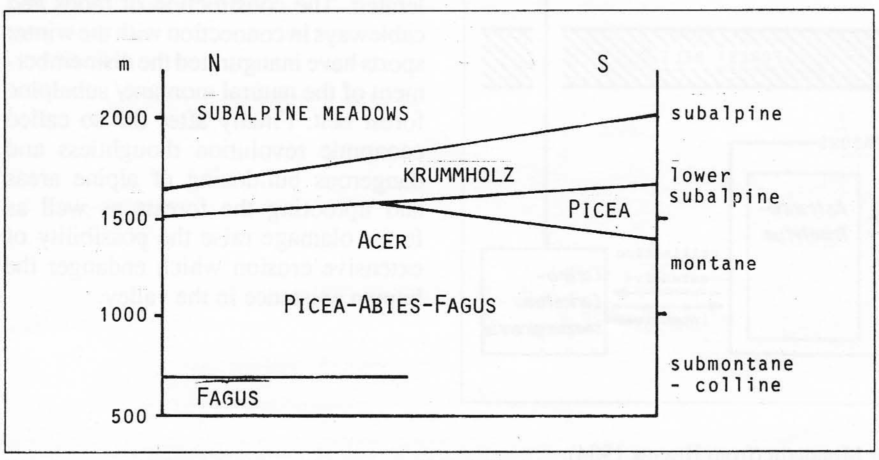

Fig. 2 — Altitudinal belts of the outer side of Northern (Limestone) Alps of Southwest Bavaria (from HERTER 1984).

The remaining primeval forests around the settlements in the valleys have been changed step by step into secondary economic woodlands.

Starting from this base of knowledge today an estimation of the real extent of human influence upon the high mountain ecosystems seems to be very critical. Comparative ecological methods, however, for instance the analysis of herb layers of the forests etc., or the evaluation of historical sources, the results of palynology etc. provide some insight into the recent past of anthropogenic vegetation.

On account of the space available for this contribution the extent of human activities in the high mountains may be demonstrated on the example of a recent analysis of a certain Alpine region in South Germany.

There, we can assume, originally in the higher colline belt beech forests might have been very common, for example *Asperido-Fagetum* also in the lower montane (suboreal) belt. These communities turn above 1250 m into maple associations (*Aceri-Fagetum*). Occasionally certain associations with fir tree (*Galio-Abietum*) are thought to be traditions to *Bazzanio-Piceetum* on ± acid substratum (OBERDORFER, 1950, 1957). About 1450 m subalpine krummholz, i.e. *Erico-Rhododendretum* on screes and fairly seldom *Alnetum viridis* (only on north-exposed slopes), lead up to characteristic subalpine/alpine grass formations above the timber line (1600-1700 m), (cf. SEIBERT, 1968).

The common profile (Fig. 2) reflects the special situation of the vegetation of the outer side of the Northern Limestone Alps, characterized by a moderate oceanic (atlantic) climate with 1200 (up to 2000) mm precipitation and an average annual temperature of 50C, with a short vegetation period (190 days) and with a snow cover of 1,5 m during winter.

The actual vegetation, however, contrasts clearly with the general view outlined above. HERTER 1984 found, that in the Iseler Mountain (Southwest-Bavaria) only the vegetation of rock faces and screes is inaffected by man ("natural"), whilst the original montane forests have been transformed to a large extent into economic forests or meadows or pastures (Fig. 3). Only protection forests etc. of very steep slopes still have preserved a close to natural condition.

As mentioned above in many cases the timber line has been depressed and the forests of the valley bottoms have been replaced by fertile meadows (like *Astrantio-Trisetetum*) and pastures (like *Festuco-Cynosuretum*, which often have been degraded (*Nardetum*). At last the remaining and still ± closed forest belt

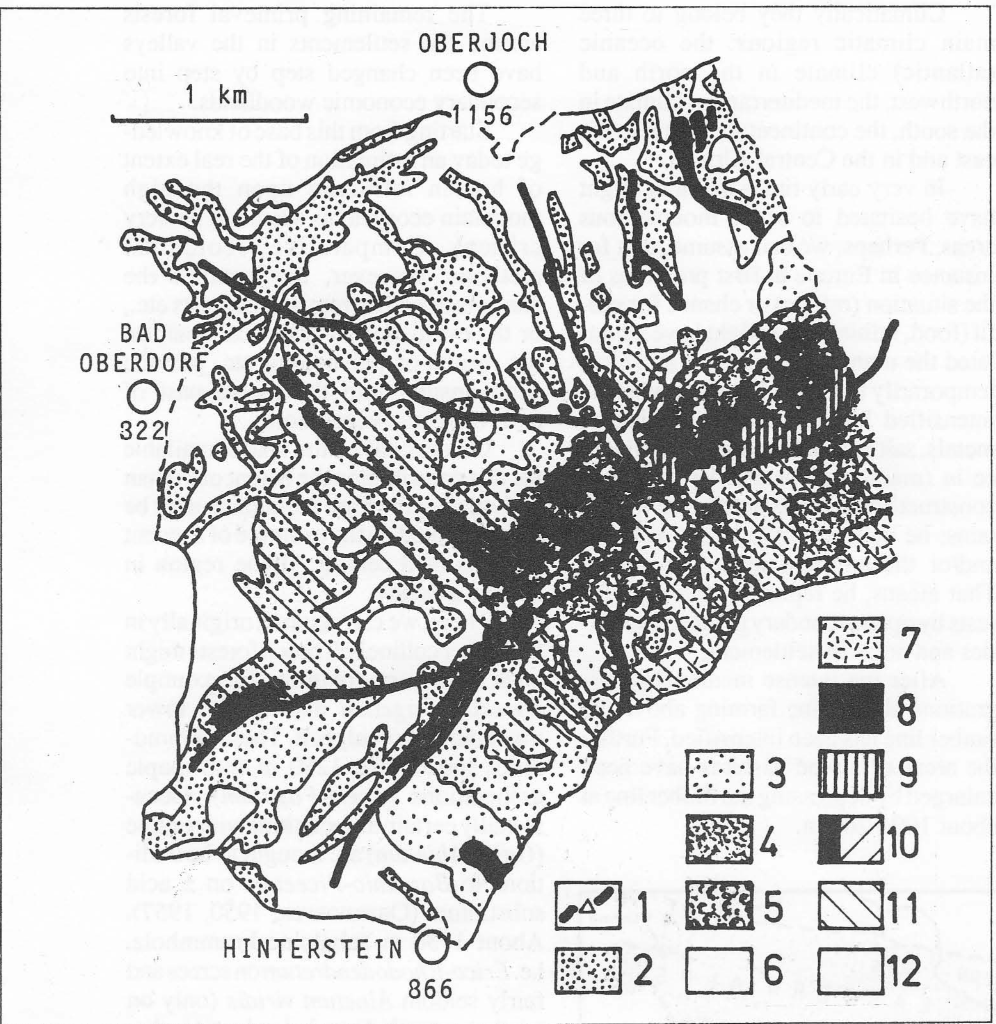

Fig. 3 — The actual vegetation of the Iseler Mountain, 1876 m (asterisk), east of Hindelang in Southwest Bavaria (schematized, from HERTER 1984). 1 = crest of the mountain and peaks (triangles); 2 = (high) forests; 3 = (economic) forests, cleared and/or reforested; 4 = forests mixed with elfinwood (mostly *Pinus mugo*); 5 = Elfinwood (*Pinus mugo* rarely *Alnus viridis*); 6 = fertile meadows; 7 = subalpine meadows (*Caricetum firmae*, *Seslerio-Caricetum sempervirentis*, *Caricetum ferrugineae*); 8 = chasmophytic formations and plant associations of screes; 9 = subalpine meadows with scree communities. Status of the actual vegetation: 10 = natural; 11 = close to natural; 12 = anthropogenic.

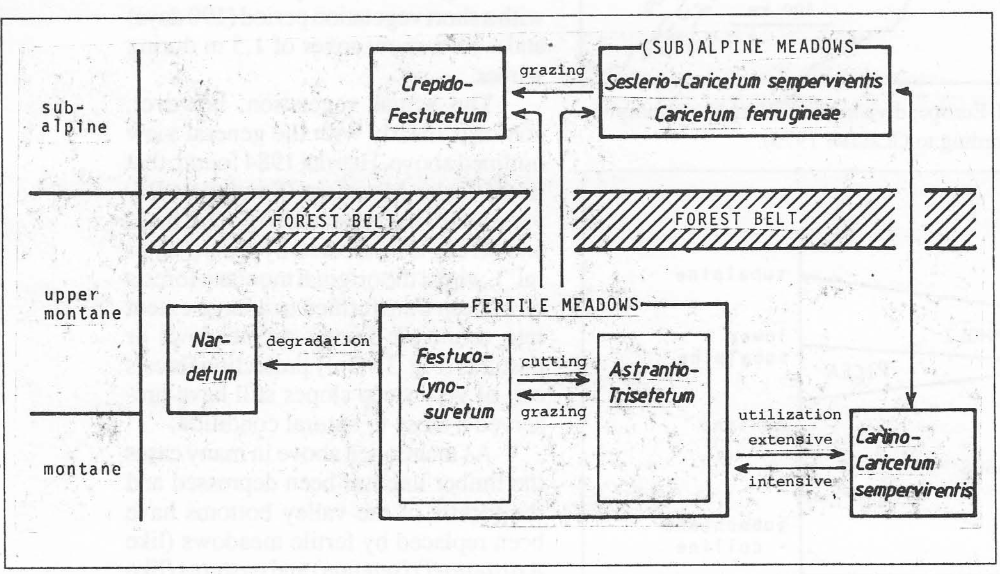

Fig. 4 — Dynamics of grassland formations of the Iseler Mountain (from HERTER 1984).

has been reduced and splitted into small ± isolated forest areas (Fig. 3). Now they are dominated mostly by spruce (*Picea abies*, 91%) Fir (*Abies alba*, 1,9 %!), beech (*Fagus sylvatica*, 7,1 %) decreases more and more or even disappear fully, because overcrowded hoofed game (roe deer, deer, chamois) prohibits natural regeneration (recently also spruce is endangered!).

The recent desintegration of the montane forest belt caused mixing of originally isolated floras of the subalpine belt with elements of secondary fertile meadows and vice versa. The opening of the forest belt and changing economic system have released interesting dynamics within the grassland and pasture communities (Fig. 4).

On account of the "economic revolution" after World War II increasing leisure time and fading willingness for agricultural work have forced the technicalization of the high mountain regions. After the forced construction of roads more and more forests have been sacrified also the (winter) sports.

Snow solified on pistes by mashines and overcrowding of the remaining alpine pastures especially with cattles and sheep fovour solifluction and erosion (see Fig. 5).

The most lasting and, perhaps, irreperable demages are caused by bulldozing the pistes in the alpine terrain. On account of other special ecological properties, sowing of grass with allochthone seeds, have been proved to be ineffective. Of course, these activities still are exceptions, but this trend seems to become intensified.

Reforestation of shut down alpine pastures resembles a protracted process, which starts very slowly on flatter grounds, but mostly it has been proved to be impeded on steep slopes by erosion ("Blaiken").

Summarizing one can ascertain that during the recent technocratic period the devastation of the natural vegetation also in the high mountains regions has accelerated. The construction of raods and cableways in connection with the winter sports have inaugurated the dismemberment of the natural montane/ subalpine forest belt. Finally after the so called economic revolution thoughtless and dangerous bulldozing of alpine areas and uprooting the forests as well as forest olamage raise the possibility of extensive erosion which endanger the human existence in the valley.

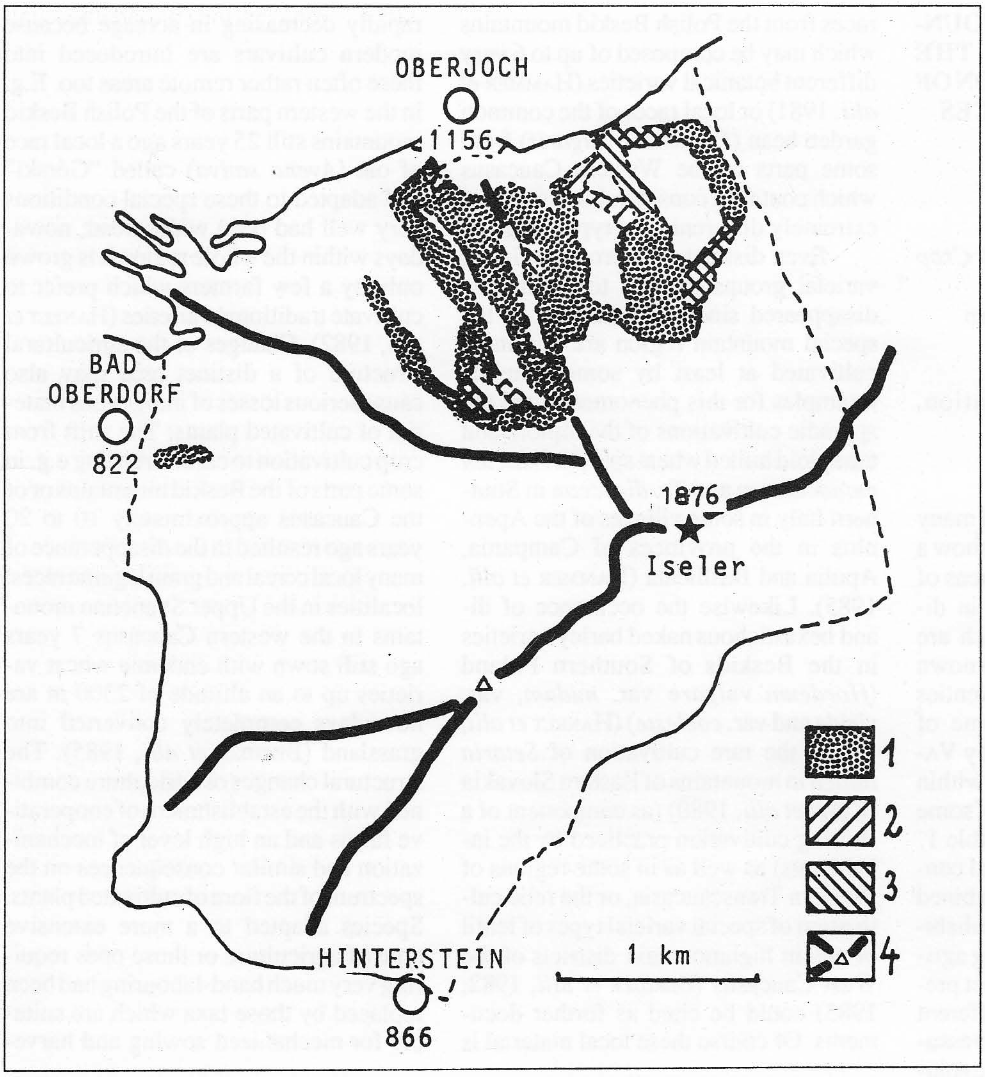

Fig. 5 — Ski pistes on the northwest and west slopes of the Iseler Mountain (from HERTER 1984). - 1 = elder ski pistes; 2 = recent uproots; 3 = bulldozed pistes; 4 = crest of mountains and peaks (triangle).

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THE IMPORTANCE OF MOUNTAINOUS REGIONS FOR THE ANALYSIS AND COLLECTION OF PLANT-GENETIC RESOURCES

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Keywords: Mountain vegetation, Cultivated plants, Gene-centers.

The phenotypic variability of many cultivated plant species does not show a uniform distribution over their areas of cultivation but is often centred in distinct regions of the world which are called gene-centres since the all-known studies of Vavilov during the twenties and thirties of our century. Some of these classic centres recognized by VAVILOV already 1926 are located within mountainous regions; for details of some examples compare the data of Table 1.

The highly diverse ecological conditions in mountains, often combined with an ethnic diversity of their inhabitants (and therefore with deviating agricultural practises and differing diet preferences) have caused rather different natural and artificial selection pressures, thus promoted an intensive evolutionary differentiation among the material of cultivated species and therefore contributed to the formation of these gene-centres. As result of the rapid spread of modern cultivars in recent decades this indigenous material suffered serious losses in many regions but the mentioned areas as well as other mountains of the world are still representing refugial or relic areas for many local variants and indigenous land-races of cultivated species which have been already replaced in other agricultural regions of the world. Therefore the world-wide collecting activities for such material have been concentrated frequently and successfully to mountain areas during the last 20 years. This has been done also by the Gatersleben institute; in the frame of its research for plant genetic resources joint missions were organized e.g. to mountainous parts of Poland, Slovakia, Spain, South Italy and Sicily as well as to the Caucasus region. In all these geographically very different areas an astonishing variability of local races of rather many crops (cereals, grain legumes, vegetables, spice plants) could be still observed in the fields and gardens. Some of these local races themselves are highly heterogenous in phenotypical respect; as illustrations may serve wheat land-races from the Polish Beskid mountains which may be composed of up to 6 very different botanical varieties (HAMMER *et alii*, 1981) or local races of the common garden bean (*Phaseolus vulgaris*) from some parts of the Western Caucasus which contain a considerable amount of extremely different seed types (Fig. 1).

Even distinct relic crop species or varietal groups thought to be already disappeared since long at least in the special mountain region are uptillnow cultivated at least by some farmers. Examples for this phenomenon are the sporadic cultivations of the diploid and tetraploid hulled wheat species *Triticum monococcum* and *Tr. dicoccon* in Southern Italy in some villages of the Apennins in the provinces of Campania, Apulia and Basilicata (HAMMER *et alii*, 1985). Likewise the occurence of di- and hexastichous naked barley varieties in the Beskids of Southern Poland (*Hordeum vulgare* var. *nudum*, var. *viride* and var. *coeleste*) (HANELT *et alii*, 1982), the rare cultivation of *Setaria italica* in mountains of Eastern Slovakia (KÜHN *et alii*, 1980) (as component of a shifting cultivation practiced by the inhabitants) as well as in some regions of Western Transcaucasia, or the relic cultivation of special varietal types of lentil or pea in highmountain districts of the West Caucasus (BERIDZE *et alii*, 1982, 1985) could be cited as further documents. Of course these local material is rapidly decreasing in acreage because modern cultivars are introduced into these often rather remote areas too. E.g. in the western parts of the Polish Beskid mountains still 25 years ago a local race of oat (*Avena sativa*) called "Górski" and adapted to these special conditions very well had been widespread; nowadays within the whole region it is grown only by a few farmers which prefer to cultivate traditional varieties (HANELT *et alii*, 1982). Changes of the agricultural structure of a distinct area may also cause serious losses of indigenous material of cultivated plants: The shift from crop cultivation to cattle breeding e.g. in some parts of the Beskid mountains or of the Caucasus approximately 10 to 20 years ago resulted in the disapperance of many local cereal and grain legume races: localities in the Upper Svanctian mountains in the western Caucasus 7 years ago still sown with endemic wheat varieties up to an altitude of 2300 m are nowadays completely converted into grassland (BERIDZE *et alii*, 1985). The structural changes of agriculture combined with the establishment of cooperative farms and an high level of mechanization had similar consequences on the spectrum of the flora of cultivated plants. Species adapted to a more extensive type of agriculture or those ones requiring very much hand-labouring had been replaced by those taxa which are suitable for mechanized sowing and harve-

Table 1

Gene-centres (VAVILOV 1926)	Mountains/highlands within these areas	Examples of highly variable cultivated species from these region
SW Asia	Hindukush, Pamir, Alai, Tien-shan, mts. of Iran and Afghanistan, Taurus Transcaucasia	*Triticum aestivum*, *Secale cereale* *Vicia faba* var *minor*, *Cicer arietinum*, *Lens culinaris*, *Cucumis melo*
SE Asia	Central and E Himalaya mts. of W China	*Hordeum vulgare* (naked barleys) *Panicum miliaceum*, *Fagopyrum esculentum*, *Glycine max*
Ethiopia	highlands and mts. of Central, N, W and S Ethiopia	*Hordeum vulgare*, *Triticum* ssp. (4x)*Pisum sativum* s.l., *Coffea arabica*
Mexico	Sierra Madre (E and W) and Central Highland	*Zea mays*, *Phaseolus vulgaris*, *Ph. coccineus*, *Capsicu annuum*, *Cucurbita pepo*, *Lycopersicon esculentum*
Peru and neighbouring countries	Andes	*Zea mays*, *Solanum tuberosum* and related taxa, *Capsicum pubescens*, *Arachis hypogaea*, *Lupinus mutabilis*

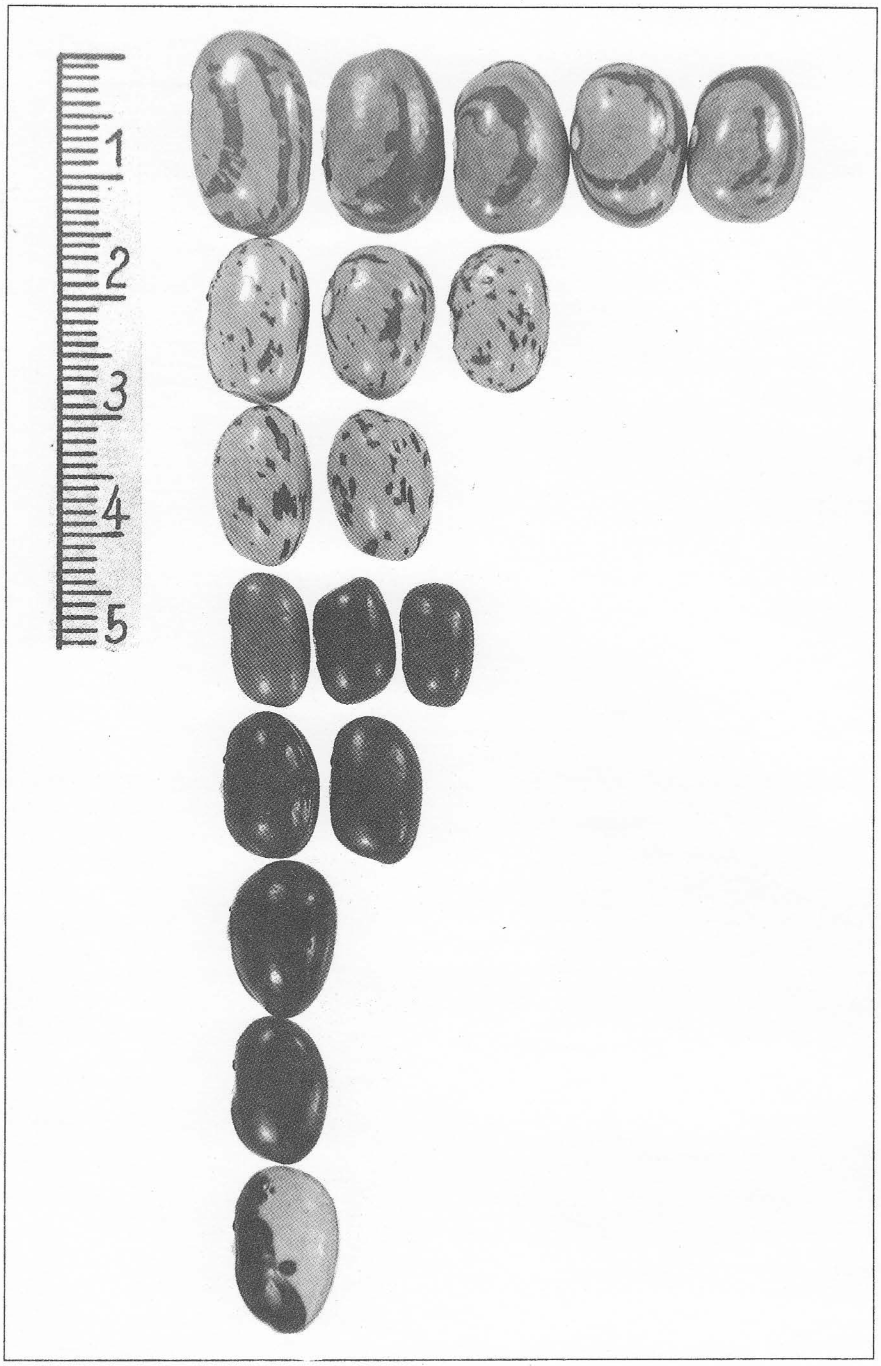

Fig. 1 — Variable local race of *Phaseolus vulgaris*, collected in Vani district, province of Imeretia, Western part of Georgian SSR.

sting and which response positively to better agrotechnics and manuring. This process had led also to the total disappearence of the famous endemic wheat species of mountainous regions in Western Georgia (*Triticum timopheevi*, 2n=28, *Tr. macha*, 2n-42, *Tr. zhukovskii*, 2n=42) which had lost their importance already before world war II, became obsolete soon afterwards and can be found nowadays only in genebanks or similar plant collections. The much more productive and less labour-consuming crop *Zea mays* took the position which formerly had these wheats and other cereals (BERIDZE *et alii*, 1983).

Collection, maintenance and evaluation of such indigenous material from the different mountainous regions are therefore an urgent necessity and an actual challenge. This material has an extremely high value for future breeding work, it proved already to be important as carrier of economically useful characters in many cases: The mentioned Georgian wheat species have been incorporated in many breeding programmes because of their resistance against several fungus diseases and their male sterile forms for hybrid breeding in wheat. Likewise indigenous Ethiopian races of barley could be used as carrier of resistance genes and most of the recent spring barley cultivars in Central Europe and other countries owe their resistance against fungi these local races from the Ethiopian highlands. Within this material also a barley race with an exceptionally high content of lysine, the so-called hiproly strain, could be detected, although the incorporation of this type seems to be extremely difficult and had led not yet to high-yielding cultivars with increased protein quality. There are very many further examples of the breeding value of local strains of cultivated plants from mountainous regions which can't be listed in detail (compare FRANKEL and HAWKES, 1975).

However it should be underlined that such areas are likewise important as plant-genetic resource centres because of the occurences of wild relatives of cultivated plant species which may serve as gene-pools for enlarging the genetic base of our crops. This may be illustrated by the situation in the genus *Allium* (HANELT, 1985): Species of the secondary gene-pool of the common onion, *Allium cepa*, are typical petrophytes of different mountain regions in the Middle East and the most closely related taxa to *A. cepa*, which are already being used in breeding research, are confined in their distribution to the Western chains of the Pamir-Alai system and those ones from neighbouring Afghanistan and northern Iran. Similarly the progenitor species of the Welsh onion, *A. fistulosum*, as well as of garlic, *A. sativum*, are mountain species from South Siberia and Mongolia (*A. altaicum*) resp. Middle Asia to Near East (*A. longicuspis*). The existence of some of these wild species is endangered as a consequence of intensive gathering for bulbs and leaves by the local inhabitants since centuries and thus they had to be included into the Red Books of USSR and some of its union republics (compare BORODIN *et alii*, 1985). For such taxa with a great potential importance for future breeding work a protection in situ by means of special nature reservates or protected areas may be more convenient than the maintenance of collected material in gene-banks where mostly the growing conditions of the natural environment for the reproduction of these species cannot be matched exactly and the danger of genetical changes and the loss of genotypes from the original population is therefore rather high.

These few remarks should encourage to take into account problems of plant-genetic resources into all activities regarding management of mountain landscapes or protection of natural vegetation in mountains.

SUMMARY

The importance of mountainous regions for plant-genetic resources has been stressed and the urgent necessity underlined to collect and evaluate indigenous material of cultivated plants in these areas for the maintenance in gene-bank collections and for incorporation in future breeding programmes.

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FOREST VEGETATION - ENVIRONMENT RELATIONSHIPS ON WEST-CENTRAL VANCOUVER ISLAND, BRITISH COLUMBIA, CANADA

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Keywords: Mountain vegetation of Canada, Reforestation, Forest management.

INTRODUCTION

The objective of this study was to quantitatively describe the structure, composition and ecological relationships of old-growth forests of west-central Vancouver island (GAGNON and BRADFIELD, 1987). These forests are the most productive in Canada. They possess the tallest trees (over 60m high) and the largest wood volumes per hectare. The harvesting of virgin forests, consisting of very large trees, must undergo a shift to the managing and harvesting of short rotation cycles of second-growth forests, consisting of smaller trees. Forest management success will rest heavily on the selection of appropriate species for replanting after logging, and on a understanding of the environmental effects of harvesting and post-harvesting treatments. In this perspective, the study of old-growth forests should provide valuable information for forest management.

More precisely, the purpose of this paper is to try to demonstrate if forest communities characterized through their structure and floristic composition can be equally characterized by the environmental characteristics of the sites they occupy. It becomes important to know how well this relationship holds if knowledge gained from the study of old-growth forests is to be applied in situations where such vegetation has already been harvested.

STUDY AREA

The study area represents an approximately 5,000 km² portion of the west coast of Vancouver Island, from the Pacific Ocean east to Port Alberni, 55 km inland, between 49°20' N and 48°45' N. The topography is extremely rugged and mountainous, ranging in elevation from sea level to 1642 m. Mountains are linked into several small ranges parallel to the coast. Climate is very moist and mild at low elevation (mean annual temperature of 9°C). A strong precipitation gradient, caused by orographic effects, exists from the coast (>3000 mm annually) towards the interior of the island (<2000 mm annually). Much cooler temperatures above 1000 m produce heavy snowpacks lasting often into mid-summer.

METHODS

Data were obtained by sampling 172 plots, at elevations up to 1000 m, located within thirteen drainage areas. Diameter at breast height was measured on all tree stems within 500 m² circular plots. Percent coverage of understory vegetation (shrubs, herbs, bryophytes and lichens) and density of tree seedlings were recorded in 20 1 m² microplots located within the large plot. Site environmental data were recorded and a soil profile was dug. Soil environmental data were obtained from the soil pit description and laboratory analyses of samples. Relationships between vegetation and environmental variation were examined using gradient analysis and multivariate methods. Gradient analysis consists of studying the variation in the composition and structure of vegetation along environmental gradients (WHITTAKER, 1967). Successive reciprocal averaging ordinations of the vegetation data (GAUCH *et alii*, 1977; PEET, 1980) led to the recognition of six vegetation groups (Floodplain, Subalpine, *Pinus contorta*, *Pseudotsuga menziesii*, *Thuja plicata*, *Abies amabilis*) and twenty-three community types.

Canonical variates analysis was used to examine relationships among the vegetation groups and community types on the basis of the environmental data. Canonical analysis accentuates differences among preestablished groups (SEAL, 1964), and was used to assess the degree of environmental similarity among what are considered to be vegetationally distinct units. These analyses, performed for the six vegetation groups and the community types within only the *Pseudotsuga* and *Thuja* groups, are presented here (Fig. 1). The Mahalanobis squared distance (ORLÒCI, 1972) was used to measure the distance between the type centroids in the environmental space (Table 1). Product moment correlations between canonical variates axes and environmental variables assist in the ecological interpretation of the analyses (Table 2).

RESULTS AND DISCUSSION

The six vegetation groups centroids are clearly separated on the 1st and 2nd canonical variates of the environmental data (Fig. 1). Very rapid drainage, crest topographic position, and lack of surficial material characterize the *Pinus contorta* group (D) (Table 2). Slower drainage, lower slope or level topographic positions, and deeper and finer surficial deposits characterize the Floodplain (F) and *Thuja* (T) groups. This large difference in environmental characteristics between these groups is reflected both by their positions on the canonical axes (Fig. 1) and the D^2 values between them (Table 1). Two community types were recognized in the F and D groups (Table 3). Group positions on the 2nd canonical variate can be best interpreted with the LFH thickness/effective rooting depth ratio; the F group is characterized by thin LFH horizons (organic horizons) and deep rooting into mineral soil (ratio closer to zero), while the T group is characterized by thick LFH horizons and shallow rooting (ratio closer to one). Although LFH horizons are thin in the D group, the rooting is very shallow. The *Pseudotsuga* group (P) is the group with the highest environmental similarity with the D group (Table 1). The *Abies* group (A), having several plots situated at high elevations, is the group most environmentally similar to the Subalpine group (SA) based on D^2 values.

Comparing only the P, T and A groups, we find that the *Pseudotsuga* and *Thuja* groups are the most environmentally different (Table 1). Plots from the P and T groups are found in different geographical parts of the study area. The *Thuja* group occurs nearest to the coast where orographic precipitation is highest and fire disturbance is virtually absent. By contrast, the *Pseudotsuga* group is found inland where precipitation is reduced by a rain shadow effect, and where fire disturbances increase in frequency (see correlation of fire disturbance with CVl of the groups, Table 2).

Most of the P community types centroids are separated clearly on the 1st two canonical variates (Fig. 1). However, types PI, P2 and P3 appear very similar environmentally although they are different vegetationally (Table 3). Vegetation structure and signs of fire disturbance indicate that fire is probably at the origin of the vegetation differences between these types, although soil seepage appears to occur in type P2. Topographic position, soil depth, effective rooting depth/soil depth ratio, and LFH pH are the environmental variables most strongly correlated with the 1st canonical axis (Table 2). Type P5, with

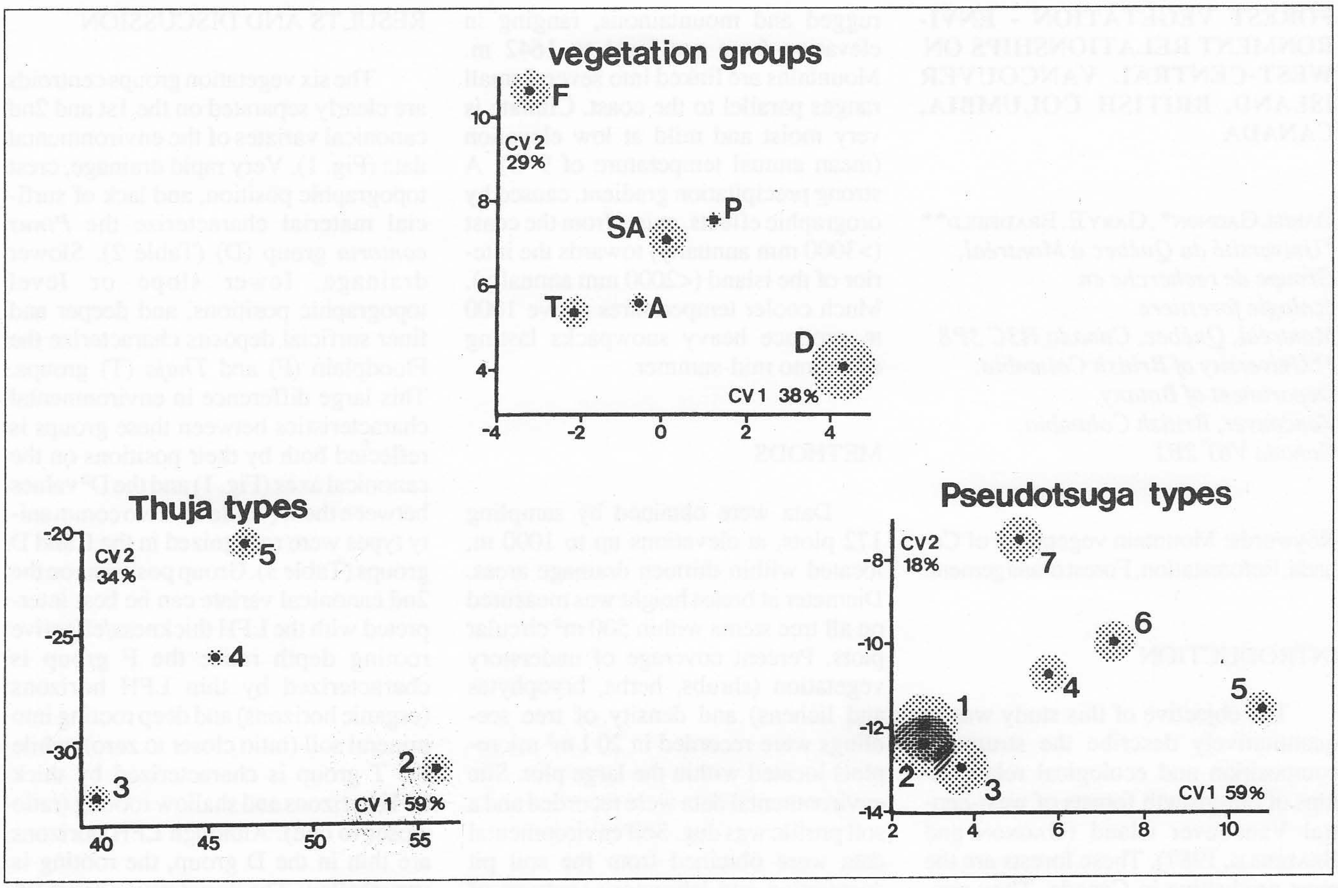

Fig. 1 — Canonical analyses of vegetation groups, and community types within two groups, based on environmental data. Shown are means of plot scores, and 90% confidence circles, on the first two canonical axes (radius = $1.645 \div \sqrt{n}$, Seal 1964).

Table 1 - Canonical analysis results of vegetation groups based on environmental data (Mahalanobis sguared distances, D^2, between groups).

Subalpine	-				
Floodplain	41.1	-			
Pinus contorta	67.7	106.9	-		
Pseudotsuga	16.5	36.6	51.2	-	
Thuja	23.5	33.9	66.0	16.1	-

the largest scores on the 1st axis, is always found on the lower topographical positions and on the deepest soils. Elevation, LFH pH, B1 horizon % N, and topographic position are strongly correlated with the 2nd canonical axis. Type P7, located toward the top of the 2nd axis, is found at high elevations on ridges and crests. Type P2, near the bottom of the 2nd axis, has the highest LFH pH because of the presence of deciduous species with calcium-rich litter (Table 3).

The T types centroids are very clearly separated on the 1st two canonical variates of the environmental data (Fig. 1). Drainage and B1 horizon % N are the only variables significantly correlated with the 1st canonical axis (Table 2). Type T2, with the largest scores on the 1st axis, is associated with productive sites, higher B1 horizon % N, and better drainage. Elevation, percent slope, and topographic position are strongly correlated with the 2nd canonical axis. Types T5 and T4, positioned toward the top of the 2nd axis, were found consistently at low elevations on level or moderately sloping terrain. Type 3 is a higher elevation variant of type T4 (Tables 2 and 3). Type T1 was not included because most plots lacked mineral soils and thus could not be compared to other types by canonical analysis.

In general, most groups and types are distinct environmentally as well as vegetationally. This relationship is weakest in fire prone *Pseudotsuga* types. However, the more productive types for forestry purposes (see basal areas above 100 m²/ha, Table 3) are easily identifiable through site characteristics.

ACKNOWLEDGEMENTS

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SUMMARY

Successful forest management rests heavily on the proper selection of tree species for reforestation after harvesting. Studies of old-growth forests on Vancouver Island have provided some information towards this goal. However,

Table 2 - Correlations between canonical variates and evironmental variables (see Fig. 1).

Environmental variables	Vegetation groups (n=157)		Pseudotsuga (n=56)		Thuja (n=36)	
	CV1	CV2	CV1	CV2	CV1	CV2
Elevation (m)	.32**	-.02	.12	.60**	-.25	-.76**
Slope (%)	.43**	-.13	.30*	-.07	.06	-.73**
Topographic position (crest to level)	-.63**	.34**	58**	-.47**	-.12	.48**
Drainage (rapid to poor)	-.83**	-.10	.03	.05	-.35*	.41*
Soil depth (cm)	-.30**	.11	.48**	.12	-.06	-.19
Surficial material (rocks to alluvial)	-.71**	.25**	-.05	.06	-.25	.35*
LFH[1] thickness (cm)	-.36**	-.47**	.38**	.23	-.02	.28
B^2_1 % coarse fragments	.52**	-.18*	-.01	-.14	.01	-.21
Eff. r. d3./soil depth	.51**	.28**	-.46**	-.20	.05	-.03
LFH thick./eff. r. d.	-.34**	-.58**	.24	.23	-.19	.26
LFH pH	-.10	.42**	-.38**	-.52**	-.28	-.01
LFH % C	.23**	-.21**	.16	.20	.33*	-.10
LFH % N	-.25**	-.38**	.39**	-.36**	-.03	-.26
LFH C/N	.41**	.22**	-.25	-.46**	.23	.12
B_1 pH	.06	.34**	-.04	-.54**	-.02	.31
B_1 % C	-.08	-.34**	-.01	-.45**	.24	-.42**
B_1 % N	-.22**	-.28**	.42**	-.43**	.39*	-.42**
B_1 % C/N	.25**	-.01	-.30	-.00	-.27	-.11
Fire disturbance (absence-presence)	.53**	.39**	-.07	-.38**	-.01	.42**
Wind disturbance (absence-presence)	-.58**	-.39**	-.08	.34**	-.18	-.09

[1] LFH soil horizons: organic horizons (litter, humus).

[2] B_1 soil horizon: first B mineral soil horizon

[3] effective rooting depth: depth at which fine root (<2 mm diam.) abundance is less than 10 per 25 cm².

** = $p \leq .01$; * = $.01 < p \leq .05$

Table 3 - Mean percent importance of trees in community types.

Community types	D1	P1	P2	P3	P4	P5	P6	P7	D2	T1	T2	T3	T4	T5	F2	F1
Number of plots	3	4	4	5	11	17	12	7	4	3	6	7	19	4	2	8
Abies amabilis				1		1	+			1	28	18	12		4	9
Acer macrophyllum			6	+	+	+										3
Arbutus menziesii	13	4														
Chamaecyparis nootkatensis		1			+	+	15	4		5						
Cornus nuttalii			6	1	1											
Picea sitchensis										1	5		+		37	35
Pinus contorta	66	1							28					11		
Pinus monticola							+		4				+	1		
Psudotsuga menziesii	20	93	67	69	50	42	33	30	17	11	3					5
Taxus brevifolia					2	+				3		1	+	6	1	
Thuja plicata	1	1	12	9	12	11	12	14	17	47	18	51	54	53	37	21
Tsuga heterophylla	1	8	17	34	44	54	55	19	34	46	25	33	29	21	26	
Mean total basal area (m²/ha)	31	86	133²	89	138	158	115	86	30	86	142	187	180	88	237	246

1 Percent importance = (relative basal area + rel. density)/2

2 Highly productive types are underlined

site characteristics, rather than old-growth vegetation, are best suited as criteria for tree species selection because of their permanency. This paper shows, through the use of canonical analyses, that many of the most productive forest community types of west-central Vancouver Island can be differentiated through environmental characteristics alone.

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POSITION AND ROLE OF GENUS TSUGA AS CONSTITUENT OF MOUNTAINOUS FORESTS

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Key words: Genus *Tsuga*, Distribution, boreal forest, Pinaceae.

GLOBAL DISTRIBUTION PATTERN

A greater part of species belonging to Pinaceae are distributed all over the Northern Hemisphaere. Among them, however, genera *Tsuga* and *Pseudotsuga* occur both in East Asia, namely in "Sino-Japanese floral region", and North America but not in the western part of the Eurasian Continent. Such distribution pattern, East Asiatic-North American distribution, is found in many plants. As to conifers, *Thuja* and *Chamaecyparis* of Cupressaceae and *Torreya* of Texaceae are of the same distribution patter. In North America, *Pseudotsuga* is distributed only in the western coastal area, while others are found both in eastern and western coastal areas (GOLTE 1974).

Of the genus *Tsuga*, 10 (OHWI 1978, KITAMURA and MURATA 1979) to 16 (TREES OF CHINA EDITORIAL COMMITTEE 1983) species are known 4 are distributed in North America and the rest in East Asia. Among the latter, 2 are found in Japan and Korea, 1 in Formosa and the rest in the continental part from China to the Himalaya.

THERMAL CONDITION OF HABITATS OF *TSUGA*.

Trees of *Tsuga*, like many other species of Pinaceae, are found from some part of the warmtemperate zones to the boreal zones. However, the core of distribution varies from species to species.

Of the North American 4 species, *T. caroliniana* and *T. mertensiana* are located to areas of higher latitude than *T. canadensis* and *T. heterophylla* (UEHARA 1977, KAVANSAGH and KELLMAN 1986). In Japan *T. sieboldii* is found in the areas from warm to cool temperate zones, while *T. diversifolia* is found in the areas from cool temperate to boreal zones. KIRA and YOSHINO (1976), using "warmth index" (KIRA 1945), have made it clear that the distribution areas of them are remarkably separated from the view point of thermal condition in the mountains of the central Japan (Fig. 1).

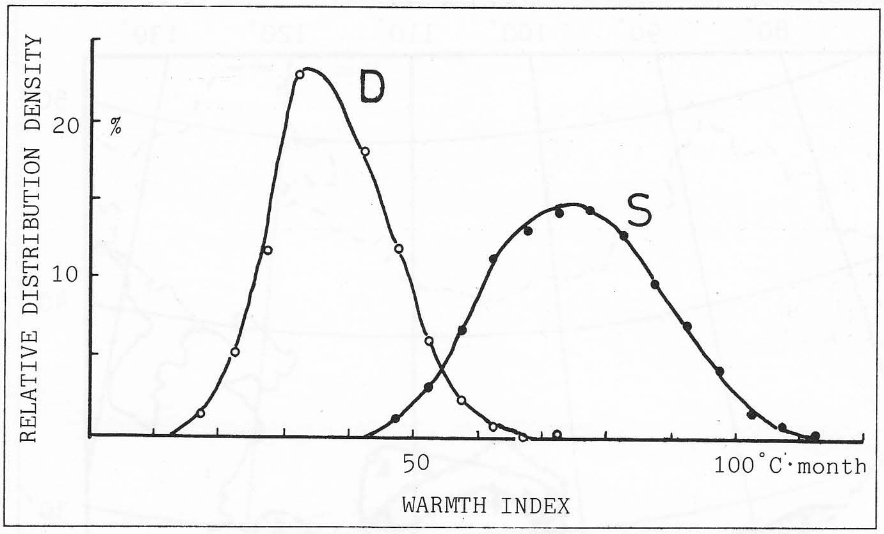

Fig. 1 — Distribution of *Tsuga sieboldii* (S) and *T. diversifolia* (D) in central Japan in accordance with warmth index (KIRA and YOSHINO 1967).

SITUATION OF *TSUGA* IN ALTITUDINAL AND ITS RELATIONSAHIP TO OTHER TREE SPECIES.

T. canadensis, found in the eastern North America, is distributed on the lowland around the great Lakes, and is often a companion species of the summergreen broadleaved forest dominated by *Acer saccharum* and pine forests by *Pinus strobus* and *P. reginosa* (KNAPP 1965). In the Appalachian Mountains it is found from the foot to the area more than 2000 m a.s.l. occurring as a companion of various types of forests. In the elevation from 800 m to 1700 m, it constitutes a coniferous forest as a dominant accompanied with such summergreen broadleaved trees as *Halesia monticola*, *Betula allgheniensis* and so on (WHITTAKER 1956).

In the western coastal area of North America, *T. mertensiana* is found in the Rocky Mountains from 600 m to ca. 3000 m a.s.l., being a companion of forests dominated by *Abies amabilis*, *A. magnifica*, *Chamaecyparis nootkatensis*, *Pinus albicaulis*, *P. contorta* spp. *murrayana* respectively. On the other hand, *T. heterophylla* is found in the lower area, and is not only a dominat species of forests together with *Thuja plicata* but a companion of temperate coniferous forests which are dominated by *Picea sitchensis*, *Pseugotsuga menziesii* var. *viridis*, *Larix occidentalis* respectively (KNAPP 1965).

In Japan *T. diversifolia* is found in Hinshu, Shikoku and Kyushu. In the northen part of Honshu it is found from 600 m to 2000 m a.s.l., in central Honshu from 1500 m to 2800 m and in Shikoku and Kyushu from 1200 m to 2300 m. Though it can occasionally be a single dominant, it usually is a constituent of boreal forests together with *Abies veitchii*, *A. mariesii*, *Picea jezoensis* and *Larix occidentalis*. *T. sieboldii*, on the other hand, is found in areas south of lat. 37° N. In its northern most distribution area, it occurs in the area from 800 m to 1000 m a.s.l., in central Honshu from 350 m to 1650 m, and in Shikoku and Kyushu from 300 m to 1800 m. It is found with *Fagus crenata*, *Quercus mongolica* var. *grosserrata* and so on in some parts of cool temperate forests, and xith *Cyclobalanopsis*, *Castanopsis* and so on in some parts of warm temperate forests. whis species is also found in Ullung Island in Korea (HAYASHI 1951, TATEWAKI and TOYAMA 1963).

Among *Tsuga* species found in China *T. formosana* is distributed in the central range of Formosa from 1300 m to 3000 m forming temperate forests with other conifers.

Continental species such as *T. longibracteata*, *T. dumosa*, *T. forestii*, *T. chinensis*, *T. oblongisquamata* and *T. tchekiangensis* are found in Shanxi, Henan, Hubei, Anhui, Sichuan, Hunan, Zhejinag, Fujian, Yunnan, Guizhou, Guangxi and Guandong provinces of China in the elevation from 300 m to 3500 m a.s.l. (Fig. 2). They are mixed with such conifers as *Abies*, *Picea*, *Pinus*, etc. and with broad leaved trees as *Betula*, *Quercus*, *Cyclobalanopsis*, *Castanopsis* and so on. In some cases they compose coniferous forests as dominants. From the view point of altitudinal belts, they are found in the upper part of the subtropical, in the warm temperate, in the cooltemperate and some times to the upper part of the boreal belt (LIU and QIU 1980, TREES OF CHINA EDITORIAL COMMITTEE 1983).

Among them, as mentioned above, *T. dumosa* is distributed also on the southern slope of the Himalaya mixed with conifers such as *Abies*, *Picea*, *Pinus*,

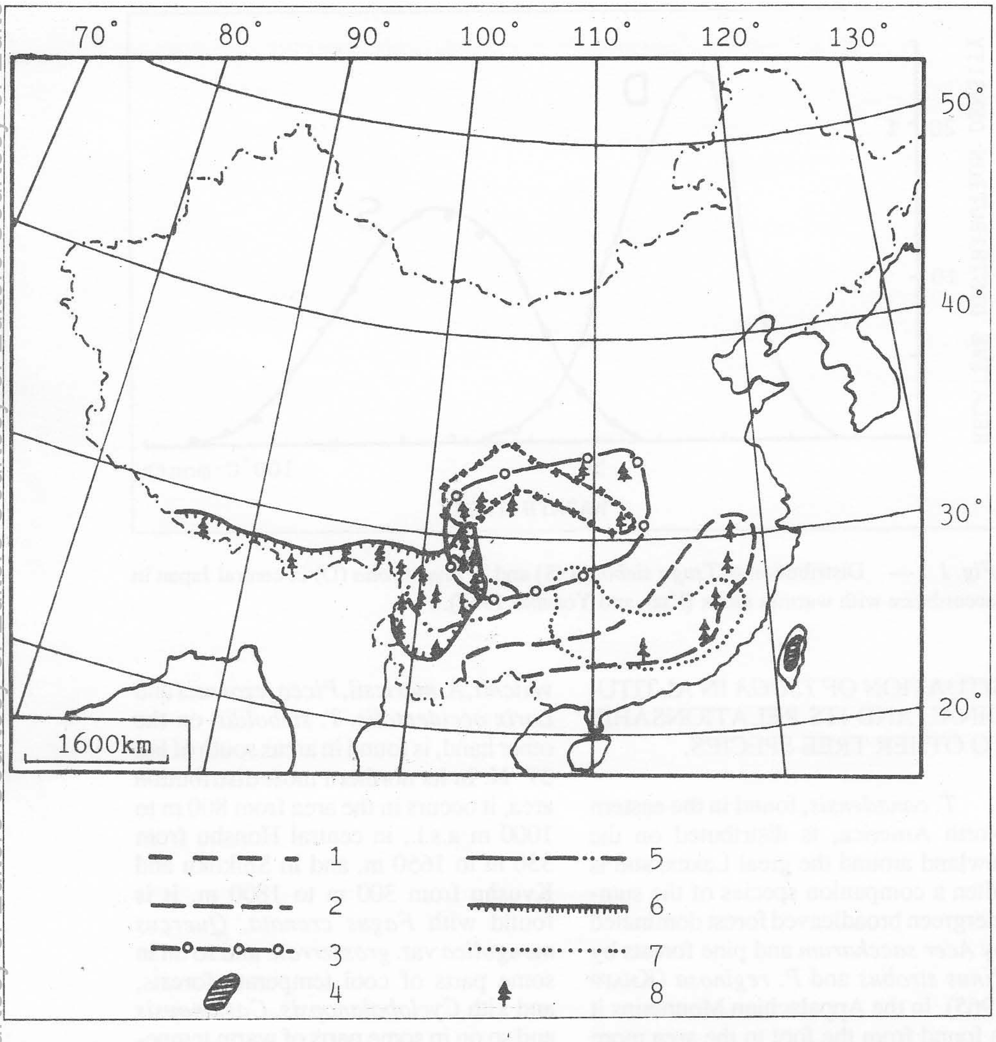

Fig. 2 — Distribution of *Tsuga* in China (LIU and QIU 1980): 1: *Tsuga oblongisquamata*; 2:*T. tchekiangensis*; 3: *T. chinensis*; 4: *T. formosana*; 5: *T. forrestii*; 6: *T. dumosa*; 7: *T. longibracteata*; 8: Locations of pure and mixed forest of *Tsuga*.

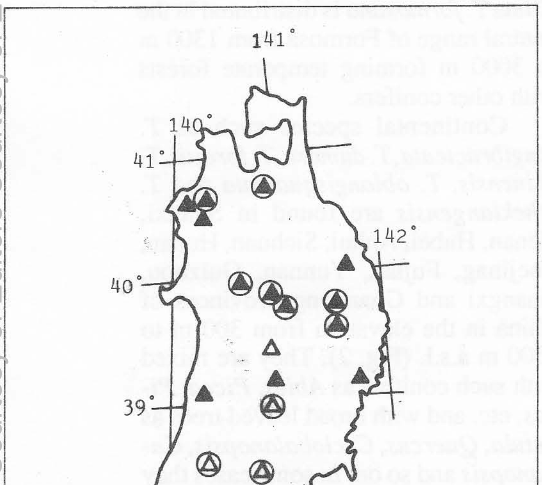

Fig.3 — Distribution of *Tsuga diversifolia* and *Abies mariesii* in the northern part of Japanese main island: solid triangles: mountains with *Tsuga diversifolia*; circled triagles: those with *Abies mariesii*; withe triangles: those without any boreal coniferous forest.

Larix and so on, with summer green broad leaved trees such as *Betula*, *Acer* and so on, and with evergreen broad leaved trees such as *Cyclobalanopsis*, *Castanopsis*, *Altingia*, *Schima* and so on. Its distribution area reaches the elevation of 3500 m where it is a component of a cloud forest (SCHWEINFURTH 1957).

THE STATUS OF *TSUGA* IN THE JAPANESE BOREAL CONIFEROUS FORESTS

In Honshu of Japan, boreal coniferous forests develop at their best in the mountainous area in the central part, Chubu district. In this district, coniferous forests are mainly dominated by *A. mariesii* and *A. veitchii* accompanied with a lot of conifers such as *Picea jesoensis*, *Pinus parviflora*, *P. koraiensis*, *Larix kaempferi* and so on. *T. diversifolia* grows with them, too.

In the northern part of Honshu, however, the species diversity of the boreal coniferous forest gets simple and it is mostly dominated by *A. mariesii*. In this district, the boreal coniferous forest occupies smaller area and is almost lacking in mountains which face directly to the sea of Japan and in some mountains of the backbone range (Fig. 3). In such mountains, the altitudinal belt, in which the boreal coniferous forest should develop, is often occupied by summer green shrubs. This phenomenon, the lack of the boreal coniferous forest, is supposed to be caused by the winter northwest monsoon which directly blows against the mountains facing the Sea of Japan. The winter monsoon is so strong bringing so much snow that conifers appear not to be able to grow because of mechanical break caused by strong wind and pressure of heavy snow (SHIDEI 1952, YOSHINO 1973, ISHIZUKA 1978).

But, even in those mountains facing the Sea of Japan stands of *T. diversifolia* can be found though they are small in acrege and discontinuous. That is it to say, in the northern part of Honshu, though *Abies mariesii* occupies larger areas as habitats, the distribution area of *T. diversifolia* is far larger than *A. mariesii* (Fig. 3). An above mentioned cause of the lack of the boreal coniferous forest in not the case of *T. diversifolia*.

Such a phenomenon of lack of coniferous forests in altitudinal belts is found also in the westernmost part of the Pyrenees and Caucasian Mountains (HOELLERMANN 1972, PLESNIK 1972). These areas, including the Sea of Japan side area of Northern Honsu in Japan lie along the eastern margin of large seas, namely Bay of Biscay, Black Sea and the Sea of Japan and face western winter monsoon which brings heavy snow to these areas. But in Rocky Mountains, which lie along the eastern margin of the Pacific Ocean facing the western winter monsson, cool temperate to boreal coniferous forests are very luxuriant. Here also the above mentioned cause of the lack of coniferous does not fit.

CONCLUSION

Trees of Pinaceae are the main constituents of the boreal forest of the Northern Hemisphare, occupying large areas also in the cool temperate, in the warm temperate and even in the subtropical zones, where the main dominant species are broad leaved trees, and are economically very important. Among these pinaceous trees, species of *Tsuga* are almost not found in the boreal zone horinzontally, their distribution areas are far smaller than those of *Abies*, *Picea*, *Pinus* and *Larix* and they are rather companions than dominants.

But, as their global distribution is very specific among species of Pinaceae and they can grow where other conifers cannot exist, they could be an important key to solve the problem of the development of mountains coniferous forests.

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(* in Japanese and ** in Chinese)

STUDIES ON THE PRODUCTIVITY AND WATER CONSERVATION CAPACITY OF VARIOUS FOREST TYPES IN THE MOUNTAINOUS REGION OF EAST HUNAN, CHINA

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Key words: Productivity; Water conservation capacity; Forest type; Mountain

It is a basic idea that the ecological function in a forest ecosystem is closely related to its community structure. Generally speaking, the most effective function is based upon the best structure of a plant community. productivity is the rate at which biomass in synthesized. Among various forest types in the same region, the more the quantity of biomass production, the better the efficiency of ecological functions, including hydrological one, in the community. Ecosystem productivity is an index which integrates the cumulative effects of the many processes and interactions which are proceeding simultaneously within the ecosystem. As a rule, the productivity is allied to the conservation capacity of water supply in a forest ecosystem also. At present, the pressure on forest and water resources is increasing exponentially with popumation density. A forest community, especially a climax forest community, has a considerable large water conservation capacity and is a source of high quality water. Therefore, it is necessary to manage both the forest and water resources together in mountainous regions where erosion takes place because of heavy rain and steep slope.

EXPERIMENTAL AND RESEARCH METHODS

The expedition was taken along the vegetational transect belt from the bank of the Ziang River, Zhuzhou County, to the top of Junshan Mt., Liling County, referring to the vertical vegetational distribution at Nanyue Mt., Hengshan County, Hunan Province. After making a thorough investigation on the vegetation and soil feature in the area, five main forest type, i.e. evergreen broad-leaved forest, China fir (*Cunninghamia lanceolata*) plantation, hairy bamboo (*Phyllostachys pubescens*) plantation, Masson pine (*Pinus massoniana*) mixed forest and scrub, are divided basing upon the data of 120 sample plots. The productivity and water conservation capacity were measured and compared with each other among these forest types.

The productivity is determined in terms of the current biomass accumulation by means of transection method in the field and counted on the basis of oven dry weight of biomass per unit area per year.

The water conservation capacity is mainly defined by way of two indices, namely the storage capacity of gravitational water and the infiltration rate in root zone of soil. The former is the basic index for the purpose of comparing and evaluating the power of receiving and containing water among various forest types. It is counted through the following formula:

$$V = 10.000.p.d.$$

Where, V: storage capacity of gravitational water (m^3/ha); d: soil depth (m), if the soil depth is less than 1 m, it is counted according to its actual depth; while the soil depth is more than 1 m, it is counted as 1 m. The infiltration rate was measured by means of a flood-type, referring to the infiltration coefficent determined in laboratory. In addition, a comprenhensive identification method of hydro-ecology was put forward by one of the authors to differentiate the conservation capacity of water supply for various forests in another paper (HOU YINGQIANG 1980).

THE VERTICAL DISTRIBUTION AND PRODUCTIVITY OF VARIOUS FOREST TYPES

The Xuefenshan Mountains run from the southwest to the northeast, which divide Hunan province into eastern part and weastern part. They are significantly different from each other in the characteristics of forest vegetations. The eastern mountain region belongs to warm and humid climatic region of mid-subtropics. Generally speaking, in a certain limit, the higher the altitude, the more the precipitation. At an altitude of 1266 m in Nanyue Mt., the average annual precipitation is 2153 mm. Therefore, mountains are major areas of ware source. Afforestation for protecting water source is the foundation of ecological balance in mountain regions (HUO YINGQIANG 1981). Moreover, the productivity of biomass and soil conditions vary with forest types in the region as shown in Table 1 and Table 2.

Evergreen broad-leaved forest is the zonal vegetation or the climax forest community in the mid-subtropics, hich mainly consists of the dominant tree species classified into the genera such as *Castanopsis*, *Lithocarpus*, *Cyclobalanopsis* and *Quercus*, etc. The average height of mature forests is genrally 15-20 m. But in the low mountains and hill areas below 500 m in altitude, *Castanopsis sclerophylla* forest and *Lithocarpus glaber* forest are common types, and the average height of these mature forests is usually 12-15 m. However, most of evergreen broad-leaved forests were nearly destroyed at all in the region, morely a few survivals remain in distant localities.

The forest type we investigated is a secondary young growth of *C. sclerophylla* - *L. glaber* forest, the successive one following pioneer Masson pine forests and intolerant deciduous broad-leaved forests, such as *Albizzia kalkora* - *Liquidambar formosana* forest, a s a result of conversation for vegetation recover. Nevertheless, it has a considerable high productivity and effective ecological function. There are a lot of seedlings and saplings of the dominant tree species under the canopy. The humus soil layer of the forest ecosystem is increasing by degrees. Some evergreen broad-leaved of higher phases, for example, *Cyclobalanopsis glauca*, *Castanopsis fargesii*, *C. eyrei*, and *C. tibetana* forests will gradually appear in the process of vegetational succession later on. China fir is the most important commercial timber tree species in the middle subtropics. The key measure to establish its plantations is to choose the suitable sites for them. They are often reforested after cutting downevergreenbroad-leaved forests or masson pine mixed forests. This species grows best at an altitude of 300-600 m. The upper limit is lower on isolated hills and mountains. The productivity of China fir plantations varies with altitude as shown in Table 3.

Hairy bamboo is the most important economical bamboo species in the middle subtropios. The vertical distribution of this species is generally below an altitude of 500 m in the region. The key measure to increase the productivity of hairy bamboo plantations is to control the appropriate density by rationally cutting every year. The relatioship between density and yield per hectare is shown in Table 4.

Masson pine is a pioneer afforested tree species which is adaptable to poor sites in subtropics. Its vertical distribution is below an altitude of 900 m in the region. The upper limit is lower on isolated hills and mountains. Masson pine forests account for more than 60% of forested area in the region. They occur

Table 1 — The productivity and quantity of biomass distribution of various forest types.

Forest type	Age (years)	Average height (m)	Density (stems/ha)	Quantity of biomass (ton/ha) Above-ground Total	Leaf	Under-ground	Grand total	Productivity (ton/ha.yr)
Evergreen broad-leaved forest	10	6.0	2445	42.4	10.6	14.1	56.5	5.65
China fir plantation	20	14.0	1760	55.3	7.6	11.4	66.7	3.34
Hairy bamboo mature plantation	13.0	2400	41.8	8.4	16.7	58.5	8.34	
Masson pinemixed forest	15	9.5	2930	48.6	9.7	13.8	62.4	4.16
Scrub	—	2.0	4275	4.9	1.2	1.6	6.5	—

Table 2 — Soil conditions under various forest types

Forest type	Color	Texture	pH	Organic matter (%)	Exchangeable (ppm) N	P	K	Total (%) N	P	K
Evergreen broad-leaved forest	dark brown	loam	4.6	11.64	196.7	62.5	64.3	0.27	0.10	1.80
China fir plantation	brown	loam	4.5	2.48	86.8	0.5	38.3	0.13	0.01	2.36
Hairy bamboo plantation	brown	loam	4.6	2.98	108.4	10.0	36.0	0.13	0.01	1.69
Masson pine mixed forest	brown yellow	clay loam	4.4	1.79	49.3	1.5	18.0	0.07	0.04	2.40
Scrub	brown black	sandy loam	5.3	19.50	—	—	—	0.66	0.23	2.94

in wastelands after the distruction of other forest types.

Generally Masson pine forests have a great potential of natural regeneration by means of dispersing their seeds on a great amount. In most cases, theirpro-ductivity is rather low due to to excessively pruning for lack of firewoodand damaging effects from pine-moth (*Dendrolimus pini*) and other pests, as well as diseases.

However, some Masson pine forests usually mix with a few evergreen broad-leaved tree species, namely *Castanopsis sclerophylla*, *Lithocarpus glaber* and *Castanopsis fargesii*, and is the intermediate type between pure Masson pine forest and evergreen broad-leaved forest, which is occupied in a progressive position of egetation succession and has a considerable high productivity as shown in Table 1.

Scrubs are various kinds of secondary degraded comminities after the deteriotration of evergreen broad-leaved forests and other types offorests. They occupy in the process of negative vegetational succession, and often occur on poor sites at high elevations. The vertical distribution of *Castanea sequinii-Rhododendron simsii* community is above an altitude of 500 m on upper part of hillside or ridge of mountains. The productivity of this type is rather low. Generally speaking, the scrubs make up less than 20% of palatable plants. They are not suitable to be used as ranges for the animal husbandry on a large scale because of low forage quality. However, thay can be managed to provide firewood in a way, or used as habitats for wildelife.

CONSERVATION CAPACITY OF WATER SUPPLY OF VARIOUS FOREST TYPES

The establishement and protection of forests for conservation of water supply is the key of watershed management, especially at localities of high altitude. They play an important role in regional hydrological equilibrium and ecological balance. It is necessary to have a high forest coverage to support a fine water conservation capacity in a forest ecosystem. Primarily based on storage capacity of gravitational water, the water conservation capacity is divided into five grades as follows; grade I: more than 1000 m^3/ha, very fine ; grade II: 800-1000 m^3/ha, fine; grade III: 600-800 m^3/ha, medium; grade IV: 400-600 m^3/ha, poor; grade V: less than 400m^3/ha, very poor. If the final infiltration rate is more than 3 mm/min., one grade should be raised correnspondingly (HOU YINGQIANG *et alii*, 1985). According to the abovestandards the water conservation capacity for various forest types is shown in Table 5.

The root systems of a forest provide a significant effect on conservation capacity of water supply (the biomass quantity of underground systems of various forest types shown in Table 1). Evergreen broad-leaved forests have

Table 3 — The increment and site index of China fir plantations at various altitudes.

Altitude (m)	Average height growth (m/year)	Average d.b.h. growth (cm/year)	Average stocking increment (m³/year)	Site index (m)
100	0.55	0.72	2.25	9.00
100-300	0.73	1.07	3.75	12.00
300-600	0.89	1.23	6.00	14.00
600-800	0.80	1.10	5.00	13.30
800-1000	0.70	1.00	3.70	10.00

Table 4 — The relatioship between density and yield of hairy bamboo plantations

Density (culms/ha)	Average d.b.h. (cm)	Average height below branch (m)	New culms in that year (culms/ha)	Dry weight of culms (ton/ha)
630	8.05	4.90	570	3.061
1215	8.94	5.50	1620	11.140
2715	9.10	5.34	1785	12.330
4365	11.10	6.15	2415	26.715
6660	9.50	5.38	1200	9.651
7785	9.56	5.45	225	1.812

Table 5 — The water conservation capacity of various forest type

Forest type	Storage capacity of gravitational water (m³/ha)	Infiltration rate (mm/min) Initial	Infiltration rate (mm/min) Final	Water conservation capacity
Evergreen broad-leaved forest	1128	5.24	2.50	very fine
Hairy bamboo plantation	655	11.31	4.53	fine
China fir plantation	732	5.17	2.05	medium
Masson pine mixed forest	661	3.15	1.84	medium
Scrub	461	5.18	2.28	poor

very deep tap roots and strong root systems; as a result, they possess the largest conservation capacity of water supply among all types. Hairy bamboo plantations have a great quantity of rhizomes which form a very strong underground system in the upper soil layer, so that the infiltration rate is the most rapid of all and the power of receiving water is fine.

China fir plantations grow on good sites but they have rather thin root systems; on the contrary, Masson pine forests grown on poor sites, they possess considerable strong root systems though. Thus it can be seen that both of them are at medium level of water conservation capacity. Scrubs grow on very poor sites, and their conservation capacity of water supply is rather poor. Nevertheless, they still have a certain power of receiving and containing water on the steep hillside and ridge of mountains. Therefore, vigorous action should be taken to protect this type and accelerate the process of positive vegetational succession forward.

CONCLUSION AND DISCUSSION

A. The forest for conservation of water supply is the ecological foundation for the exploitation of vegetation and the development of economics in mountains regions. The capacity of receiving and containing water varies with forest types.

B. Evergreen broad-leaved forests play a very important in regional ecological balance. There fore, it would be a serious mistake if they had been destroyed on a large scale for developing China fir plantations. Some efficient measures should be taken to protect them.

C. Hairy bamboo plantations have the quickest infiltration rate of soil water, and therby their water conservation capacity is considerable fine. The suitable density for hairy bamboo is 3000-4500culms/ha, which will be provided with both high productivity of biomass and large capacity of water conservation.

D. On the premise that the most suitable tree species are chosen for each site, the more ideal forest-soil types ought to be planned for the existing conditions, so that water conservation function can be exerted fully in a forest ecosystem and the productive potential of forested land can be utiliezed to a higher degree.

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STUDIES ON THE DISTRIBUTION AND FORMATIVE CAUSES OF FORESTS IN THE GREATER KHINGAN MTS, NORTHEAST OF CHINA

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Key words: Adaption, Strategies, Biological characters, Forest distribution, Greater Khingan Mts.

INTRODUCTION

The forest area of the Greater Khingan Mts. includes Yakeshi forest region and Jagedaqi forest region, i.e. north of the Mountains. Plant species are relatively simple and most of them are the floral elements of East Sibirica in the area. Natural Dahurian Larch (*Larix gmelini*) forest is dominat vegetation form and distributed widely. mongolian Scotch Pine (*Pinus sylvestris* var. *mongolica*) forest only occurs on the dry and barren ridges. Asian White Birch (*Betula platyphylla*) forest appears on the gentle and humid north- or east-facing slopes. Dahurian Birch (*Betula dahurica*) and Mongolian Oak (*Quercus mongolica*) forests become dominant forest types in the south and southeast of the area. They occupy the drier sites. Spruce forests only appear in the cold and humid valleys where the principal edificator is Yezo Spruce (*Picea jezoensis*) with the island distribution in north of Yilehuli branch range. The tree species (except spruces) are all light-demanders and pioneers. This shows that the disturbances maybe heavy here. The annual precipitation ranges from 400-500 mm. It is only one-fifth of the annual precipitation in spring. The variable rate of temperature is higher. This makes snow melt and litter dry rapidly. Wind is also strong in spring. All factors make forest fire occur easily in the Greater Khingan Mts. Maybe the critical factor affecting the formation of the present forests is forest fire in the area. There fore, the authors try to discuss the adaption and ecologicla strategies of the principal tree species by comparing their biological and ecological characters in Northeast of China, the distribution of forests and provide scientific basis for the management in the area.

THE FORMATIVE CAUSES OF PRESENT FORESTS IN THE FOREST AREA OF THE GREATER KHINGAN MTS.

1) The biological characters of the principal tree species in northeast of China

The biological characters of tree species are determined by their genetic factors. They are internal factors affecting the distribution of trees. The biological characters of the principal tree species in northeast of China are very different (see Table 1). The six species of conifers have scarcely asexual reproductive ability. But the sexual reproductive ability of three broad-leaved tree species is relarively higher, particularly, Mongolian Oak. The two species of birches, their seeds are very small in large amounts with wings and the dispensal distance is very far. The seeds of Khingan Fir are heavier with short wings and the scales of cone are deciduous together with seeds. The distance of seed dispersal is closer and the density is higher. The seeds of Korean Pine is disseminated mainly by squirrels for a long distance even more than one kilometre. Korean Pine can appear in the birch forests before spruces in the East Mountainous Area in Northeast of China. But there are no distribution of Korean Pine in the Forest Area of the greater Khingan Mts. Also there are no distribution of Khingan Fir and spruce forests are only distributed in the very narrow area here.

2) Adaption to temperature

Dahurian Larch, Mongolian Scotch Pine, Khingan Fir, Yezo Spruce and Korean Spruce are the characteristics species in cold-temperate zone. Korean Pine is principal edificator in mixed Korean Pine and deciduous broad-leaved forest in temperate zone. Asian White Birch and Dahurian Birch are the principal edificators in deciduous broad-leaved forests of mountainous area in temperate deciduous broad-leaved forest region. Their order of cold resistance is following (see Fig. 1).

3) Adaption to Moisture

Based on our investigations and the research on man-made forest of Korean Spruce, the results show that the ecological amplitude of Korean Spruce in eurytopic. Its dry-resistance is stronger (see Fig. 2).

4) Adaptation to Light

The shade tolerance is a very important factor affecting the regeneration of tree understory. In many cases, shade tolerance may be the major factor accounting for a plant's performance in the understory (SPURR and BARNES, 1980). Dahurina Larch, Assian White Birch, Mongolian Scotch Pine, Mongolian Oak Dahurian Birch are light-demanders and pioneers. Khingan Fir, Yezo Spruce, Korean Spruce and Korean Pine are tolerant trees (see Fig. 3).

5) Adaption to Forest Fire

The fire-resistance of tree species is one of the important indices of tree adaption to fire. There are many factors affecting fire-resistance of tree species. The important ones are: site, thickness of tree bark, proliferation after fire, depth of roots, depth of crown, and size and number of tree killed by fire. By the analysis of those factors, we obtain the order of fire-resisting capacity of the principal tree species in Northeast China (see Fig. 4). The fire-resistance of trees is one index of adaption to fire. The sexual and asexual reproductive capacity of trees and the adaption to environment after fire all reflect the adaption to fire in different degrees. based on above-mentioned factors, we will divide each of them into five classes and give each class a numerical value. According to the sum of numerical value, we can determine the fire adaption capacity of the trees (see Table 2). Forest fire is serious in the greater Khingan Mts.

The relationship between the distribution of the trees and the fire cycle is close in the forest area (see Table 3). The broad leaved trees have the higher fire adaptioncapacity. The increase of them is closely related to the shortening of the fire cycle.

6) Ecological Strategies of the Trees

MACARTHUR and WILSON (1967) advanced K-selection and r-selection. In recent years another concept has emerged concerning plant strategies and resource allocation, i.e., C, S and R selction (GRIME, 1979). According to above-mentioned considerations, and the size and life-span (Table 4) of the trees, we can arrange the principal trees in the r-K strategies series (see Fig. 5). Referring to listing of characteristics for each of C, S, and R strategies (RADOSEVICH and HOLT, 1984), we believe that Asian White Birch and Dahurian Birch are the tree species with characteristics of ruderal plants; Dahurian Larch, Mongolian Oak, Mongolian Scotch Pine and Korean Spruce and Khingan Fir are

Table 1 - The biological characters of the principal forest trees in Northeast China

	Age of fruition (yrs.)	The quantity of fruition	Adult scale or bract	Size of seedwing (length X width) (cm)	Size of seed (length x width) (cm)	Weight of 1000 seeds (g)
Khingan fir (*Abies nephrolepis*)	80-160	more	deciduous	1.0 X 0.5	0.4-0.6 0.4	10.00
Yezo spruce (*Picea jezonsis*)	80-160	more	persistent	0.9 X 0.35	0.3-0.4 X 0.2	2.10
Korean pine (*Pinus koraiensis*)	140-240	7080 seeds	persistent	——	1.2-1.6 X 1.0	555.6
Korean spruce (*Picea koraiensis*)	80-160	about 400 cones	persistent	1.3-1.6 X 0.5	0.4 X 0.2	4.68
Mongolian scotch pine (*P. sylvestris* var. *mongolica*)	40-100	4000-5000 seeds	persistent	1.1-1.5 X 0.5	0.45-0.6 X 0.3	5.88
Dahurian larch (*Larix gmelinii*)	60-160	4000-17000 seeds	persistent	0.9 X 0.45	0.43 X 0.30	4.00
Asian white birch (*Betula platyphylla*)	15-20	much more	dciduous	very small	very small	lightest
Dahurian birch (*Betula dahurica*)	15-20	much more	deciduous	very small	very small	lightest
Mongolian oak (*Quercus mongolica*)	15-30	less	persistent	——	2.0-2.3 X 1.3	heavy

	Link between seed and wing	Distance of seed dispersal (m)	The way of seed dispersal	Rot-resistance of seed	Asexual reproductive ability	Growth of young tree
Khingan fir (*Abies nephrolepis*)	not easy to seperate	closer 30	wind	strong	very weak	slowly
Yezo spruce (*Picea jezonsis*)	easy to seperate	30-50 (120)	wind	strong	very weak	slowly
Korean spruce (*Picea koraiensis*)	easy to separate	30-50 (120)	wind	strong	very weak	slowly
Korean pine (*Pinus koraiensis*)	——	——	bird or squirrel	strong	very weak	very slowly
Mongolian scotch pine (*P. sylvestris* var. *mongolica*)	not easy to seperate	200-250 (500)	wind	strong	very weak	fast
Dahurian larch (*Larix gmelinii*)	not easy to seperate	30-50 (150)	wind	strong	weak	much faster
Asian white birch (*Betula platyphylla*)	not easy to seperate	very far	wind	strong	strong	very fast
Dahurian birch (*Betula dahurica*)	not easy to seperate	very far (1000)	wind	strong	strong	very fast
Mongolian oak (*Quercus mongolica*)	——	around parent trees	animal or gravity	strong	stronger	very fast

Table 2 - Fire-adaption capacity of tree species

	sexual reproduction		asexual reproduction		fire resistance capacity		adaption capacity to fire		sum
	class	value	class	value	class	value	class	value	value
Dahurian larch	2	4	4	2	1	5	4	2	13
Mongolian scotch pine	3	3	5	1	1	5	4	3	12
Mongolian oak	5	1	1	5	2	4	1	5	15
Dahurian birch	1	5	2	4	2	4	3	3	16
Asian white birch	1	5	2	4	3	3	4	2	14
Korean pine	5	1	5	1	2	4	4	2	8
Korean spruce	4	2	5	1	5	1	3	3	7
Yezo spruce	3	3	5	1	4	2	5	1	7
Khingan fir	4	2	5	1	5	1	5	1	5

Table 3 - Fire cycle and composition of tree species (%)

Region	Fire cycle (year)	conifers	Mongolian oak Dahurina birch	Other broad-leaf trees
North	110-120	89.72	0.2	10.08
East	30-40	76.80	2.27	20.93
South	15-20	42.07	24.03	33.90

Table 4 - Tree size and life-span

	Height (m)	Diameter (cm)	Life span (year)
Asian White Birch	20	50	70-100
Dahurian Birch	20	50	70-100
Mongolian Oak	30	60	350
Dahurian Larch	30	80	350-400
Mongolian Scotch Pine	30	100	200
Korean Spruce	35	100	250
Khingan Fir	30	50	200
Yezo Spruce	50	150	300-400
Korean Pine	40	150	500

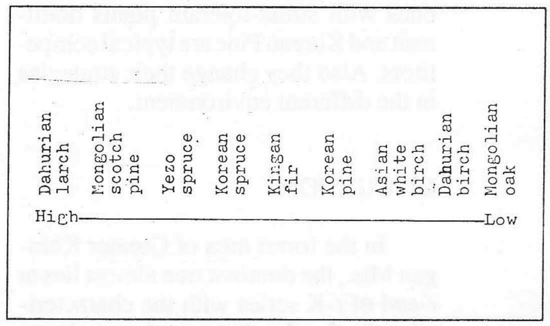

Fig. 1 — The order of cold-resistence of trees.

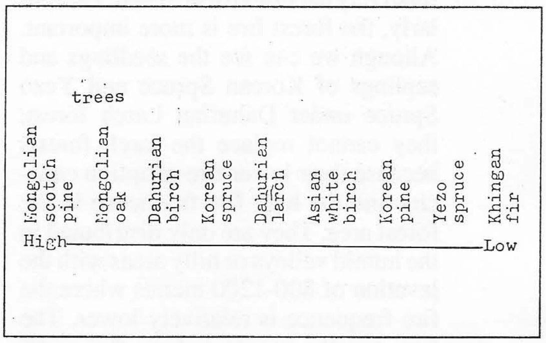

Fig. 2 — The order of the dry-resistence of the principal trees.

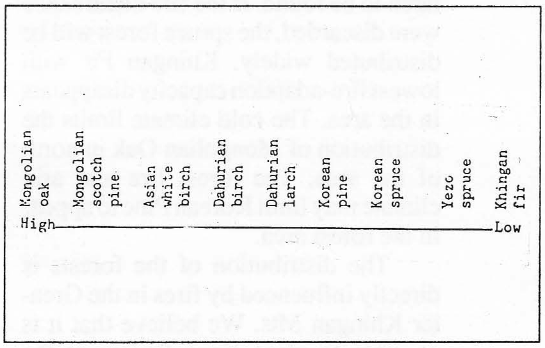

Fig. 3 — The order of tree tolerance.

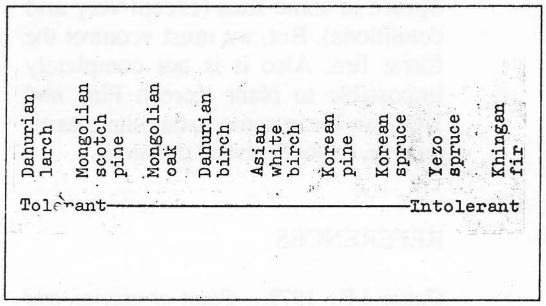

Fig. 4 — The order of fire-resistence.

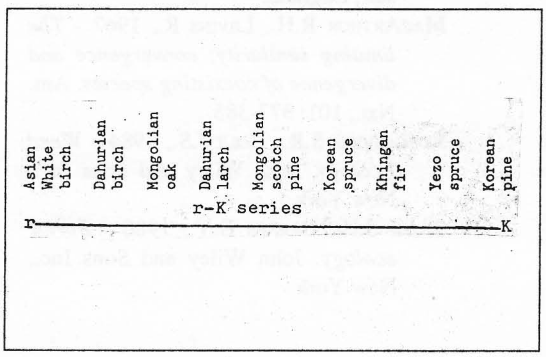

Fig. 5 — r-K strategies series of tree species.

ones with stress-tolerant plants dominant and Korean Pine are typical competitors. Also they change their strategies in the different environment.

DISCUSSION

In the forest area of Greater Khingan Mts., the dominat tree almost lies at r-end of r-K series with the characteristics of ruderal and stress-tolerant plants. This shows that the environments are relatively harsh and distributed. Particularly, the forest fire is more important. Altough we can see the seedlings and saplings of Korean Spruce and Yezo Spruce under Dahurian Larch forest, they cannot replace the larch forests because their lower fire-adaption capacity and the high fire frequence in the forest area. They are only distributed in the humid valleys or hilly areas with the levation of 800-1200 metres where the fire frequence is relatively lower. The fire usually recurs before the zonal vegetation has arrived at the spruce stage. This explains the high proportion of larch to be found. If the fire disturbance were discarded, the spruce forest will be distributed widely. Khingan Fir with lowest fire-adaption capacity disappears in the area. The cold climate limits the distribution of Mongolian Oak in north of the area. The forest fire and arid climate may limit Korean Pine to appear in the forest area.

The distribution of the forests is directly influenced by fires in the Greater Khingan Mts. We believe that it is possible to plant Yezo Spruce at the elevation of 800-1200 m. and Korean Spruce in some sites (except very arid conditions). But, we must vcontrol the forest fire.. Also it is not completely impossible to plant Korean Pine and Khingan Fir in some better sites, particularly, in southeast of the area.

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FOREST VEGETATION AND SOIL MICROBIOLOGY OF "DRIFTLESS REGION" IN CENTRAL NORTH AMERICA

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Key words: Quercus, Soil microbiology, Glaciation.

ABSTRACT

The "Driftless Region" of Wisconsin, USA, is unglaciated, featuring steep slopes, Ioess deposits, limestone outcrops and diverse vegetation. The purpose of our study was to characterize forest vegetation and temporal changes in soil microbiology in this phytogeographically transitional region. *Quercus* species dominated upper and lower slope positions, although other genera including *Acer*, *Populus*, *Fraxinus*, *Betula*, *Ulmus*, *Carya* and *Prunus* were observed. Bacterial populations replaced fugal populations in both mineral and organic soil horizons following forest disturbance. The impact of forest management in montane ecosystem structure and function should include an assessment of soil microbes.

INTRODUCTION

Forests constitute a significant portion of vegetation which inhabits montane ecosystems worldwide (ALLEN, 1985). Intensive management of montane forests should be based on integrated knowledge of biological and mineralogical properties of soils and the vegetation they support. Soil response to forest management is highly site specific and related to local differences in parent material, pH, moisture, temperature, and elevation. It is generally accepted that removal of forests interrupts cycling of nutrients from vegetation to soil and significantly alters soil physical and chemical properties (BINKLEY, 1984).

Forest management has a significant immediate impact on soil microbial populations especially in fragile montane ecosystems (HENDRICKSON *et alii*, 1982). Measurements of microbial activity one year after forest harvesting (i.e., clearcutting) reveal increases in numbers of nitrifying bacteria, higher total bacterial populations, reduced total and active fungal biomass and reduced incidence of mycorrhizal associations. In Sweden, studies revealed forest litter removal following clearcutting reduced fungal and bacterial biomass compared to sites with litter present (BOOTH, 1980; LUNDGREN, 1982).

Few studies have directly examined long-term soil and litter microbial activities after forest harvesting in montane ecosystems. Reduced decay of leaf and woody litter following clearcutting has been attributed to reduced soil moisture and high temperatures in the Appalachian mountains in North America (ABBOTT and CROSSLEY, 1982). We hypothesize forest removal may induce a reversion of soil biological properties similar to those found in agricultural soils due to unfavorable environmental conditions. Moreover, bacterial activity may replace fungal activity and litter decomposition may shift from organic to mineral horizons following harvesting. The objective of the present study was to determine the effect of two harvesting methods, clearcut and shelterwood cut, on soil microbial activities in the "Driftless Region" of Wisconsin, USA.

METHODS

The study area is the Hardies Creek Experimental Forest located in the "Driftless Region" of Southwestern Wisconsin, USA (GODEL, 1985). The climate is continental, with mean temperatures of 9.7C in January and 22C in July. Annual precipitation averages 79 cm. The site occupies a steep ridge (30-40% slope) on rolling terrain. In the USDA soil classification system, the soils a Hixon loam, formed in loess and fine grained sandstone underlain by glauconitic lenses and limestone detritus (LANGTON, 1977).

A second-growth broadleaf forest developed on the site since conifer species were removed around 1900. Dominant genera include *Quercus*, *Acer*, *Betula*, *Populus*, and *Carya*. Five years prior to the present study (1979), a one hectare site was clearcut and an adjacent hectare was subjected to a shelterwood cut (i.e., 50% crown cover removal). Leaf litter which accumulated during logging operations was not removed. An adjacent uncut hectare served as a control.

Soil moisture, pH and temperature and microbial populations were measured in upper mineral (0-5 cm) and litter (Oi) horizons in 27 randomly established plots on each site in May, July and September, 1985. Soil properties and microbial populations in soil and litter were measured using methods described by HENDRICKSON *et alii* (1985).

RESULTS

The forest vegetation at Hardies Creek Experiment Forest was composed primarily of *Quercus* species (Table 1). Minor components of the stand included the genera *Acer*, *Populus*, *Fraxinus*, *Betula*, *Ulmus*, *Carya* and *Prunus*. A dense understory of *Cornus*, *Corylus*, *Amenlanchier* and *Crataegus* was present in open stands. Interrupted fern (*Osmunda claytoniana*) formed a dense cover on eastern and northern aspects. Evidence suggested the stand had been frequented by fire.

The forest floor environment was influenced by forest management (Table 2). Moisture content of mineral soil and litter was reduced on the clearcut site relative to the control on each sampling date. Temperature of the upper mineral horizon increased following the clearcut treatment. Mineral soil and litter pH were relatively higher on clearcut site. However, temporal variations in litter pH reached a maximum in July.

Bacterial populations in mineral soil and organic horizons were greater on the clearcut site than on the control site (Table 2). On each sampling date, bacterial populations in mineral soil on the clearcut site were two-three fold greater than measured on the adjacent control (uncut) site. *Arthrobacter* species were the dominant bacteria identified on both the shelterwood and clearcut sites. *Pseudomonas* species were frequently observed in cultures collected from the control site.

Fungal populations in mineral horizons and, to a lesser degree in organic horizons, were less numerous on the clearcut site than on the control or shelterwood site (Table 2). Generally, fungal populations were greater in the organic horizon relative to the mineral horizon. *Penicillium* and *Trichoderma* species were abundant in litter sampled from the shelterwood and control site. *Aspergillus* colonies were observed in cultures obtained from the clearcut site. Actinomycetes were not observed in cultures from any site.

DISCUSSION

The "Driftless Region" is bordered by the *Acer-Betula-Populus* forest type to the North and East, the *Quercus-Carya* type to the South and the short grass prairie to the West. Limestone outcrops, loess deposits and steep terrain are common. Thus, the region has been cha-

Table 1 — Distribution of forest vegetation in Hardies Creek Experimental Forest, Wisconsin, USA.

Species	Percent[1]	Slope Position	Drainage Class
Quercus rubra	83	upper	rapid
Q. alba	9	middle-upper	rapid
Q. ellipsoidallis	4	all	rapid
Acer saccharum	1	lower	slow
Populus deltoides	1	all	slow
Fraxinus pennsylvanica	1	lower	slow
Betula papyrifera	1	upper	rapid

[1] Percent importance = (relative basal area + relative density) / 2

Table 2 — Seasonal pattern of soil properties and microbial populations on four sites at Hardies Creek Experimental Forest, Wisconsin, USA.

Variable	Clear Cut mineral soil (0-5 cm)	Clear Cut litter (1-3 cm)	Shelterwood Cut mineral soil (0-5 cm)	Shelterwood Cut litter (1-4 cm)	Control mineral soil (0-5 cm)	Control litter (1-5 cm)
May						
moisture (%)	20	52	21	49	21	57
pH	5.8	4.9	5.1	4.7	5.0	4.7
Temperature (°C)	40		32		33	
Fungi/Actinomycetes (10^4 / g)	87±11	124±17	166±18	357±42	125±20	416±35
Bacteria (10^{-5} / g)	426±38	342±61	259±20	405±57	184±21	209±24
July						
moisture (%)	4	15	6	17	6	17
pH	5.9	5.5	5.5	5.0	5.5	5.0
Temperature (°C)	43	—	44	—	34	—
Fungi/Actinomycetes (10^4 / g)	61±15	69±6	142±15	291±30	99±27	360±56
Bacteria (10^{-5} / g)	309±29	245±10	206±19	370±25	102±12	193±33
September						
moisture (%)	16	43	17	44	18	49
pH	5.5	4.9	5.2	4.7	5.3	4.5
Temperature (°C)	40	—	35	—	35	—
Fungi/Actinomycetes (10^4 / g)	93±8	102±7	144±32	322±19	111±52	404±49
Bacteria (10^{-5} / g)	410±27	353±42	310±10	466±28	163±14	228±34

racterized as phytogeographically transitional (BRAUN, 1967). Although traditionally classified as the *Acer-Tilia* forest type, many of the existing forests in the region are dominated by *Quercus* species. CURTIS (1959) described the upland forests of southern Wisconsin as gradational from xerophytic to mesophytic depending on the proportion of mesophytic species present.

Drier and warmer forest floor conditions observed on the clearcut site in our study have also been found on clearcut sites in Sweden (BAATH, 1980), Canada (HENDRICKSON *et alii*, 1985), and in the southern USA (EDWARDS and ROSS-TODD, 1983). This effect is probably due to increased exposure to wind and solar radiation (YIN, unpublished data). Our results suggest that floor warming and drying alters the composition of soil and litter microflora causing an increase in the proportion of bacterial species. Moreover, surface conditions on the clearcut site are less favorable for microbial activity. The slight increase in microbial populations in May and September, regardless of harvest treatment, may be associated with litter availability, root growth, moisture, or temperature fluctuations.

The fungi and bacteria observed in leaf litter cultures in our study are classified as primary colonizers by GARRETT (1963). Fungi such as *Penicillium* and *Trichoderma*, which were observed on all three sites, are dependent upon carbohydrate substrates from leaf litter for growth and reproduction. *Pseudomonas* bacteria, which was primarily observed on samples from the control (uncut) site, prefer moisture conditions. HENDRICKSON *et alii* (1982) report that *Pseudomonas* species are especially well suited to digest and metabolize *Quercus* litter.

The effect of forest management on soil environment and microbial populations on the *Quercus* sites in our study is dramatic. Bacterial populations tended to replace fungal activity as the environment was modified. Patterns of decomposition may also shift as nutrients and microbial activities are altered (YIN, under investigation). The significant role of fungi and bacteria in ecosystem structure and function (e.g., nutrient cycling) has been demonstrated (HENDRICKSON, 1982). Disruption of that role will have a major effect on forest productivity. Thus, the impact of forest management and harvesting in montane ecosystems should be assessed in terms of changes in suitability of the forest floor environment for soil microbes.

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STRUCTURE AND SUCCESSION IN TREE STRATUM OF MT. ZHONG SHAN, NANJING

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Key words: Mt. Zhong Shan of Nanjing; Fuzzy cluster; Ordination; Succession; Vegetation structure; Vegetation classification.

INTRODUCTION

Zhong Shan or as more popularly known, Zijinshan (the Purple Mountain) is located in the east suburb of the Nanjing city, its extreme western foothills being located within the city wall. It is the west part of Ning Zhen range and a place rich in scenary and relics. The mountain is widely recognized as a forest preserve for scenic purpose. Although this area is prohibited from logging by virtue of its inclusion in the Sun Yet-sen Memorial park, its large portion is not subject to various management project. Guidelines for managing this forest are now sketcky because informations on the basic ecological analysis such as succession, nutrient cycling, and the development of community structure, etc. are still lacking. Past studies have concerned mostly on the assessment and management of wildlife and timber stocks.

The purpose of this paper is to describe the forest vegetation in Zhong Shan in a way of providing an insight into its basic structure and dynamics. A second major purpose of this study is to explore the successional roles of the three local dominantive older stands on mesic sites, i.e. *Pinus massioniana*, *Quercus variabilis* and *Liquidambar formosana*. Most previous studies on the roles played by these species in Zhing Shan have involved disturbed areas with discontinuous forest either at Spirit Valleyt or at Sun Yet-sen's Mausoleum and at Ming Tomb. Only few studies on relatively undisturbed and heavily forested areas in the southern slope of Zhong Shan (e.q. CHIEN, 1932, CHU *et alii*, 1952, XIANG *et alii*, 1983). Because the region of our studies falls into the above category, informations on the roles of these three species should help in clarifying their successional relationships generally.

NATURAL BACKGROUND OF THE INVESTIGATED AREA

The investigated area is situated to the southern slope of Zhong Shan, centered at latitude 32°03' N longitude 118° 48' E. It accounts for 42% (10 km²)of the total Zhong Shan area. The whole mountain extends to become exposed as an arch in a south-west direction and south-east direction of about ten kilometers with a width from north to south of about tree kilometers as a dome in a north direction. It attains a height of 459 meters and is the highest peak a north direction. It attains a height of 459 meters and is the highest peak of the Ning Zhen range. There are three high points in the ridge, the highest of which is the first peak, forming the central point of the mountain.

The geology of Zhong Shan has been described in early time (HSICH, 1928). Local climate is warm, moist and continental with cold winters and very hot summers, as it is of Northern Subtropical Climatic Zone (WANG, 1931).

Before the first Forest Station of Jiangsu Province made any plantation on the mountain in the beginning of this century the slope of Zhong Shan was practically bare of wood (CHIEN, 1932). On the south foot there are two patches of wood, one is located at the Spirit Valley and a much smaller one at the Ming Tomb. The forest of Zhong Shan, though seriously damaged in the last century, its southern slope has been well protected since 1940. Vegetation of the investigated area possesses the general characteristics of the local vegetation in its floristic composition, physiognomy and stand structure and is now in a stage of progressive succession (XIANG *et alii*, 1983). According to the materials obtained by our field observation, about 850 species of vascular plants belonging to more than 450 genera and 135 families were descibed. Among the various life forms, the hemicryptophytes are the most aboundant ones and the phanerophytes play an important role in the forest. The main element in the general distributional pattern was the north temperate element and then the Pantropical element. There are about 6 main ligneous types: *Pinus massoniana* woods, *Quercus variabilis* woods, *Liquidambar formosana* woods, *Pinus massoniana* + *Ilex chinensis* woods, *Quercus grandulifera* var. *brevipetiolata* woods and *Pinus massoniana* + *Quercus variabilis* + *Liquidambar formosana* + *Castanopsis sclerophylla* woods, etc.

METHODS

In this paper, fuzzy clustering analysis is used as stands clustering. The procedures of this methods include: first of all, the calculation of similarity matrix R and then transformation of R to fuzzy equivalent relation R, finally, clustering. Establishing fuzzy equivalent matrix R* is the key of this method. Mark R2, R4, 8,........, Rk = R2k = R* is a fuzzy equivalent matrix, then the other procedures are the same general approached (ZADCH, 1965).

Tree species composition in 23 randomly selected stands (including 690 points by "point-centred quarter") from the southern slope of Zhong Shan was analyzed by Bray - Curtis polar ordination and fuzzy clustering. Since the vegetation in the Zhong Shan investigated area consists of discrete clusters of compositionally similar stands rather a continuously varying composition, therefore, vegetation samples (stands) were selected randomly. To ensure objectivity accurately in the analysis, two contrasting data manipulation techniques were employed. Ordination emphasizes continuity, while cluster analysis emphasizes discreteness in vegetation samples. Whereas ordination determines the position of all stands relative to each other in N-dimensional space based on their dissimilarities, cluster analysis computers the similarities between all stand combinations and expresses the results undimensionally. This ordination revealed discrete groups of stand types that corresponded closely with those delineated by cluster analysis. Since the sample was unkiased, representative, and minimally distorted by the analysis of real discontinuities, which were attributed to discontinuities in either (a) environmental factors (to vary with the tickness of humus layer) or (b) rates of compositional change (NICHOLSON, 1979).

RESULTS AND DISCUSSION

Results of both ordination (Fig. 1, 2) and size class analysis (Fig. 3) have

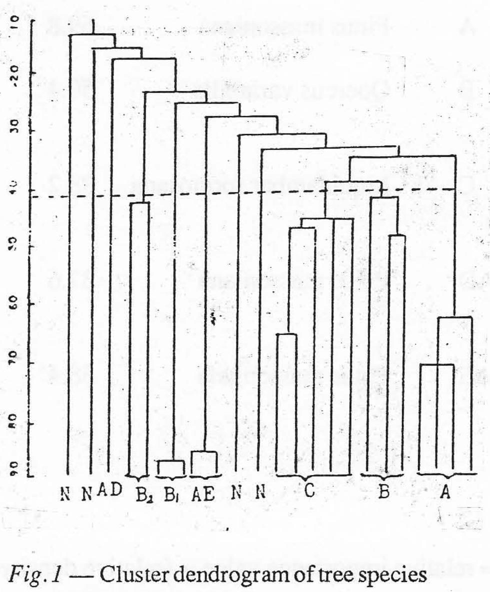

Fig. 1 — Cluster dendrogram of tree species m. stands by Fuzzy Cluster.

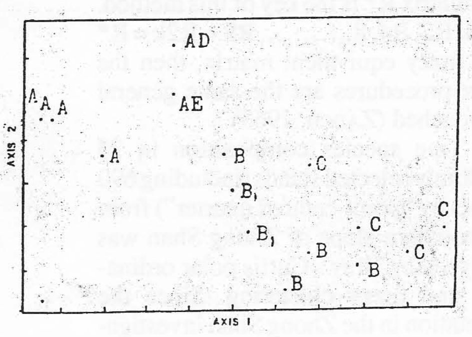

Fig. 2 — Stand clusters plotted on the axis 1 vs. 2 ordination by Bray-curtis polar ordination.

shown the dynamical relations of *Pinus massoniana* stand, *Quercus variabilis* stand and *Liquidambar formosana* stand were also assessed with the aid of ordination and cluster analysis (Table 1).

Density of their tree and saplings and their rations in A, B and C cluster stands (Table 2) has shown that the reproductive trends and suggested that the pinewood is now reaching its mature age. Its saplings II were barely represented in A, B, C, stands. Though its seedlings are numerous, none of them could attain to their establishment.

In many cases, *Pinus massoniana* stand not only would change into *Quercus variabilis* stand or *Liquidambar formosana* stand and *Quercus glandulifera* var. *brevipetiolata*stand, but also may become a type which includes broadleavedsclerophyll. The *Quercus variabilis* stand is evidently one of the most typical forms among all of important forest found in this region and forms the first stage of forest development. *Quercus glandulifera* var. *brevipetiolata* stand is found at higher altitude. But *Quercus variabilis* samplings occur in smaller numbers as compared with *Liquidambar formosana* and its saplings/tree densityratio is < 1.0 in all stands because of the excessive seed collection. The former needs light for the growth of their seedlings, but in this case less light intensity would be required than the latter. They grew well under the canopy, possibly it is the next developing stage following the *Quercus glandulifera* var. *brevipetiolata* stand and/or the *Quercus variabilis* stand.

Moreover, some intolerant species of evergreen broad-leaved trees such as *Castanopsis sclerophylla* and *Ilex chinensis* in a stage of succession are found at midslope of the mountain or at the ravines of the Sun Yet-sen Mausoleum and the Spririt Valley respectively. Instead, other tolerant species such as *Litsea coreana* var. *sinensis* is found in the ravine *Pterocarya stenoptera* woods and *Cinnamomum camphora* is found in the open pine woods.

The abundance of *Quercus variabilis* ranks recently first on the list of all tree species in the central portion of the woods immediately surrounding the temple of Spirit Valley and only the in 14th order fifty years ago and is the 7th order thirty years ago (Xiang *et alii*, 1983). As compared with fifty years ago, there was no indication of the development into a type of broad-leaved sclerophyll nature (Chien, 1932), but this type of stand is found recently and as we still know that virgin evergreen species exist in this region such as *Lithocarpus glabra*. This conditionis the same as fifty years ago that trees is common in Nanjing are widely spread species in this country and there are several kinds of woody plants, although scattered here and there, but by no means common. These trees found on Zhong Shan are *Cornus walterii*, *Ehretia thyrsiflora*, *Meliosma oldhamii* and *Tilia miqueliana*. These trees are occasionnally observed in forests in vicinaty of Nanjing, Meliosma of rare tree here has been found in moist woods and tickets in the ravine. From their distribution and natural habitat it may be safe to say that all of ythem are mesophytic trees and some of them from important members of forests in Western China. Hence the presence of these in the woods of Nanjing

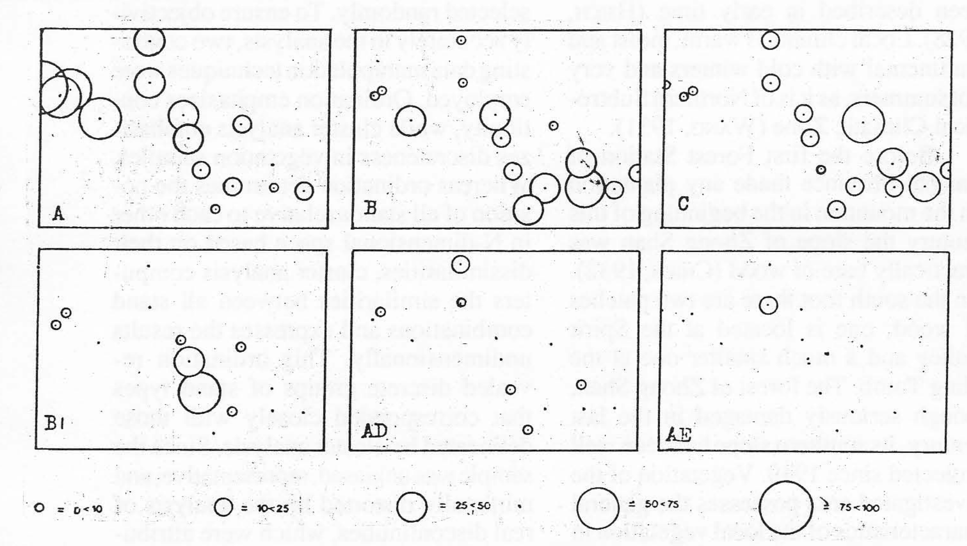

Fig. 3 — Relative importance values of (A) *Pinus massoniana*, (B) *Quercus variabilis*, (C) *Liquidambar formosana*, (B1) *Q. glandulifera* var. *brevipetiolata*, (AD) *Ilex chinensis*, (AE) *Castanopsis sclerophylla* plotted on the axis 1vs. 2. ordination each stand. Dot indicates zero importance value.

Table 1 - Leading tree species in stand cluster

Cluster	First dominant species	RIV	Second dominant species	RIV
A	Pinus massoniana	69.8	Quercus variabilis	10.6
B	Quercus variabilis	50.4	Pinus massoniana Liquidambar formosana	11.1 8.9
C	Liquidambar formosana	38.2	Quercus variabilis Pistacia chinensis	17.7 9.4
AD	Pinus massoniana	37.6	Ilex chinensis Liquidambar formosana	24.7 15.5
AE	Pinus massoniana	38.4	Quercus variabilis Liquidambar formosana Castanopsis sclerophylla	25.0 20.2 5.5

RIV = relative importance value = (relative density + relative basal area/2) sufficiently indicate an advanced stage in the forest development, and it may be further interpreted that the natural woods in the lower Yangtze Valley are more or less similar in ecological aspects to those in lower altitudes of western China (CHIEN, 1932).

If the Zhong Shan forest is well protected from further destruction, it would be possible to develop into a typical forest of deciduous and broad-leaved evergreen mixed in vegetation, if the source of seeds in available, even develop into a small patch of broad-leaved forest including evergreen trees such as Fagaceae tree species: *Castanopsis sclerophylla*, *Lithocarpus glaber*, *Cyclobalanopsis glauca* and *C. marsinaefolia* and Lauraceae tree species: *Cinnamomum chekiangensis*, *C. camphora*, *Phoebe sheareri* and *Litsea coreana* var. *sinensis*.

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Table 2 — Mean density (Stems/ha) of *Pinus massoniana*, *Quercus variabilis* and *Liquidambar formosana* saplings and trees and saplings: tree ratios in A, B and C cluster stands.

Species		A	B	C
Pinus massoniana:				
saplings	I	1818.2	14.3	0
	II	0	0	0
trees		500	21.4	20
saplings/tree ratio	I	3.64	0.67	-
Quercus variabilis:				
saplings	I	545.5	778.6	200
	II	45.5	85.7	0
tree		191.0	532.9	40
saplings/tree ratio	I	2.86	1.46	5.00
	II	0.24	0.11	-
Liquidambar formosana:				
saplings	I	4000.0	410.0	850.0
	II	2300.0	214.3	550.0
tree		481.8	110.0	300.0
saplings/tree ratio	I	8.3	3.72	2.83
	II	4.77	1.95	1.83

* Saplings I H ≤ 0.33 m; II H > 0.33 m; DHB ≤ 2.5 cm.

ACIDIFICATION PHENOMENA IN EUROPEAN BEECH FORESTS

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Keywords: Mountain vegetation of Europe, Acid rain, Forest decline.

Fagus sylvatica L. is a very important tree in the deciduous mountain forests of Central Europe. As shown by many investigations in the last decade it is more and more affected by damages of leaves and crown development (see e.g. ROLOFF 1986).

Difficulties concerning natural regeneration of beech forests are also recorded (GEHRMANN & ULRICH 1982). In the view of many authors (e.g. ULRICH *et alii* 1979) soil acidification, which in the meantime was proved by many authors (e.g. BUTZKE 1981; FALKENGREN-GRERUP *et alii* 1987; DAHL 1988; HALLBÄCKEN & TAMM 1986), is one of the main causes for the forest damage to be observed in Central Europe. If soil acidification has taken place, the herb layer, a sensitive indicator of habitat conditions, ought to show a reaction. It is thus the aim of our investigations to discover whether and to what extent changes are taking place, and whether these changes can be correlated with stress parameters in certain circumstances.

The methods used will be listened merely by headings for reasons of space. Reference should be made to he studies which have already appeared to date (NEITE & WITTIG 1985; WITTIG *et alii* 1985). The following methods have been used within the scope of the project described here:

- repetition of phytosociological relevés from previous years;
- comparison of species combination and of mean indicator values (for the indicator value method, see ELLENBERG 1979);
- detailed mapping of vegetation in the stem flow area of beech trees;
- comparative soil analyses in the stem flow area of beech trees and in the centre of beech forests stands.

The repetition of 44 photosociological relevés of the beech forests growing on loess soils (*Milio-Fagetum*) of the Westphalian Bight produced the following results (for a detailed account, see WITTIG *et alii* 1985; WITTIG & WERNER 1986): From 1976 to 1983 acid and nitrogen indicator plants have increased remarkably in the herb layer. The increase reaches a lower extent in the group of the nitrogen indicators than in that on of the acid indicators. It is possible to disregard light indicators in this respect, as the light indicator value applies to flowering and fructiferous specimen; however, only stunted individuals were found in the forests investigated. In the mean average indicator values, only the reading for soil reaction has changed significantly; using an unweighted method of calculation, an average reduction by 0.29 units was noted.

The investigations by TREPL (1982) show that forest communities are very conservative in terms of their combination of species: They do not react to usual annual fluctuations of habitat conditions, but only change their combination of species when a development has taken place in the same direction over years. In contrast to e.g. the situation in soil pH measurement, the present results thus permit not only the conclusion that site conditions were apparently more favourable for acidophilic species in 1983 than in 1976, but it is also possible to show a trend: Between 1976 and 1983, a favouring of acidophilous and nitrophilous species took place in the Milio-Fagetum of the Westphalian Bight. Whether there is an increase of acid indicators under the influence of acid precipitation or not depends upon the soil type and thus also upon the investigated forest community. So the results of other authors showing only an increase of nitrogen indicators but no increase of acid indicators are not contradictory to those mentioned above, because they are obtained in different communities (see WITTIG 1988).

Many individual causes, or a combination of such causes, can be responsible for the acidification of soils, e.g. natural ageing processes of the forest ecosystem, of nutrients, climate, forest resources management, immissions, deposition ("acid rain"). If the latter are involved, the soil at comparable sites ought to be more acid at locations with increased H^+ -deposition. This leads us to the investigations made in the area around the trunk of *Fagus sylvatica*.

In recent times, the area around beech trunks has been described as a special site by numerous authors (see bibliographical summary in JOCHHEIM 1985). The majority of authors detects a clearly higher H^+ - concentration in the soil solution for this area over that in greater distance from trees. Furthermore in several beech forests of Central Europe an increase of acid indicators was reported (GLAVAC *et alii* 1970; WITTIG & NEITE 1983; JOCHHEIM 1985), whereas base indicators generally avoid this micro-site.

Investigations in the Milio-Fagetum indicate that a reduction in pH in the area around the trunk can also be detected in this forest community, and that the results measured are reproduceable: Approximately the same pH values and differences between stem flow area and "normal" forest soil were found in 1983 as in 1984 (BALLACH *et alii* 1985).

As for deposition, it is known that the area around the trunk represents a site supplied with a volume of rainwater approximately 5 times hither than the "normal" forest soil (EIDMANN 1959), and that the water running down the trunk has a lower pH than that dripping from the crown of the tree (Table 1 in JOCHHEIM 1985). With the aid of the flow of elements published by MATZNER *et alii* (1982), JOCHHEIM has calculated for the Solling Forest (period 1969-1982) a 23-times higher deposition rate of H^+ ions in the area affected by stem flow than on "normal" forest soil.

The occurence of acidification in the stem flow area described above could be either "from natural causes", i.e. caused by the beech itself, or alternatively be the consequence of higher acid deposition due to immissions, or stem from both causes. The observations made by TÜXEN (1977) support a natural thinning with associated acidification of the site. The known fact that soils in areas with heavy rainfall suffer a more rapid impoverishment in nutrients than those in areas with less rain fall also constitutes a possible explanation for the phenomena observed. Finally, the beech tree could itself be responsible for the acidification by excretion of acids via bark.

If the theory of natural causes for trunk acidification is correct, it should be possible to detect such a phenomenon in all areas of growth of *Fagus sylvatica*. If acid rain is the cause, it should only be possible to detect the appropriate phenomena in areas with a high rate of acid deposition. In order to answer the question of causes for the peculiarity of the stem flow area, we therefore investigated *Fagus sylvatica* forests in South Europe (Spain, Italy), West Europe (Ireland, France) , and Hungary (WITTIG 1986; WITTIG & VENANZONI 1987; WITTIG *et alii* 1987; WERNER *et alii* 1987) and compared the results, considering also the publications of other authors (Austria: GLATZEL *et alii* 1985; Corsica and Croatia: GLAVAC *et alii* 1985; Germany: GLAVAC *et alii* 1970; KOENIES 1982; JOCHHEIM 1985; NEITE & RUNGE 1986; NEITE 1987; Sweden: FALKENGREN-GRERUP 1989; Switzerland: FLÜCKINGER *et alii* 1984).

All studies available from Central Europe testify both to a drop in pH and to a change in the herb layer in the area around the beech trunk. It was possible to detect a reduction in pH in the stem flow area in the Hungarian Bükk and

Matra Mountains and in North and Central Italy (WERNER *et alii* 1987). But no observations of any significant differences in soil pH between stem flow area and "normal" forest soil could be made in South and West Europe, nor were there any signs of an increase of acid indicators in the trunk base area. By these results it is proved, that the changes in the stem flow area of *Fagus sylvatica* are not natural changes but caused by deposition of acidity. Heavy metals, too, may play an important role. A report of the distribution of lead in the soils of the stem flow area of European beech forests is given by WITTIG (1989) and WITTIG & NEITE (1989).

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ECOLOGICAL ASSESSMENT OF VEGETATION RESOURCES AND ITS MANAGEMENT OF YI-COUNTY IN SOUTH PART OF ANHUI PROVINCE.

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Key words: Mountain vegetation of China, Vegetation resources, Landscape ecology.

INTRODUCTION

China is a mountainous country, especially in southern China, mountain area accounts for more than 70% of total area. There fore the reasonable utilization and protection of mountain vegetation resources will have great impact on the quality of people's life, not only at present but also in the future.

In order to develop the local economics and to prevent the destruction of ecological balance simultaneously, the ecological assessment of mountain vegetation and a further management program is necessary. Let us take Yi-County as example to approach this subject.

GENERAL CHARACTERISTICS OF YI-COUNTY

Yi-County is located at 29" 47' - 30" 12' N and 117" 38' - 118" 06' E in South Anhui. Its total area is approximately 857.82 km. The area of mountains and middle part of Yi-county is generally about 500-800 m. The highest peak is on altitude of 1432 m. The Stratum of this region is constituted of solid and light metamorphic sand rocks of Proterozoic area. Peaks tower magnificently, valleys are deeply cut, and the slopes of the region are about 40°, occasionally 50". In the north part the low mountains are generally about 400-600 m high above sea level, and their relative height 200-400 m. The stratum is Cambrian and Ordovician era, mainly composed of argillaceous rocks like shale, phyllite, etc. The slopes are about 30°. In south part, the low mountains and hills less than 400 m in altitude. Relative height is less than 250 m, most of them are of Mesozoic era and cultivated of red sand conglomerate and sandstone, as well as purple sand stone of Tertiary. The slopes are about 25°, and the county town located at the basin, which is formed by granite intrusive rocks through a long period of erosion. Additionally there are two limestone bands located at southern and northern parts, with some basins spreaded over.

The climate of Yi-County is warm and wet (Fig. 1), with clear-cut four seasons. The mean annual temperature is 25.8° C. January is the coldest month with 3.7° C, and July is the warmest month with 27.1° C. The accumulation temperature above 10° C is 4948.7° C. The frostfree period is 210-310 days. The warm index is +131.2, cold index is -1.3. The annual precipitation amounts 1686.1 mm. The maximum rainfalls occur during spring (march to May will hold 37%), and summer (July to August 38%). At autumn (September to November) and winter (December to February), it is relatively less, holds 13% and 12% separetely. The annual relative humidity is 78%.

The main soil type of the county is yellow-red earth, which is distributed over the region below the attitude of 800 m. The soil layer is mostly deep and fertile, pH = 5.5-5.6. Additionally, there are also some purple soil with clay texture, pH = 6.5-7.5. At the mountain region with the altitude of 800-1000 m, it is mostly mountain yellow earth, with clayish texture and week acidic reaction. Above 1000 m there spread the mountainous yellow brown soil with thin soin layer. At the basin the cultivation of rice has impact on the soil, then the rice soil is formed. Additionally, on the steep slopes and severe sites, the erosive yiung soil occurs. The climate climax of Yi-County is evergreen broadleaved forest, but under the longterm human influence, its sites are much reduced. Today, vast areas are covered by secondary shrubs and shrub grass thickets, as well as the artificial forests and cultivated vegetations (see map).

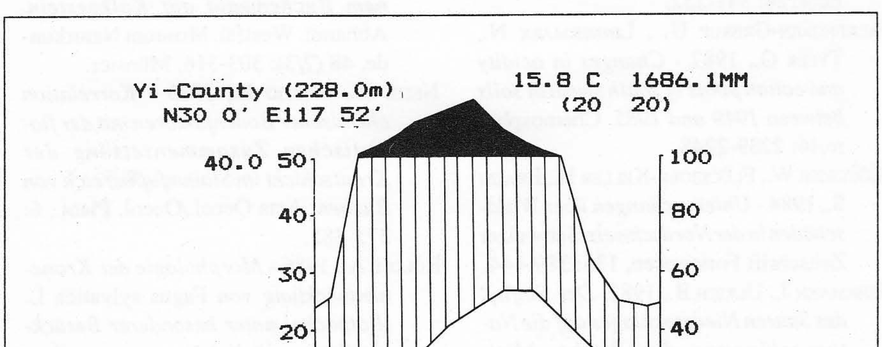


Fig. 1 — The climatograph of Yi-County.

METHODS OF ECOLOGICAL ASSESSMENT OF VEGETATION

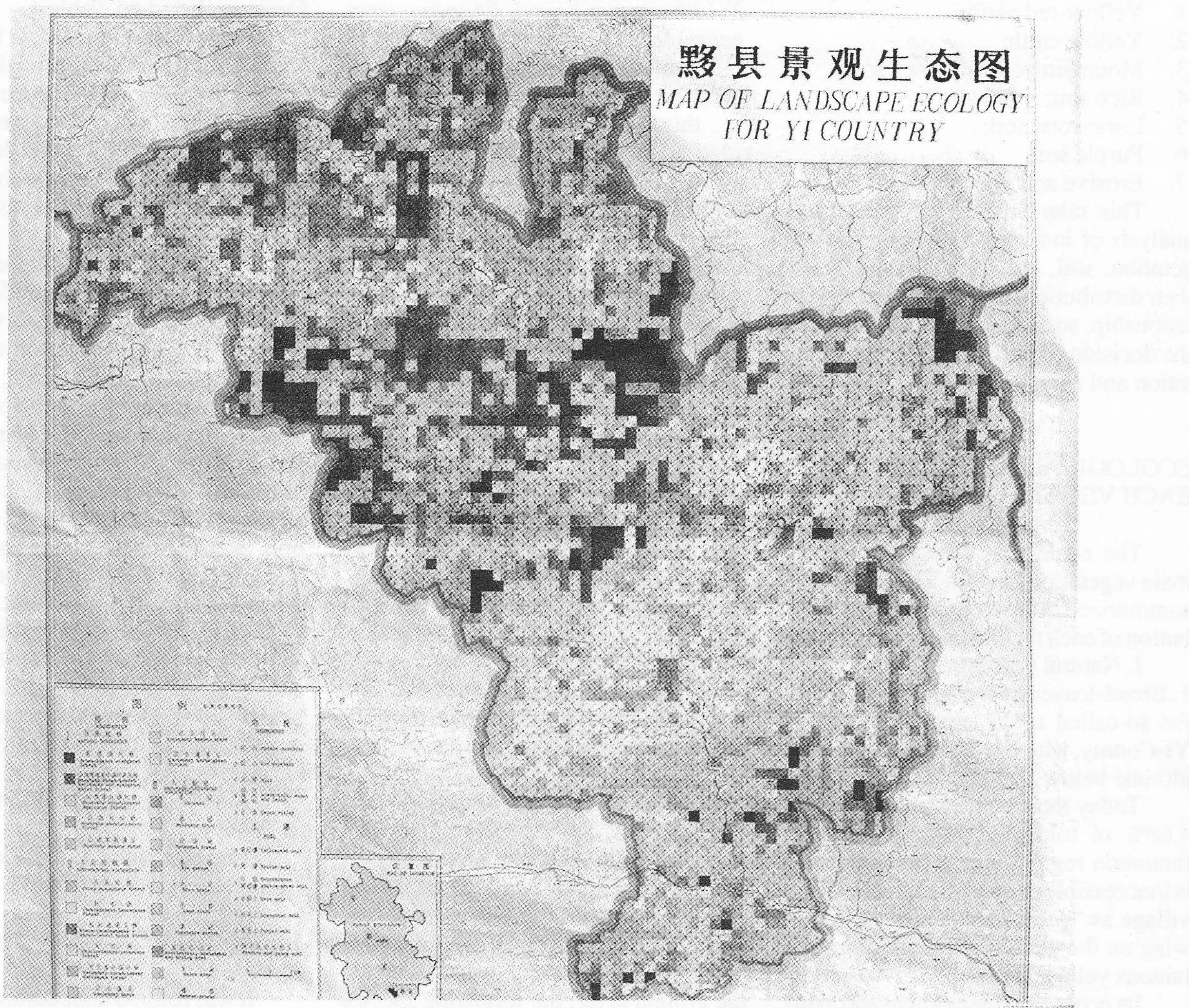
Based on the detail vegetation survey and other investigation about soil, topography, forestry, agriculture and social economics, we set up 5 criteria, for ecological and economic assessment partly in accordance with the works of MIYAWAKI *et alii* (1975, 1984). Each of them is divided into five classes as follows:

(I). layer structure:
- Class 1. barren ground with no vegetation coverage;
- Class 2. plant community with only one layer;
- Class 3. with 1-2 layers;
- Class 4. with 2-3 layers
- Class 5. with 4 or more than 4 layers.

(II). primary productivity
- Class 1. 0-0.005 tons per hectare per year;
- Class 2. 0.005-2 tons/ha./y.;
- Class 3. 2-10 tons/ha./y.;
- Class 4. 10-15 tons/ha./y.;
- Class 5. more than 15 tons/ha./y.

The primary productivity for each vegetation type is decided with the references of works by LIETH (1975), SHIDEI *et alii* (1977), KIRA *et alii* (1978) and FENG *et alii* (1984). The primary productivity of shrub is measure by JING (1985).

(III). Natural grade:
- Class 1. area under unregular and deastic human influence, or with sparse annual pioneer plant communities;
- Class 2. area under regular and



strong human influence, with various species plant communities;

Class 3. secondary perennial gras slands and thickets with few species and poor differentiation of layers;

Class 4. secondary forests and artificial forests and moderate habitats;

Class 5. natural and seminatural vegetations.

(IV). Environmental effect:

Class 1. very strong erosion, huge environmental stress;

Class 2. strong erosion, big environmental stress;

Class 3. median erosion, moderate environmental stress;

Class 4. weak erosion, less environmental stress;

Class 5. very weak erosion, little environmental stress.

(V). Economic benefit: it referred to realistic or temporary economic benefit and potential economic benefit. The 5 classes for the former are:

Class 1. less than 1/5 of the low limit of the class (the ave rageincome level of this region;

Class 2. range from 1/5 of the low limit to the low limit of class 3;

Class 3. average income level (500-5000 yuan/ha./y.) of this region;

Class 4. range from high limit of class 3, to three times of it;

Class 5. more than three times of high limit of class 3.

The 5 classes for the latter are:

Class 1. in the nera future, e.g. in five years or longer, the economic benefit may increase from 0-10% than present time;

Class 2. may increase 10-50%;

Class 3. may increase 50-100%;

Class 4. may increase 100-200%;

Class 5. may increase more than 200%.

Evidently, the first three criteria are concerned with the vegetation characters itself, while the fourth one is related with the environmental factores. Altgrate index accounts for the value of vegetation type in the respect of ecological effect as well as economic benefit. The second one is to integrate the class number of different ecological asessment with that of potential economic benefit, this index will be of the value of the vegetation type more on the side of potential economic benefit.

Additionally, we have made a map of landscape ecology facilitating the application of the assessment data in the administrating plan.

On the map with the scale 1: 50,000 chaquers are drawn, each lattice is 1 cm2 used as one unir of mapping. All the dominant types of vegetation, soil, and geomorphy are fixed into it.

A. The vegetation (including land exploitation) is classified into 23 types (see the map).

B. The geomorphology is classified into 5 types, they are.

1. Middle mountains: above 800m al titude, relative height is 500-600 m.
2. Low mountains: 500-800 m altitude, relative height 200-400 m.
3. Hill, 250-500 m of altitude, relative height 100-250 m.
4. Lower hills, mounds and basins: less than 250 m altitude.
5. Basin valley.

C. The soil is classified into 7 types:

1. Yellow-red earth;
2. Yellow earth;
3. Mountain yellow brown soil;
4. Rice soil;
5. Limestone soil;
6. Purple soil;
7. Erosive and young soil.

This map promts the statics and analysis of individual element like vegetation, soil, etc. as well as to study their distribution, formation and interrelationship, so as to provide evidencefor the decision of policies for land exploitation and reformation.

ECOLOGICAL ASSESSMENT FOR EACH VEGETATION TYPE

The ecological asessment for the main vegetation types in Yi-County was summarized in the table 1. and the distribution of each typeis shown on the map.

I. Natural vegetation:

1. Broad-leaved evergreen forest: this is the so-called zonal vegetation type of Yi-County, which is distributed over the altitude below 800-900 m.

Today their stands hold only about 4.66% of told area, and spread over mountain region, where transportation is inaccessible or they remain around the village as "geomancy forest". It's growing on the yellow-red earth or mountainous yellow earth.

Its ecological assessment and synthetic assessment values are highest, shown on table 1.

The broad-leaved-evergreen forest of this region contains many valuable economic plants and animals, which are expected to be opened up and exploited they have great development potentialities, but up to now very few attention has been payed to them. They are not well conserved and reasonably utilized.

According to the dominant-type and diagnostic species the vegetation type is divided into three communities (see table 2):

1) *Cyclobalanopsis glauca*, *Lithocarpus glaber*, *Castanopsis sclerophylla* forest;
2) *Castanopsis eyrei*, *Cyclobalanopsis glauca* forest;
3) *Lithocarpus henryi*, *Litsea coreana* var. *sinensis* forest.

2. Mountain broad-leaved deciduous evergreen mixed forest:

this type of vegetation is distributed generally over the slope of mountains with altitude of 900-1100 m or in valleys at lower altitude. They hold 1.23% of the total area. The ecological asessment is shown in Table 1.

This type contains two communities (see Table 2):

1) *Lithocarpus henryi*, *Castanea seguinii* forest;
2) *Lithocarpus henryi*, *Emmenopterys hebryi* forest;

3. Mountain broad-leaved deciduous forest:

this type scattered overmountain ridge or mountain valley with altitude above 1100 m. It holds only 0.15% of the total area, and has a habitat with yellow brown soil, thin soil layer and much rock outcrops and stones. The common plant community is *Castanea seguinii*, *Platycarya strobilacea* forest, normally distributed over the slope with altityde above 1100 m. Additionally in the valley above 1000 m, part of region is covered with *Cyclocarya paliurus* forest.

4. Mountain needle-leaved forest:

in this county only *Pinus taiwanensis* forest occurs, which is distributed mainly over mountain area above 900 m altitude. Its low limit of distribution tends to reach the high limit of the *Pinus massoniana* forest.

Pinus taiwanensis forest has tree layers. The tree layer dominated by *Pinus*, sometimes mixed with few *Castanea seguinii*, *Quercus glandulifera* var. *brevipetiolata*, *Toxicodendron sylvestre*, *Cornus cosa*, *Sorbus folgeri*, etc. The species of shrub layer are mainly of *Lindera obtusiloba*, *Symplocos chinensis*, *Corylopsis sinensis*, *Lespedeza bicolor*, *Crataegus cuneata*, *Spiraea chinensis*, *Hydrangea umbellata*. In the ground layer, the following species frequently occur: *Carex* sp., *Pteridium aquilinum* var. *latiusculum*, *Erigeron annuus*, *Arundinella hirta*; etc.

Pinus taiwanensis can grow on the high mountain region with the thin and poor soils, even at rock fissure. It is a valuable species for greenery of this region.

5. Mountain meadow shrub:

this community type distributed over the mountain ridge and mountaintop. Its ecological assessment value and species composition are present on Table 1 and 3.

In this vegetation type, there are many medical and edible plants, furthermore is has a capability of soil and water conservation. Therefore it must be protected and reasonably utilized in the future.

II. Seminatural vegetation:

6. *Pinus massoniana* forest:

It has both natural and artificial stands. The artificial forest is roughly managed, so that it looks like seminatural stands. They are distributed over low mountains and hills with altitude below 900 m.

Pinus massoniana can grow on the dry and poor soil. It is the pioneer tree species for greenery of the lower mountain region.

The species constituents of this forest are listed on Table 4.

7. *Cunninghamia lanceolata* forest:

most of them are artificial forests in this county. Generally, they are roughly managed and exist in seminatural state. They are cultivated on the slopes with altitude below 800 m and with deep soil layer. The species constituents are listed on Table 4.

The wood of *Cunninghamia lanceolata* is an excellent building material. The economic benefit is very high.

8. *Pinus-Cunninghamia*-broad-leaved mixed forest:

Both natural and seminatureal stands exist. The species composition is shown in Table 4. The community structure is much more complex, therefore its efficiency for soil and water conservation is relatively high. It favours the improvement of soil and decrease of the tree diseases and insect pests.

9. *Phyllostachys pubescens* forest:

bamboo forests are distributed over gentle slope and low altitude valley below 800 m. They are adepted to warm, moist, fertile and deep soil, most of them are cultivated stands.

The species composition is shown in Table 4.

The efficiency for soil and water conservation is weak, but its economic benefit is high.

10. Secondary deciduous broad-leaved forest:

It was formed after deforestation of broad-leaved evergreen forest, and distributed over the region of altitude below 800-900 m.

Its ecological assessment value is shown in table 1. and the temporal economic benfit is not high, but its efficiency for soil and water conservation as well as improvement of the ecological environment are relatively high.

According to the species composition it can be divided into 3 communities (see Table 5.).

1) *Quercus faberi*, *Liquidambar formosana* forest;
2) *Castanea mollissima* forest;
3) *Sassafras tsumu* forest.

11. Secondary shrub:

this vegetation type was formed after deforestation or as a stage in succession. It is widely distributed over the low mountains and hill area. Its habitat shows somewhat of drought.

The economic benefit is low, so this type has to be transformed as well as reasonably utilized.

It may be divided into two communities (see Table 6):

1) *Loroepetalum chinense*, *Vaccinium bracteatum*, *Rhododendron simsii* community.
2) *Quercus faberi*, *Rhus chinensis*, *Vitex negundo* var. *cannabifolia* community.

12. Secondary grove of bamboo:

also a secondary vegetation type after the deforestation it is distributed over sunny slopes on low mountains and hills.

Its ecological and species composition are shown in Table 1 and Table 6 separately.

13. Secondary shrub-grass thickets:

if the secondary are cut and fired repeatedly, it will be transformed into secondary shrub-grass thickets, which will also be formedon old-field. They are commonly distributed at low mountain and hillregion, where the population density is very large. When the discruption is stopped, it will be reformed to the forest through the shrub stage.

There is one community of this type in Yi-County.

III. Cultivated vegetation:

14. Orchard:

the orchard accounts for about 100 hectares, and is commonly distributed on low hills, mounds and basins, near the village. The common species are: peach, pear, kaki, persimmon, chinese chestnut, chinese torreya and chinese-date. Additionally, there are relative amount for orange, tangerine and loquat. Their management are extensive and the production is lower.

The community structure is simple. Under the fruit tree layer there are more or less shrubs and herbaceous plants, occasionally intercropping with dry grains and legumes. Its ecological assessment is show in Table 1.

15. Mulberry field:

it is distributed mainly over gentle slopes, mountainfeet, mounds and river terraces, generally monocultivated. The local area is about 540 hectares. Silkworms are raised with leaves of mulberry. Its economic benefit is high.

16. Economic forest:

above 660 hectares of economic forest in the county is distributed over hills and mountain region. They are of: tong oil (*Aleunites fordii*), tea oil (*Camellia oleifera*), oriental oak (*Quercus variabilis*), *Litsea cubeba*, Lacquer tree (*Toxicodendron vernicifluum*), generally formed a little stands. Although the economic benefit is big, but as a result of extensive management, the production is somewhat low.

17. Tea garden:

the area of tea gardens will be more than 3000 hectares. In this region they are usually distributed on slopes and feet of hills, or terraced field.

The old modelled tea gardens are sparse, with low coverage and production. The new modelled ones is better, and production much higher.

18. Rice field:

Its total area accounts for 9000 hectares and holds 70% of field area throughtout the county, mainly distributed at basins, river valleys slopes of hills at an altitude below 800 m. The rice will be cropped once or twice per year. During the winter either wheat, rape or green manure crop will be cultivated or the land will lie fallow.

19. Land field:

its area is about 3210 hectares, holds 26% of the county's farmland. It is distributed on the gentle slopes of mountains and ridges of hills. The cultivated plants are always: wheat, maize, sweet potato, and other dry land crops and economic plants, such as rape, cotton, sesame, soybean, etc. Up till now they are roughly managed, the production level is low. They have to be intensively managed. Some of the land field on the steep slopes should actually be stopped to cultivate crops and reforestation be developed.

20. Vegetable garden:

they are distributed around the residential area. The area accounts for about 225 hectares. There are a lot of vegetables, e.g. green leaved vegetables, melons and legumes, generally intensively manged. The economic benefit is high.

PROPOSALS FOR MANAGEMENT

According to the statistic of each vegetation type's area from the ecological landscape map, the total area of Yi-County account for 8565 hectares. Among them farmland (rice field and land field) holds 14.64% of total area, garden or plantation (orchard, mulberry field, tea garden, vegetable garden, economic forest) holds about 5.25%, forest holds 59.56 (6.38% of natural forest and 53.18% of seminatural forest), various shrub about 16.89%, in the remainder water area about 1.31%, residential industrial and mining area about 2.09%, and barren ground about 0.29%. The forrest area is relative big, which shows that as a mountainous county. Yi, still keeps a certain degree of natureness. The distribution of each vegetation type on the map distinctly shows the principle of landscape ecology, e.g. natural forests commonly distributed in remote mountains and cultivated field concretrated on plain, basin or low hill region around the settlement. As for the shrubs except those sparsely distributed on on mountain tops and steeep slopes, where the natural condition is quite poor, most of them are distributed over the region with convenient transportation , dense population and frequent human activity.

From Table 1, it distinctly shows: the synthetic assessment value of each forest type is higher than cultivated area and garden. Futhermore, the natural forest is much higher than needle leaved forest and seminatural forest, not only the ecological efficiency is better, but also the potential economic benefit is grater. At present time the area of regional broad-leaved evergreen forest is too small and proportion is too low. Up to now, the relatively high ecological benefit and potential economic benefit are still not regarded. They are always cut down and substituted by monocultived needle-leaved forest. However the monocultivated afforestation has to be changed into mixed cultivated. It is necessary to improve the conservation of natural and seminatural broad-leaved forest and to enhance the resonable utilization of them.

The proportion of farmland area is not large, but the average area per capita is more than in other regions with dense population in Anhui Province. In the current situation, the potential for its increment is very limited. Therefore it is necessary to maintain this level and pay more attention to manipulation of lands in order to increase the yield per unit area.

The serious problem lies in the fact, that the shrub area is too big which surpasses the total area of farmland. Both of its ecological and economical benefit are rather poor. They should be trasformed, except the mountain shrub-grass thickets growing on the ridge and top of mountains. Under the local climate condition the secondary shrub may easily be changed into secondary broad-leaved forest, in case they are confinded to facilitate afforestation. Of course some suitable methods have to be adopted, so that various useful tree species will be developed under out will and control. A part of them will turn out to be charcoal forest, the other part can be changed into orchards or economic forests. Additionally some stands may be used to set up for artificial experiment grassland so as to develop the animal husbandry and regulate the production.

The residential, industrial and mining area including the streets and roads should be afforested and the environmental protection enchanced. In order to meet the needs of the development of production and improve the living standards of the people, area of vegetable garden has to be enlarged and to increase the varieties of vegetable.

It is worthy to point out, that the water area covers a certain part of the county, and has a relative great potential productivity. A part of them may be used to develop the water electricity and irrigation, while the pools and reservoirs, which account for 490 hectares may be used to develop the aquatic products.

Based on the above result of synthetic assessment analysis, we have made a proposal for regulating the proportion between the main vegetation types that is: keeping the farmland area at current level, 15% of total areas exerting big efforts to developing and protecting the broad-leaved forest, especially the evergreen forest, reforming most part of shrubs into forests so expanding the forest area to 70%, a part of shrubs can be transformed into economical forest, if the habitat is suitable, then the garden and plantation area will be enlarged to 7-8%.

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OZE NATURAL AREA (JAPAN): ONE EXAMPLE OF CONSERVATION AND RESTORATION IN A MOUNTAINOUS AREA

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Keywords: Mountain vegetation of Japan, Nature conservation, Restoration of Vegetation.

INTRODUCTION

Oze comprises the central, primitive landscape in the Nikko National Park, one of 27 national parks in Japan. The Oze area contains the largest montane mire in Japan (*Sphagnum* bog, peat bogs, *Moliniopsis* and sedge fens, marsh fens, etc.) and includes native forests of *Fagus crenata*, *Abies mariesii*, *Ulmus davidiana*, *Salix sachalinensis*, etc. The natural vegetation and animal populations have maintained a dynamic equilibrium within this waterwetland ecosystem complex over long periods of time.

The Ozegahara mire and surrounding area were studied in 1966-69 (MIYAWAKI & FUJIWARA 1970) and then again in 1983-86, in order to monitor the changes in the vegetation. The vegetation of Ozegahara was then analyzed phytosociologically and mapped (MIYAWAKI & FUJIWARA *et alii*, in press). The vegetation of the Oze area shows a very high degree of naturalness. Oze was designated as a specially protected area within the National Park in 1953 (by the Environment Agency) and then as a national monument in 1960 (by the Ministry of Education, Science and Culture).

Japan once had many natural areas, but now most are disturbed, with only small natural areas remaining. Oze is one such remaining area, due to the protection of the central, very sensitive area by the surrounding natural forests. The periphery and outside are used for forestry, in particular for afforestations of *Larix kaempferi*. Some highways also pass through the outer areas, bringing many tourists to Oze and particularly to the central natural area. This natural area is important for education, recreation, and nature observation for many people (now over 500,000 visits per year).

The mire vegetation along the roadways had been disturbed badly by 1969. After 15 years of recovery, though, secondary vegetation has become well established (see Figure 4). We thus consider that the natural area is protected to the best of our ability, as a sanctuary. Utilization of the outer areas will still be permitted.

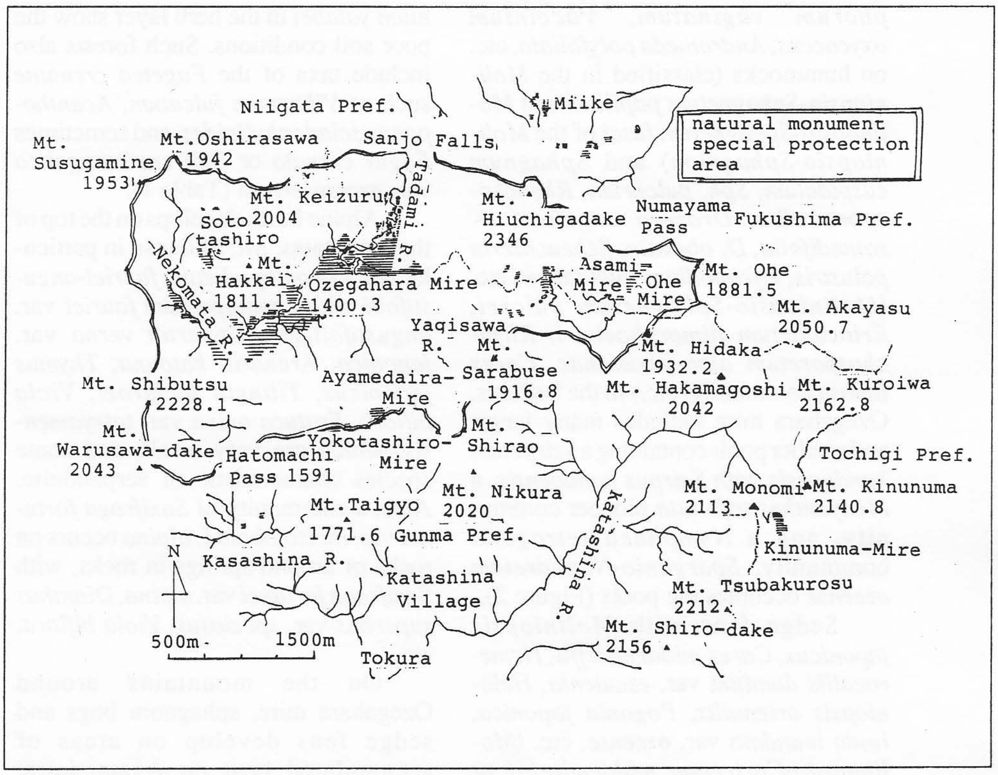

Fig. 1 – Location of Ozegahara Mire and its surroundings.

LOCATION AND NATURAL ENVIRONMENT

Oze is located in north central Japan, approximately between 36°50'N and 36°58'N latitude and 139°13'E and 139°22'E longitude. Site conditions and vegetation correspond to this moist temperate-zone location.

The central part of Oze is Ozegahara mire (1400 m above sea level), located in the Oze basin near the source of the Tadami River, which flows to the Japan Sea (Figure 1). Ozegahara mire is situated on thick peat 5-6 meters deep, with an area of 17.6 km² (about 3 km north-south and 6 km east-west), including gallery forest zones. The volcano Hiuchi (Hiuchigatake, 2346 m) on the east side of Ozegahara mire is a stratovolcano which was formed during the late Quaternary and covers a basement of granite which crops out along the Tadami valley on the western margin of the volcano (KURO *et alii* 1954; SAKAGUCHI, ARAI and SOIIMA 1982). Ozegahara basin was once a lake formed by lava from Mt. Hiuchi (blocking drainage from the valley) but developed later into a wetland after partial drainage (SATO 1954). Mt. Shibutsu (Shibutsu-zan, 2228 m), on the west side of the basin, is composed of serpentinite, which - influences the distribution of vegetation: 1. a forest limit which is about 1500 m lower than on other mountains; 2. endemic and/or special serpentine species; and 3. conifer forest (*Abies*, *Pinus*, *Tsuga*, *Thujopsis*) from the top to the foot of the mountain (about 1400 m). Around Ozegahara are located also Mt. Keizuru (Keizuru-san, 2001 m) to the north and Ayamedaira (1969 m) to the south. Mt. Keizuru has a conspicuous dome-shaped rise composed of andesite. Ayamedaira has a flat top covered by sphagnum bogs. This mountain was a shield volcano. Further to the south and east of Ayamedaira, Oze is surrounded also by Mt. Sarabuse (1917 m), Mt. Nikura (2020 m), Mt. Shirodake (2156 m), Mt. Tsubakurosu (2212 m), and Mt. Monomi (2113 m) (see Figure 1).

The mean annual temperature at Ozenuma (Oze lake, 1665 m) is 1.9°C, with total annual rainfall of 1630 mm and total annual snow depth of 1385 cm. The Oze area has a severe climate showing the Japan Sea influence, with deep snow layers in winter.

VEGETATION OF OZE

In Oze, Ozegahara mire is characterized by its wide complexes of sphagnum bogs and sedge fens with marsh fens (ponds with *Phragmites communis*, *Carex rhynchophysa*, etc.), which develop along streams. The sphagnum bogs are composed of *Sphagnum papillosum*, *Sph. magellanicum*, *Sph. fuscum*, *Erio-*

phorum vaginatum, *Vaccinium oxycoccus*, *Andromeda polyfoliata*, etc. on hummocks (classified in the *Moliniopsio-Sphagnetum papillosi* and *Molinopsio-Sphagnetum fusci* of the *Moliniopsio-Sphagnion*) and *Sphagnum cuspidatum*, *Sph. pulchrum*, *Rhynchospora alba*, *Drosera angelica*, *D. rotundifolia*, *D. obovata*, *Scheuchzeria palustris*, *Lycopodium inundatum*, etc. (*Moliniopsio-Sphagnetum pulchri*, *Eriocauletum dimorphoelytri*, *Rhynchosporetum albo-yasudanae*, *Carex limosa* community, etc.) in the hollows. Ozegahara mire includes many larger and smaller pools containing a *Scirpetum hondoensis* with *Scirpus hondoensis*, a *Menyanthes trifoliata* pioneer community, and a *Nymphaea tetragona* community. *Sparganio-Nupharetum ozeense* occupies the pools (Figure 2).

Sedge fens with *Moliniopsis japonicus*, *Carex middendorffii*, *Hemerocallis dumltiei* var. *esculenta*, *Heloniopsis orientalis*, *Pogonia japonica*, *Inula inundata* var. *ozeense*, etc. (*Moliniopsio-Caricetum middendorffii* or *Inulo-Moliniopsietum japonicae*) surround the sphagnum bogs and/or Ozegahara mire, adding color with their flowers in summer.

Along streams, *Vallisnerio denseserrulata-Hippurisetum vulgaris*, *Caricetum rhynchophysae*, *Angelico genuflexo-Caricetum vesicariae*, and *Equisetum fluviatile* f. *linneanum* occur. Behind these marsh fens or areas of accumulated soil occur galleries with *Salix sessilifolia*, *Ulmus davidiana*, *Fraxinus mandschurica* var. *japonica*, and tall-forb communities involving an *Angelica decursiva-Aster glehnii* var. *hondoensis* community. In many cases these areas have mantel communities such as a *Rhododendro-Maletum*, a *Salix sachalinensis* community, etc.

Around Ozegahara, various forests descend to the foot of the mountains. *Fagus crenata* forests (*Aucubo-Fagetum crenatae*) come down Mt. Hiuchi, Mt. Keizuru, and Ayamedaira on areas of deeper soil. Large areas of *Fagus* forest remain on Mt. Nikura and Sarabuse. On the other hand, an *Abietetum mariesii* covers the steep slopes at the foot of Mt. Hiuchi around Lake Oze and the foot of Mt. Shibutsu. An *Ilici-Thujetum standishii* occurs on poor soils with exposed parent material around the Nekomata river, in the mire, and on Ayamedaira and/or Mt. Monomi to Mt. Tsubakurosu. It includes *Thuja standishii*, *Tsuga diversiflora*, and *Pinus parviflora* var. *pentaphylla* in the tree layer and *Rhododendron albrechtii*, *Ilex sugerokii* var. *brevipedunculata*, *Rh. metternichii* var. *pentamerum*, and *Rh. brachycarpum* in the shrub layer. *Ilex rugosa*, *Epigaea asiatica*, and *Vaccinium yatabei* in the herb layer show the poor soil conditions. Such forests also include taxa of the *Fagetea crenatae* such as *Viburnum fulcatum*, *Acanthopanax sciadophylloides*, and sometimes *Fagus crenata* or *Quercus mongolica* var. *grosseserrata* (Table 1).

Alpine heath develops on the top of the mountains. Mt. Shibutsu in particular has a *Leontopodietum fauriei-angustifolii* with *Leontopodium fauriei* var. *angustifolium*, *Minuartia verna* var. *japonica*, *Arenaria katouna*, *Thymus japonicus*, *Tilingia tachiroei*, *Viola biflora*, *Festuca ovina* var. *tateyamensis*, which are very small, and some species characteristic of serpentinite. Also, a community of *Saxifraga fortunei* var. *incisolobata* f. *alpina* occurs on rocks or around springs in rocks, with *Saxifraga fortunei* var. *alpina*, *Dianthus superbus* var. *speciosus*, *Viola biflora*, etc.

On the mountains around Ozegahara mire, sphagnum bogs and sedge fens develop on areas of accumulated peat on Ayamedaira, Yokotashiro, Sototashiro, and Kinunuma mire. These have *Sphagnum compactum* bogs and *Carex blepharicarpa* fields (*Rhynchosporo-Sphagnetum compactae*, *Faurio-Caricetum blepharicarpae*) which occur on areas with shallow peat (about 5-10 cm, over lava). *Pinus pumila* scrub (*Vaccinio-Pinetum pumilae*) develops around the heath or mire, from 1800 to 2200 m.

The southern parts of Ayamedaira, Mt. Shirao, and Mt. Sarabuse are used for plantations of *Larix kaempferi* or secondary forests for firewood (Figure 3).

CHARACTER OF THE VEGETATION OF OZE

Sphagnum bogs in Ozegahara mire can be divided into two types. One contains *Sphagnum papillosum*, *Sph. magellanicum*, *Sph. fuscum*, and *Sph. capillaceum*, which are species of the *Moliniopsio-Sphagnion* of the *Eriophoro-Sphagnetalia* papillosi in the *Oxycocco-Sphagnetea*. These species occur on areas of deep peat with much rainfall and snowfall. On slopes, on the other hand, *Sphagnum compactum* or *Sph. tenellum* bogs are found on areas of shallow peat, with *Fauria crista-galli*, *Geum penta-petalum*, *Coptis trifoliata*, and other snowpatch plants. These represent the *Rhynchosporo yasudanae-Sphagnetum tenelli* and the *Carici-Sphagnetum compacti*. The former occurs on areas of much deeper snow than the latter, but there are also mixed stands. These two associations normally occur in mountain bogs, but at Ozegahara mire the *Carici-Sphagnetum* occurs on shallow-peat areas disturbed by human walking. These *Sphagnum* communities occur as far north as montane areas on Hokkaido.

Fagus crenata forests of the Oze area are characterized by the lack of *Aucuba borealis*, *Torreya japonica* var. *nana*, etc. Southern parts of Oze have an *Abietetum veitchii-mariesii*, as opposed to the *Abietetum mariesii* around Ozegahara mire. This appears to be related to snow depth, the former occurring on areas of shallow snow and the latter on areas of deep snow.

CONSERVATION AND RESTORATION OF MOUNTAIN VEGETATION

There are not many sphagnum bogs in Japan. These do occur at Sarobetsu Kushiro, Kiritappu mire, and Ochiishimisaki in the lowlands of Hokkaido, with *Rubus chamaemorus* *Chamaedaphne calyculata*, *Empetrum nigrum*, etc. Some species occur in the sphagnum mires of Tohoku, such as Oguninuma mire, Yaheidaira mire, Akaiyachi mire in Fukushima Prefecture and Ojiromori mire in Akita Prefecture. Sphagnum bogs in these lowlands of Hokkaido are similar to the cool-temperate mires of Canada, the northeastern USA, and northwestern Europe. Mires in the subalpine belt include Kirigamine mire, Hachimantai mire, and Hakkoda mire (central to northern Honshu) plus Shokanbetsu mire, Taisetsu (Uryunuma) mire, and Matsunoyama mire. The largest mire ecosystem is in Ozegahara mire. It is unrivaled in the sense that it is the largest in area and that the natural state of the mire and its surrounding mountains is maintained almost intact. If the environment is stable, the mire vegetation can grow in the more severe environments where forest cannot grow. The mire vegetation is very sensitive, however, to sudden environmental changes and to human impact. The Ozegahara mire vegetation, which had long been in balance, was degraded quickly during the 1950-60's to secondary vegetation or bare ground in some parts (Miyawaki 1967; Miyawaki & Fujiwara 1968, 1969, 1970; Fujiwara and Miyawaki 1985; see Figures 4-6).

The vegetation of disturbed areas of Ozegahara has recovered considerably since 1967, as follows:

1. Most of the secondary vegetation along the boardwalk has recovered in the past 15 years. There are many places where the natural vegetation flourishes.

2. In the areas where human intru-

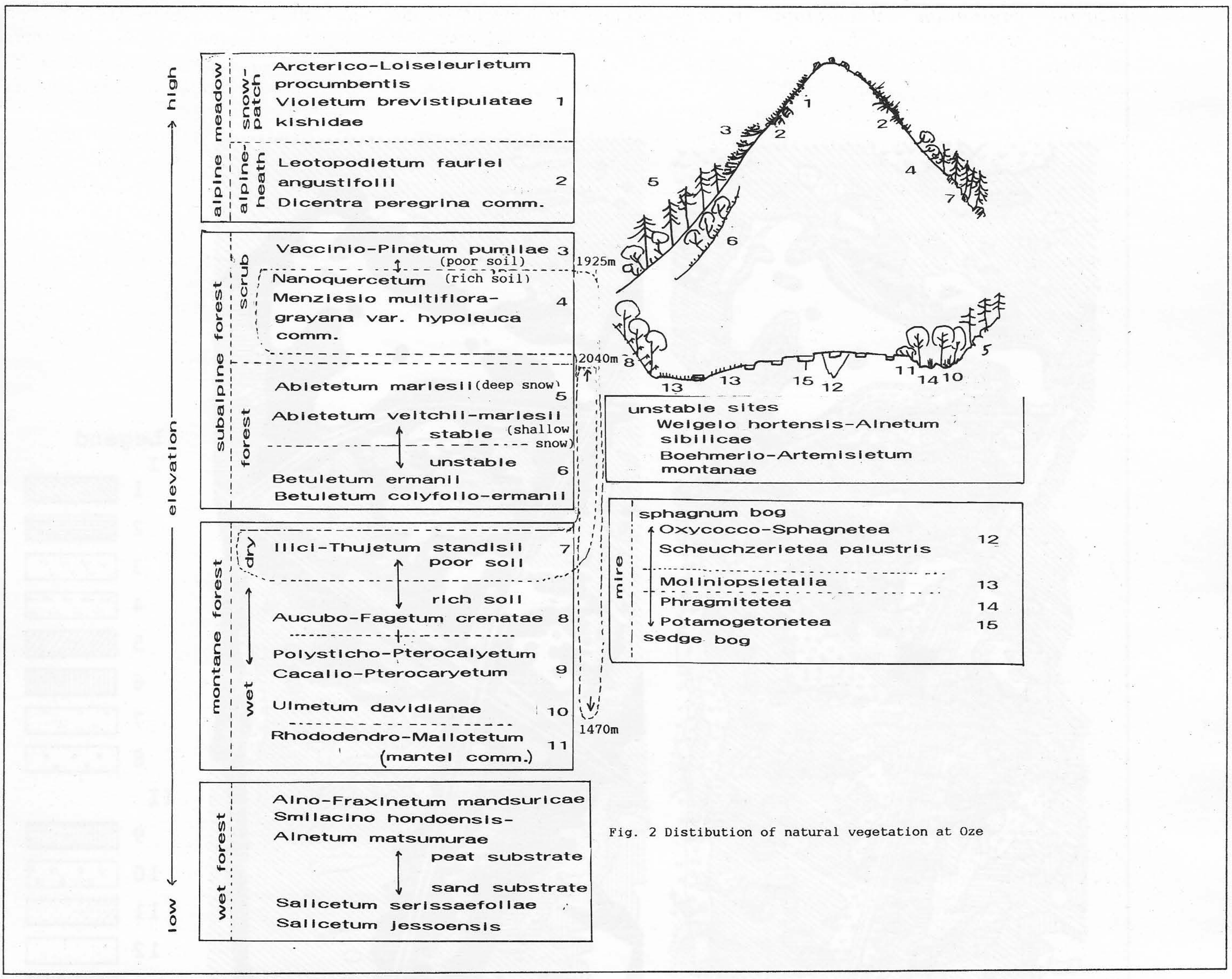

Fig. 2 — Distribution of natural vegetation at Oze.

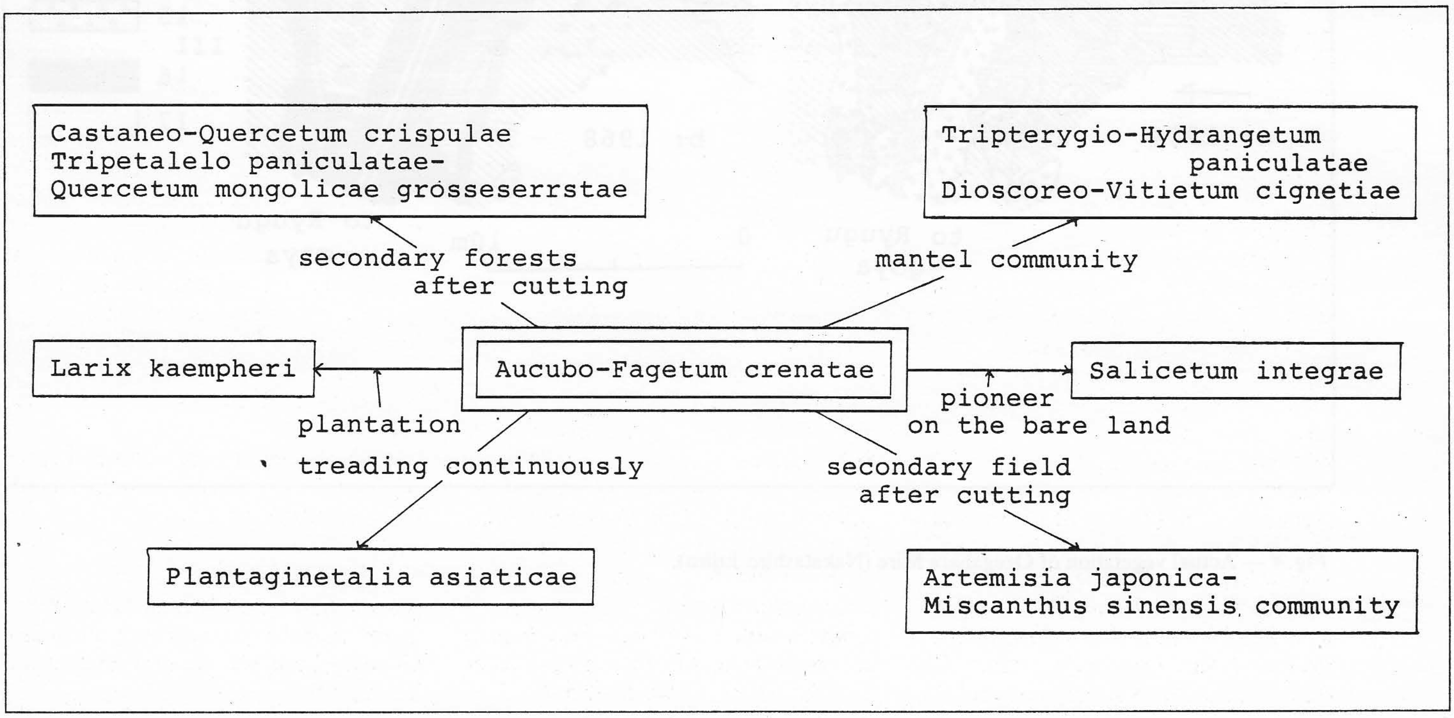

Fig. 3 — The relationship between natural vegetation and substitute vegetation.

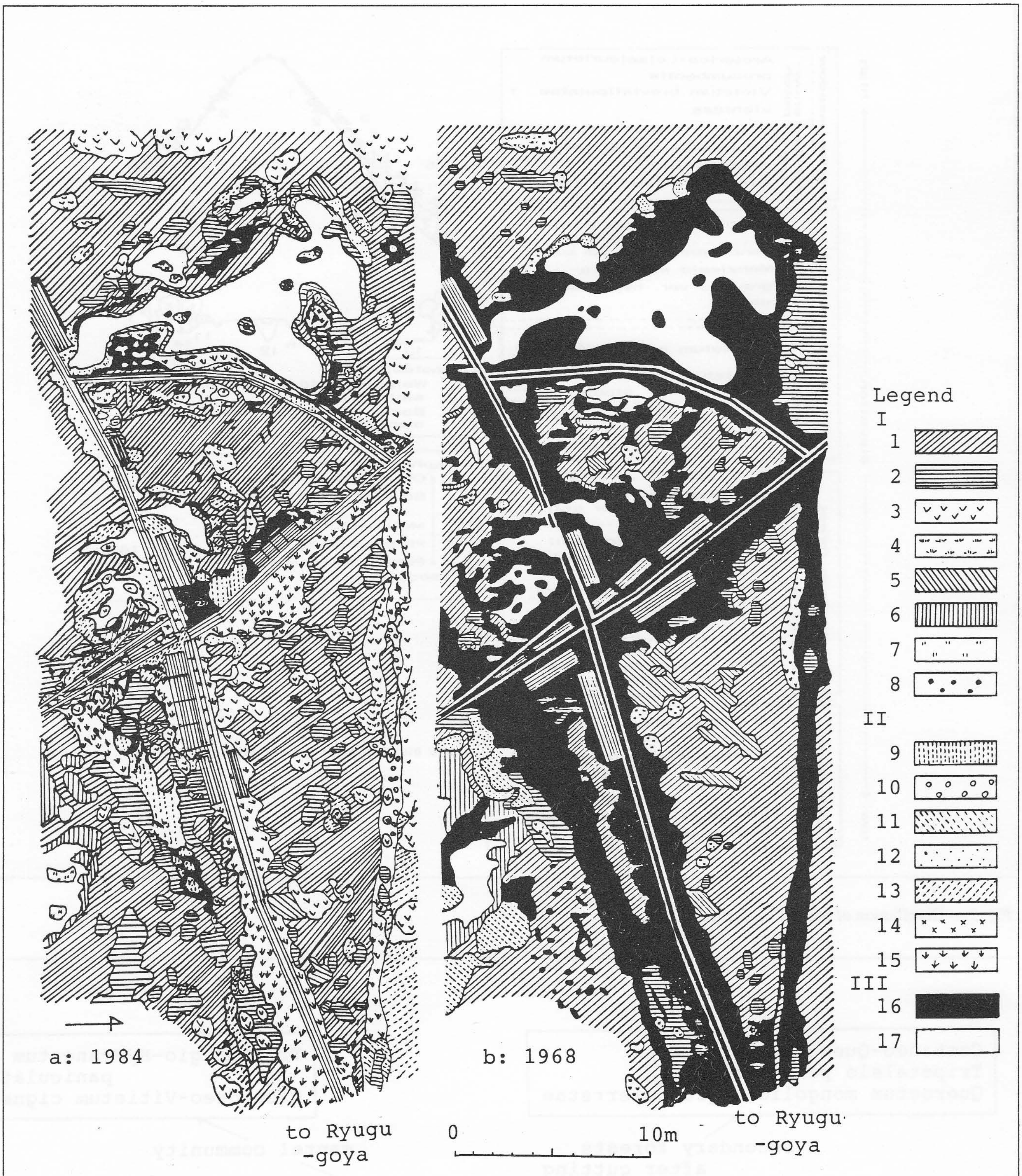

Fig. 4 — Actual vegetation of Ozegahara Mire (Nakatashiro Jujiro).

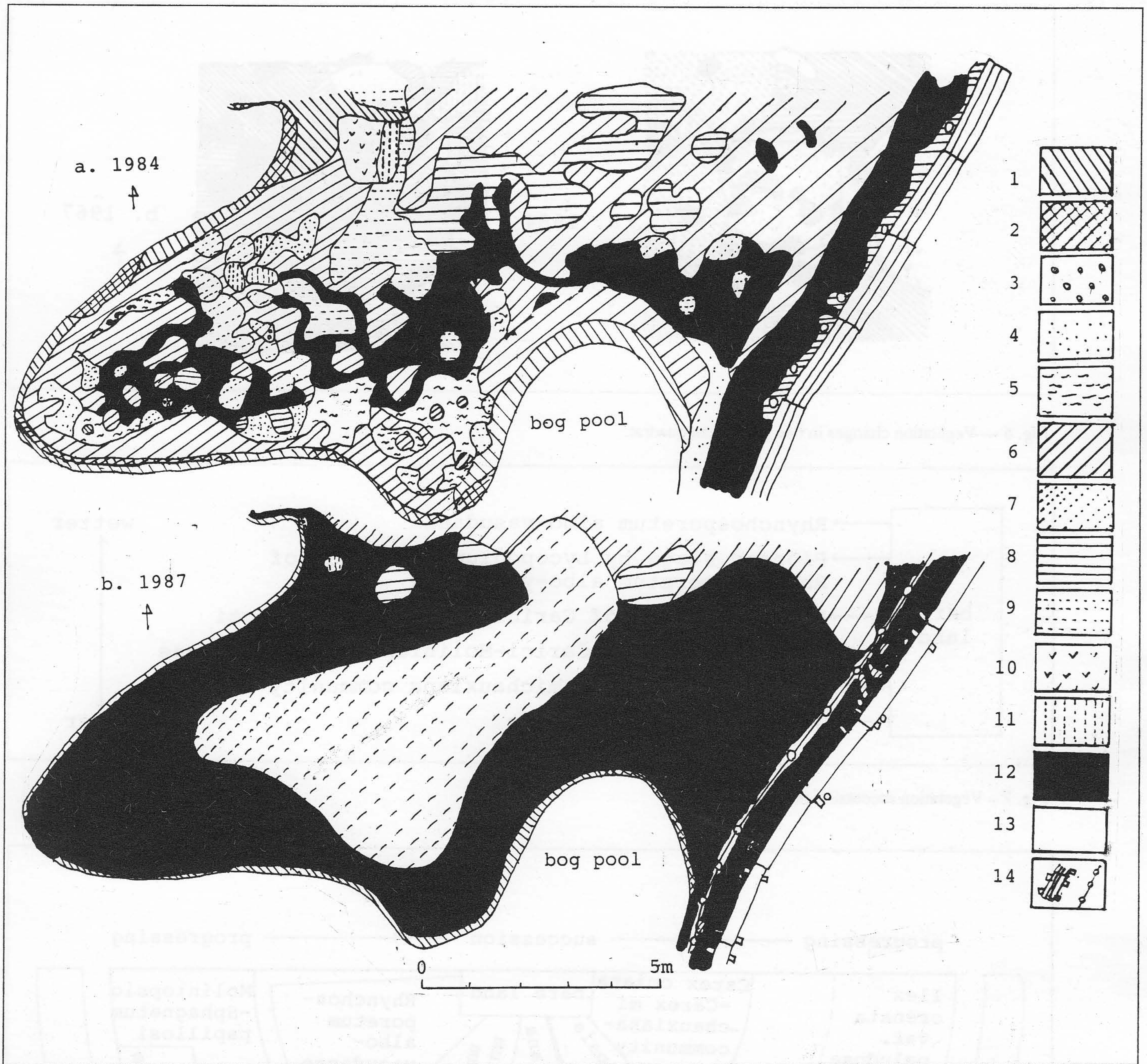

Fig. 5 — Vegetation changes around the one bog pool.

sion is prohibited, the bare ground of 1973 has recovered to a *Rhynchosporetum albo-yasudanae* in 1984; the *Rhynchosporetum albo-yasudanae* areas of 1973 have now become a *Carici omiana-Sphagnetum compacti*.

3. The *Junco-Caricetum albatae* continues to exist in 1984.

4. Most of the bare ground has disappeared and become a *Carici- Moliniopsietum japonicae* and a *Carex omiana-C. michauxiana* community.

5. In the area of artificial plantations (of the natural vegetation), the recovery is quite good where peat drainage and the resulting overland flow and erosion have been prevented.

Al though Ozegahara mire has recovered, the montane mires around Ozegahara have not yet recovered. Montane mires occur in harsher environments characterized by more overland drainage from acidic peat areas (especially during spring snowmelt), low temperatures, and shorter growing seasons. In order to enhance recovery of these areas, the following steps seem necessary:

1. Dense, cross-stitched plantations of peat vegetation in order to retard the overland outflow from the peat areas themselves, which may otherwise wash away the recovering natural vegetation.

2. Protection of both higher and lower areas of the topography by sowing the bare ground between clumps with R*hynchospora yasudana*, *Rh. alba*, *Moliniopsis japonicus*, *Carex omiana*, etc.

3. Mulching with rice straw (after planting), for additional protection against the erosive outflow from the peat areas. (Rice straw appears to be the best material to use.)

4. Planting of the *Rhynchospora yasudana* in cross-stitched patterns with lines at right angles, for best protection of planted areas against the outflow from the peat.

Conservation measures for the montane vegetation must consider the

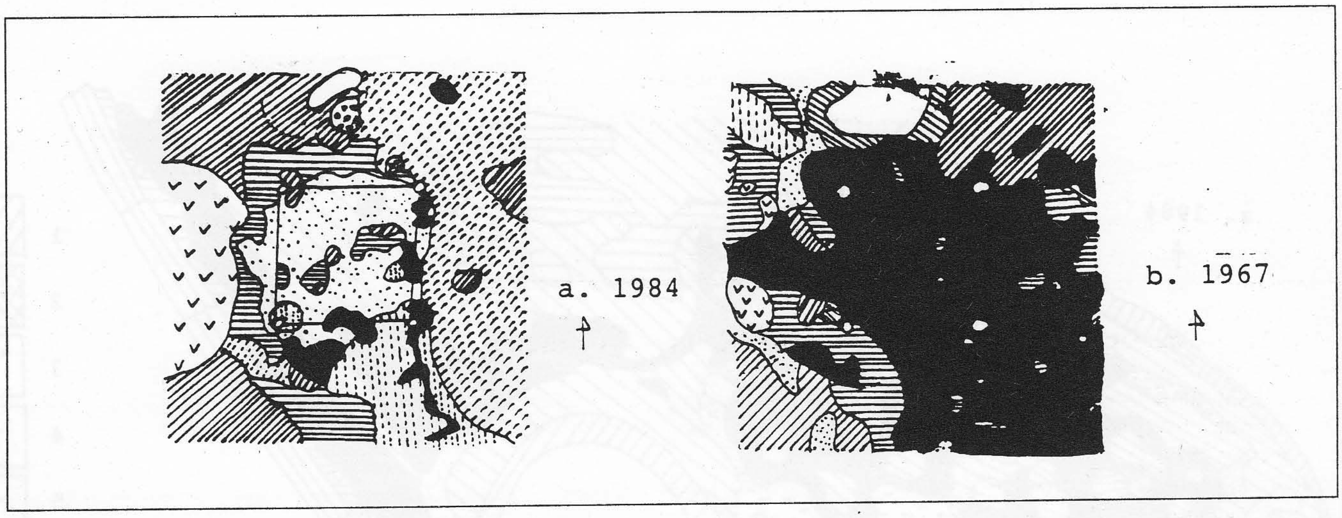

Fig. 6 — Vegetation changes in one permanent quadrat.

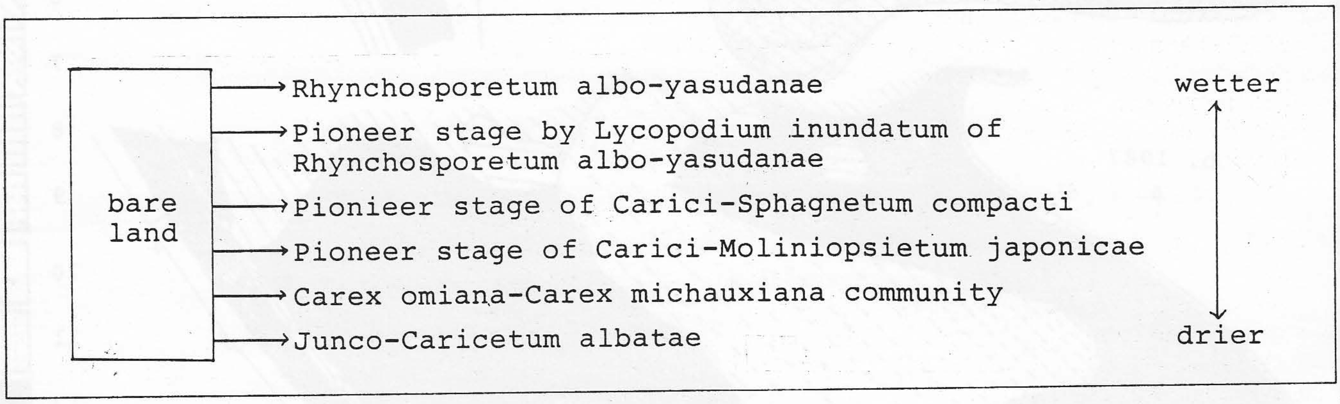

Fig. 7 – Vegetation succession on bare land.

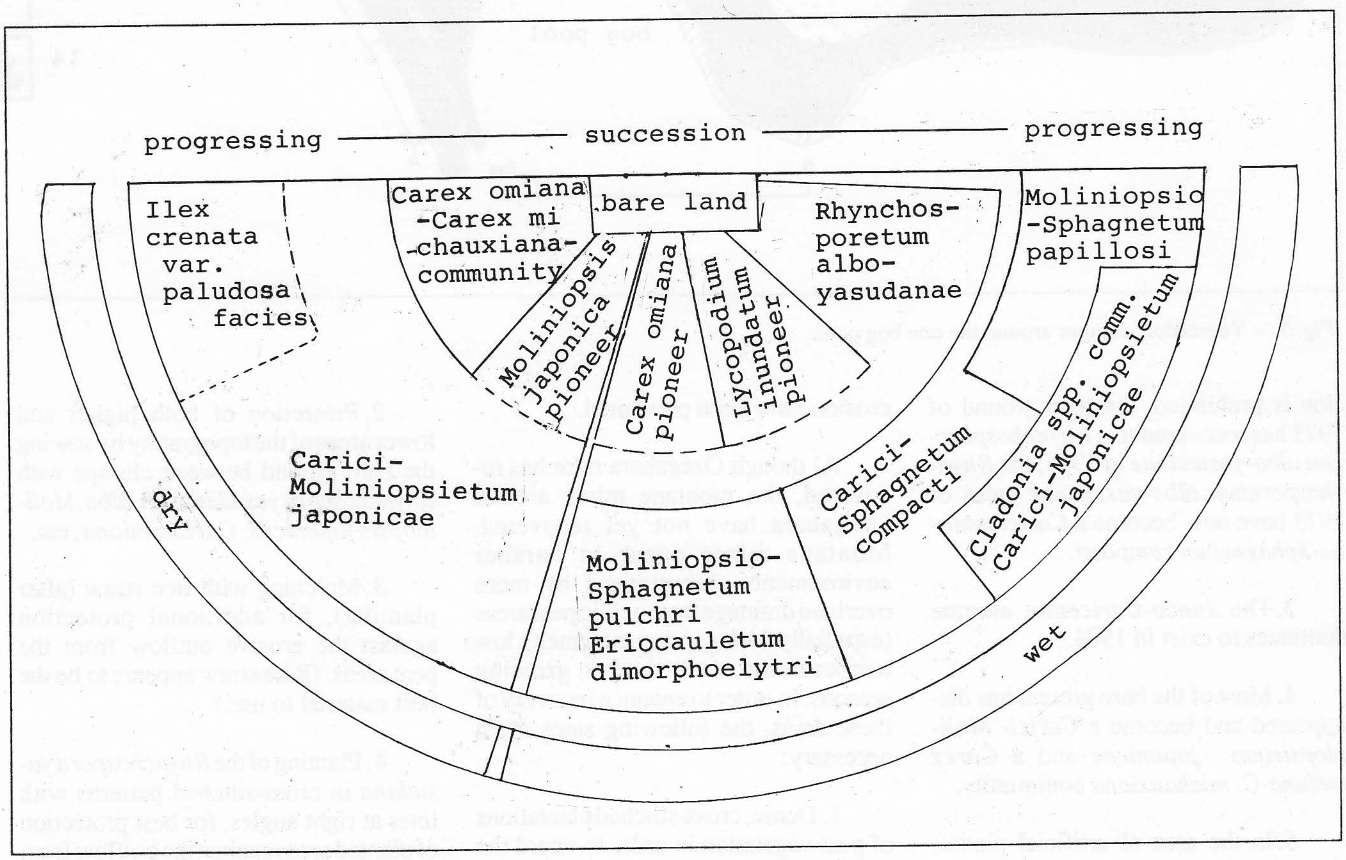

Fig. 8 —Vegetation succession sequence on bare land at Nakatashiro Jujiro of Ozegahara Mire.

total mountain area, which provides natural resources such as a natural biotic gene pool, food, a productive ecosystem, water, and so on. The surrounding areas are used for secondary forests for charcoal or firewood or are developed as plantations for timber, wood chips, etc. These areas play an important part as a buffer zone for protecting the area of natural forest. The outermost areas are developed as urban or residence areas (see schematic in Figure 8).

Oze is a system with its own distinct, nice natural harmony. The central part is the sensitive mire, with surrounding natural vegetation (forests with heath, etc.) protecting the mire. People use the outer areas only. This design reflects traditional Japanese landscape use, with conservation but also utilization of the natural resources which remain. The harmony of conservation, restoration, and utilization of natural resources begins with education of the general public which uses these resources.

CONCLUSION

Japan once had many large natural areas, but now most are disturbed, with only small natural areas remaining, mainly in high but also some lower mountains. These are especially important as complexes involving several different types of ecosystems. This is true not only in Japan but also throughout the world, as shown by the presentations of other scientists here.

We have attempted to protect these natural areas and we must continue to protect the areas of natural montane vegetation remaining, as sanctuaries for endangered life forms and as ecosystems involving balance between both animals and humans.

Disturbed areas are to be restored by direct revegetation, including reforestation of steep slopes and replanting of wet meadows.

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VEGETATION MAPPING OF THE MOUNTAIN MASSIFS USING SIGMETA

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Mountain vegetation is distributed vertically in altitudinal belts, each of them corresponding to a determined climax association.

An interesting topic in geobotanical mapping is the cartographic representation of vegetation in these altitudinal belts with emphasis in the linkages between the vegetation types and habitat conditions (aspect, substratum, inclination etc.). To this end, different types of maps can be used, as phytosociological, dynamic and potential ones. Using phytosociological maps, plant associations of a particular territory are represented, each one in a different colour according to their species composition affinity to the syntaxonomic units (alliances, orders and classes). The integrated phytosociological maps represent the sigmeta (vegetation series), each of them including one climax association and one or more secondary plant associations which are dynamically linked among them. All plant communities belonging to a single series are indicated with the same colour, using different tones.

In this manner, many vegetation maps on various scale were realized in the Apennines range. The following altitudinal belts together with their corresponding sigmeta were singled out:

- Hill belt with the *Quercus ilex, Q. pubescens, Q. petraea, Carpinus betulus* and *Ostrya carpinifolia* series;
- Mountain belt with the *Fagus sylvatica* series;
- Subalpine belt with the *Vaccinium myrtillus* series;
- Alpine belt with the *Luzula italica* and *Elyna bellardii* series.

The scale 1: 50,000 seemed to be the best one for a good "sightseeing" of the vegetation distribution in mountain chains (Pedrotti, 1982; Ballelli & Biondi, 1982; Francalancia & Orsomando, 1981; Orsomando, 1985).

It is obvious that the integrated phytosociological maps have more significance with respect to the classical ones because they contain more information. In fact, using these maps the following phenomena, closely related to mountain chains, are pointed out very clearly: altitudinal zonation, dynamic relationships within the sigmeta and ecological determinism of the potential vegetation (*Abstract*).

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THE ROLE OF VEGETATION IN WATER-SOIL CONSERVATION IN MOUNTAINOUS AREA OF SHANDONG PROVINCE

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Key words: Water-soil conservation, Water-soil erosion, Soil erosion mould

INTRODUCTION

The area of Shandong is 153, 300 square kilometres; 35% of total area are mountains and hills. Since the vegetation of mountain regions was destroyed on a large scale for a long time, water and soil erosion was very serious. At present the erosion area occupies 80.5% of total area, and the soil horizon decreases 2.7 mm every year. The soil nutrients which are lost from the soil every year, are equal to 3,500,000 metric ton of standard chemical ferilizer, so that the soil has been decreasing year after year, and fertilizer has been wasted. These make agricultural production and livelihood very difficult.

At present, the most important task for developing the economy of mountain regions is to prevent water-soil erosion. We must speed up all kinds of water-soil conservancy works, but the most important method is to protect and develop vegetation.

It is common knowledge that vegetation can control water-soil erosion. In our survey and calculation at typical regions in the Yi-Meng mountainous area of Shandong, the method was to take samples and measure erosion quantity in different kinds of drainage areas. We used the profile method and the signal method for different kinds of earth types in the same drainage area to get erosion quantity. We also calculated the area and erosion using a ground survey and using 1: 1000 aerial photography. Finally the erosion quantity of the small drainage area was matched against the quantity of silt in the river.

THE NATURAL CONDITIONS AND SOIL EROSION SITUATION

Mengying county is located at 30° 02' - 35° 26' and 117° 45' - 118° 14' E. The climate of this region is of the warm-temperate monsoon type, and the annual mean temperature is 12.8° C. The coldest month is January with a mean temperature of -2.9° C; the warmest month is July, with 26.7° C. The annual precipitation is 857.2 mm, but the seasonal distribution of precipitation is uneven. The rainy season is from June to September, during which falls nearly 75% of the annual precipitation. The dry season is from October to May, where the precipitation occupies just over 25%. So it is wet from June to September and dry from October to May.

The other important characteristics are the variability ratio of annual precipitation is large, with rainfall in a wet year being more than two times that of a dry year, and the intensity and frequency of rainstorms is the highest in Shandong province. The greater the intensity of storms, the greater will be resulting erosion.

There are mainly two types of soil in the region, the brown earth formed on the gneissic granite rock mountains, and the Drab soil formed on the limestone mountains. The characteristics of the parent rock are different, and this influences the soil texture. The particle size of Brown earth is larger and it is less cohesive than Drab soil, with the result that the soil erosion of brown earth is greater than that of Drab soil. In the regions of gneissic granite rock mountains the soil erosion mould is 3,600 t/km^2 , whereas, in the limestone mountain regions it is about 1,650 t/km^2 (ZHOU, 1983).

The main trees in Yi-Meng mountains are *Robinia pseudoacacia*, *Quercus acutissima*, *Pinus tabulaeformis*, *Platycladus orientalis* etc. After the forests have been destroyed, grassy thicket is the dominant secondary vegetation. The floristic composition of grassy thicket is not complex. It generally consists of nine to thirty one species. The dominant herbs are *Themeda triandra* var. *japonica* and *Bothriochloa ischaemum*, whic are mixed with shrubs, mainly *Vitex negundo* var. *heterophylla* and *Zizyphus jujuba* (ZHOU and YE 1985).

Grassy thicket control of soil erosion is not as good as forest. However, it still can have substantial protective effect. Under a well covered grassy thicket, the mould of soil erosion is 2;700 t/km^2 (ZHOU and YE 1985).

According to the measurement of the deposit material in the An-De reservoir, the catchment are of the reservoir, not including dams within that area, is 1, 174 km^2. After the upstream vegetation was destroyed during the period 1973-1978. The soil erosion mould increased to 3475 t/km^2, an increase of 39.95% over the pre-1973 figure. The average amount of soil erosion from farmland is 2.09 t/mu/yr, which resaults in a reduction of 3 mm from the soil layer (ZHOU 1983).

SURVEY

The results show, that among the wood land, xylophyta is the dominant species; herbosa, i.e. grassland, and sparsely vegetated slope cover less than 30%. The mould of soil erosion is the smallest in the wood land, 2.70 t/mu/yr (1 ha = 15 mu); grassland is second, at 3.50 t; sparsely vegetated slope shows the severe erosion, about 4.69 t/mu/yr. The depth of soil erosion of the wood land, grasslandand sparsely vegetated slope respectively are 2.5 mm, 3.9 mm, 5.0 mm, every year. Thus, forest has the largest effect; it reduces water-soil erosion to one half the quantity that occurs on a sparsely vegetated slope. Grassland also provides some protection.

The effect of vegetation on water-soil conservation is closely related to the type of vegetation. Because trees are tall and the structure of a forest community is complex, the canopy can intercept rain. Thus, the rain falls down slowly along the trunk, and the grass continuously intercepts it. This decreases raindrop impact on the soil surface; instead, a vast amount of precipitation permeates into the soil, and surfacerunoff is decreased. There fore, the role of forest is bigger than herbage. the sparsely vegetated slope has a large amount of bare soil, so the interception is small and there is even more surface runoff.

Community structure can be of great importance in affecting the intensity of soil erosion, mainly depending on the density and interception. The thicker the vegetation the weaker the impact of raindrops on the surface of the soil. Thus, if the forest density is larger, the mould of soil erosion is smaller, and the depth of soil erosion is shallower. For example, with a density of 0.9, the soil erosion is 0.5 t/mu/yr, and the erosion depth is 0.55 mm; with a density 0.7-0.9, 0.6 t, 0.7 mm; 0.5-0.7, 2.0 t, 2.2 mm; 0.3-0.5, 2.7 t, 2.5 mm. The biggest erosion occurs if the trees only grow on the edge of the farmland, 6.75 t/mu/yr, 7.5 mm.

Grassland has the same general effect as forest. If the coverage is 0.7-0.9, the results are 1.7 t/mu/yr, 1.8 mm; for 0.5-0.7, 2.0 t, 2.3 mm; for 0.3-0.5, 4.7 t, 5.3 mm. These numbers clearly show that the effectiveness of soil erosion control by grassland is also directly related to its coverage.

Because the vegetation of the sparsely vegetated slope has been widely destroyed, it has much bare soil on it, and plant interception of rain is weak. The fast-falling raindrops directly impact the surface of the soil. The amount of surface runoff intercepted by plants is also small, so that warer-soil erosion are large. Among various types of sparsely vegetated slope, we get the following figures: uncontrolled grazing land, 3.1 t/mu/yr, 3.4 mm; open space, 4.3 t, 4.8 mm; recently reclaimed wasteland, 5.8 t, 5.3 mm; ground on which even the grass roots had been dug up, 5.7 t, 6.3 mm.

Though the soil erosion of sparsely vegetated slope is serious, still it is better than bare sandyland, which has very little plant cover. On bare sandy land, the soil erosion mould is 9.0 t/mu/yr, and the erosion depth of the soil 10.2 mm every year.

DISCUSSION

In view of these facts, we can affirm that vegetation prevents soil-water eroion. Furthermore, forest is better than other forms f vegetation. At present, water soil erosion is serious, and floods and droughts frequently occur. These phenomena are closely related to the fact that woods had been destroyed on a massive scale. up to now the degree of forest cover in Shandong is only 9.5%. Though the quantity in the mountain regions is larger than this, it still does not exceed 15%. Moreover, most of the forest is made up of young trees, so it can not play a major role.

In order to promote production and raise the living standards of the masses in mountain regions, the most urgent task is to speed up vegetation reconstruction. We must stop the destruction of the natural vegetation, and the clearing of forests for cultivation, prevent the excessive felling of trees and cutting of grass, and prohibit uncontrolled grazing. Moreover, we must close hillsides to facilitate afforestation, and plant trees and grass there. These are important measures for the reasonable utilization and reconstruction of vegetation in a mountainous area (Zhou 1984).

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NATURAL VEGETATION AND CHANGING BIOTA WITHIN THE NEW ZEALAND MOUNTAINS

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Keywords: Mountain vegetation of New Zealand, Vegetation belts, Human impacts on vegetation.

New Zealand mountain vegetation has been extensively modified by fire, domestic sheep and cattle, naturalised herbivores, fertilisers and introduced plants. While the most obvious changes result from European settlement, mainly after 1840 A.D., change began with the arrival of Polynesians; it was effected through the introduction of rats and dogs, fire, and hunting, which decimated or exterminated much of the native fauna, including giant herbivorous birds (Dinornithiformes), large insects, and the primitive reptile *Sphenodon*.

The introduced herbivores have altered the composition of vegetation and patterns of succession and regeneration. The ecological results of the extinction of native herbivores may show in unusual age structures of populations of long-lived native conifers. Effects of animals on the vegetation have been against a background of recurring climatic and geological catastrophes. Introduced plants are important mainly in seral communities, and in extensive montane grasslands which have developed after forest fires during the last 1000 years.

FEATURES OF THE MOUNTAIN VEGETATION

The axial mountain chain of New Zealand runs southwest - northeast, rising to 3765 m in Mt Cook in the Southern Alps. It results from a Pliocene-Quaternary orogeny, which has uplifted ancient sandstones, schists, granites, ultramafic and volcanic rocks, and hard limestones. Younger sedimentary and volcanic rocks form the lowlands and hill country, but mostly have been stripped from the mountains, except along the outer flanks and in intermontane basins. In the North Island, four active volcanic cones lie west of the main axis and exceed it in height, the highest being Mt Ruapehu, at 2797 m.

The mountain flora of New Zealand reflects extreme isolation, Australia, at 2000 km, being the nearest continent. It also reflects the youth of the mountains, and cooling from warm Miocene climates. Its origins are complex (BARLOW, 1986). Some genera (e.g. *Nothofagus, Podocarpus*) were in New Zealand before it separated from Australia in the late-Cretaceous, others are genera of subantarctic distribution (e.g. the cushion plants *Phyllachne* and *Donatia*) that may include survivors from an ancient Antarctic flora (notably *Hectorella*), many are endemic representatives of cosmopolitan genera of cool climates, some of which have speciated profusely in New Zealand (e.g. *Epilobium, Ranunculus, Poa*), and a few are conspecific with northern hemisphere plants (e.g. *Carex pyrenaica, Deschampsia caespitosa*). Finally, there are genera centred in New Zealand, that have speciated mainly in the mountains (e.g., *Chionochloa, Aciphylla, Celmisia, Hebe*).

The greatest speciation has occurred in herbaceous and fast-growing shrubby genera, and especially among plants exploiting recent soils as contrasted with strongly weathered and leached soils. There is a notable lack of trees that can withstand severe cold or drought, regenerate readily after fire, or vigorously colonise denuded and unstable habitats.

Altitudinal zonation begins from lowlands that experience mean annual temperatures about 14° C at lat. 38° S, and 9° C at lat. 46°. On the wetter mountains, evergreen forests continue up to a timberline which reaches 1520 m at lat 39°S, and 970 m at lat. 46°. On the lower slopes, these are dominated by a mixture that includes podocarps, *Weinmannia* (Cunoniaceae) and *Metrosideros* (Myrtaceae). Subalpine forests are mostly dominated by *Nothofagus*, but in some localities there is dense, floristically varied scrub instead. Tussock grasslands extend above the timberline and along frosty valley floors; they also clothe eastern ranges in the rain-shadow of the Southern Alps where, however, they are mostly fire-induced. Sparse, high-alpine vegetation extends above the mountain grasslands to the permanent snowline, which rises from 2000 m on the western flank of the Alps, to 2800 m on drier eastern mountains.

HUMAN OCCUPATION AND THE INTRODUCED FAUNA

New Zealand was first settled by voyagers from Polynesia who arrived about 800 A.D.; whether there was further contact with Polynesia after this time is still debated. The Dutch explorer Abel Tasman sailed along the New Zealand coast in 1642, and the Englishman James Cook landed in 1769, but European settlement did not begin until around 1800, and became organised and large scale only after 1840. Since then, the native vegetation and most of the native animals have been replaced through the lowlands and much of the hill country by the domesticated plants and animals of agriculture and silviculture, and by the wild plants and animals that have been deliberately or accidentally introduced.

Until recently, it had been accepted that the neolithic Polynesian inhabitants, or Maori, scarcely influenced the vegetation, except over small areas through fire or cultivation (COCKAYNE 1928). Modern research, supported by reappraisal of records left by early observers, shows that the effects of Polynesian settlement were scarcely less profound than those resulting from European settlement (DAVIDSON 1984; MCGLONE 1983). The Maori population may have scarcely reached 150,000 by the time of European contact, but over a millenium had occupied and cultivated considerable areas; fires had swept nearly half of the country; and a considerable part of the fauna had become extinct, either through hunting or predation by the rat (*Rattus exulans*) and dog that the Polynesians brought with them. The extinct fauna includes giant, herbivorous ratite birds (Dinorthiformes or moa) that existed as about 12 species and in large numbers, a large eagle (*Harpagornis*), other birds with or without the power of flight, and large herbivorous beetles. Many other animals including the archaic reptile *Sphenodon* had been reduced to remnant populations, mainly on offshore islands.

In contrast to the lowlands, the mountains are still almost entirely clothed with native vegetation. There were few permanent Maori settlements, and high rainfall generally protected mountain vegetation from fire. The important exception is on the eastern ranges of the South Island, where logs, buried forest soils and charcoal tell of deforestation. However, the mountains did not escape the faunal extinctions, although they provide last refuges for a few species, including the flightless rail *Notornis* and the flightless parrot *Strigops*.

European attempts to exploit the mountains have been more determined. Where virgin vegetation or secondary vegetation induced by Maori fires could be burnt, it was burnt, sown with introduced grasses (contaminated with many weeds) and stocked with sheep. Where there were economic minerals, further areas were cleared by fire or felling. However, in the mountains, in contrast to the lowlands and hill country, modified landscapes are still dominated by native rather than introduced plants, notably the shrubs *Leptospermum* and *Kunzea* (Myrtaceae) and *Cassinia* (Asteraceae), together with bracken (*Pteridium*). On the drier ranges, tussock grasses (*Poa* and *Festuca* spp.) prevail, and are usually accompanied by the spiny shrub *Discaria* (Rhamnaceae). Where annual rainfall is less than 500 mm, overgrazed native grasslands on the lower slopes and intermontane basins have been replaced by semi-desert vegetation dominated by moss-like mats of *Raoulia* (Asteraceae), which in early summer are masked by ephemeral adventive grasses and flower heads of adventive forbs.

Areas that have not been directly modified by man and domestic stock have been colonised by introduced wild animals. Herbivores include European rabbits and hares in the grasslands, and several species of deer, the most widespread being red deer, which use both grassland and forest. There are chamois and Himalayan tahr in the alpine country of the South Island, and the arboreal Australian possum (*Trichosurus vulpecula*). There are also feral sheep, cattle, pigs and goats.

Cats, mustelids (introduced to control rabbits) and, in the early days of European settlement, wild dogs are regarded as main culprits in the further decline and, in some cases, extinction of native birds, but the most important causes may have been destruction of lowland habitats and the later introductions of rats (*Rattus rattus* and *R. norvegicus*) that displaced *R. exulans* from most of the New Zealand mainland. These omnivorous creatures eat eggs and nestlings and even kill nesting adult birds. Other mammals that are generally herbivorous have also contributed to the decline of native birds and other indigenous fauna (e.g., the diverse assemblage of large, carnivorous snails). This is through destruction of habitat, competition for nesting sites, and in the case of pigs, uprooting of the ground and predation of eggs and invertebrates.

Thirty six species of bird have been naturalised, most of these being passerines. The vast majority of birds encountered in the lowlands belong to this assemblage which is also well represented in the mountains, mainly in the open country. A few birds, e.g. the European blackbird and some finches, have penetrated the largest tracts of native forest. There is circumstantial evidence of serious competition with native birds. In addition, the modified environments may have facilitated the establishment of several species of birds and plants that have spontaneously dispersed from Australia. Many species of insect and other invertebrates also have been brought into New Zealand over the last 150 years, and although most are associated with man-induced ecosystems, some have spread very widely. These include the honey bee and wasps *Vespa germanica* and *V. vulgaris* which compete with native birds for nectar and honeydew.

INTERACTION BETWEEN ADVENTIVE FAUNA AND INDIGENOUS VEGETATION

The effects of introduced animals that become established in native vegetation range from competing for resources with resident native animals and occupying niches left vacant through the extinction of native species, through to grossly modifying ecosystems by predation or grazing. Although much of the evidence for such effects is anecdotal (King 1984), the influence of some introduced herbivores has been studied intensively. For example, it is known that the establishment of red deer in a new area leads to predictable changes (Clarke 1976). First, the population builds up rapidly on a diet of highly palatable understorey species; when the latter are eaten out, the animals turn their attention to less palatable plants, which include seedlings of the dominant trees, especially *Nothofagus*. As food resources decrease, the deer sharply decrease in vitality and numbers, but are still numerous enough to prevent adequate regeneration.

Alpine grasslands have also been greatly depleted by grazing mammals, often with the assistance of fire. First, palatable large forbs, including species of *Ranunculus*, *Dolichoglottis* related to *Senecio* and umbellifers in the genera *Anisotome* and *Gingidia* are eliminated, and these may be followed by the more palatable species of the large dominant tussock grass *Chionochloa*. Since 1967, when the commercial demand for venison led to hunting from helicopters, deer numbers have been drastically reduced, leading to recovery of the forests and alpine grasslands.

These biotic influences have been against a background of recurring climatic and geological catastrophes, the roles of which have, until recently, been underestimated. In parts of the Southern Alps, precipitation exceeds 10 m annually and in a 24 hour period can reach 680 mm (Griffiths & McSaveney 1983). Such storms, as well as frequent earthquakes that reflect continuing orogeny, trigger massive landslides and deliver huge quantities of debris to streams, thereby initiating primary successions on a large scale. The central part of the North Island has active andesitic volcanoes that likewise support successional vegetation; this region also experiences explosive eruptions every thousand years or so, which devastate landscapes for distances of up to 80 km, and deposit significant amounts of tephra to even greater distances. Gales, avalanches and breakage by snow frequently initiate secondary succession in mountain forests. Drought is an important cause of canopy death, both directly and by triggering massive epidemics of phytophagous insects (Hosking & Kershaw 1985).

Weinmannia racemosa and *Metrosideros umbellata* stands on the western flanks of the Southern Alps provide an example of interaction betweeen physical events and introduced herbivores. These important canopy trees are palatable to possums, which defoliate the crowns. Their seedlings establish on bare ground exposed by landslides and develop into even-aged stands. Whereas young stands are relatively immune to damage by possums, large trees are usually browsed to death, so that stands collapse prematurely (Stewart & Veblen 1982). In subalpine *Nothofagus* forests, the density and vigour of seedlings is reduced both by deer, and by shading within even-aged stands resulting from windthrow; these effects have sometimes been confused (Wardle 1984).

The extinction of indigenous herbivores may be reflected in the structure of certain forests, which include scattered, large, coniferous trees (Podocarpaceae and *Libocedrus*) as an overstorey to the main canopy of broadleaved trees; while there may be seedlings and saplings, there is a distinct dearth of young conifers. This phenomenon seems too widespread to be explained in terms of succession or regeneration cycles. Since introduced herbivores can favour conifer seedlings by removing more palatable competitors, the apparent hiatus in conifer regeneration possibly corresponds to an ecological vacuum that prevailed from the extinction of the former herbivores until the introduction of the present ones (Wardle 1991).

Naturalised plants are few in the mountain forests, but hardy exotic trees, especially *Pinus contorta*, that have been introduced for shelter and soil conservation are proving able to invade alpine vegetation. The relatively dry, fire-induced, mid-altitude tussock grasslands of the eastern ranges of the South Island seem likely to change beyond recognition through natural invasion by introduced grasses, forbs, shrubs and trees. This process is hastened by use of fertilisers, oversowing with seed of more productive pasture species, and afforestation. The wide, braided gravel riverbeds of the South Island, that result from mass wasting of the mountains, have been colonised in their lower reaches by naturalised shrubs (mainly the legumes *Ulex europaeus* and *Cytisus scoparius*) and *Salix fragilis*. Upstream spread into the mountains is slow but inevitable.

In 16% of New Zealand, the native vegetation and fauna are legally protected within national and forest parks and other reserves (DINGWALL 1982). Nearly all of this protected domain lies in the mountains, together with other state lands that have *de facto* protection through inaccessibility. Actual protection, however, depends on adequate control of introduced animals and removal of the more dangerous weeds. The mountain grasslands in the east of the South Island are mainly state-owned, but subject to long-term leases to graziers. Conservation of these grasslands and other open plant communities, with their distinctive biotas, poses more difficult problems, both ecological and in terms of competing land uses.

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THE ROLE OF EFFECTIVE MANAGEMENT OF PROTECTED AREAS IN VEGETATION

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Key words: Vegetation, Protected area, Conservation

There are many different vegetation types in China, but excessive exploitation has been gone beyond the allowing scope. Recently, the crux of the matter lies in strengthening the construction of protected areas and perfecting their effective management, giving attention to conservation of rare and endangered species, directing agricultural development from the view point of natural conservation, unfolding research of integrated watershed planning and ecological equilibrium (JHONSON W.C. etc., 1976, WANG HUEN-PU, 1980, 1984, 1984).

The following items should be discussed by the all those concerning to have an effective management for protected areas in China.

DEFINING THE AIM AND THE ROLE OF THE ESTABLISHED PROTECTED AREA.

Any protected area needs to be established after field research, it is necessary to define what type does it belong to, such as scientific reserve, national park, managed protected area, etc. After defining the aim and the role, then it is possible to determine the means of effective management. Otherwise, the established protected area will become a place of negative conservation, and is difficult to play its multi-purpose roles (CNPPA/IUCN, 1978, 1979, DASMANN R.F., 1973, WANG HUEN-PU, 1980).

DEFINING THE LIMITS AND BOUNDARIES OF THE PROTECTED AREA.

The average, limits, and different managed region of the protected areas are determined by the aim of the area and the protected objects. The boundaries must be clear, and the map of the area must be drawn, if necessary the boundary markes must be established, if there is a residential area, one would ask the opinions of the inhabitants about the establishment of this protected area in order to let them understand the significance and the role of reserve, and give consideration to their traditional benifits as far as possible. Meanwhile, it must bring into play their action of managing the protected area, and admit them, if possible, to be managers, workers of forest policemen. Residential areas within protected areas have to be removed out the other places, as fully as possible, or change them into manage officies of protected area step by step. If there are mineral resources within the protected area has been established. One must also pay attention to the protection of environment in the process of exploitation of mineral resources, even if the protected area is not established. Ina aword, any dispute may occur about the land or resources must be resolved in clearly and unambiguous terms. Finally, national or different levels of protected areas must be determined through legal procedures. If any one violates the managementregulations or its related stipulations, one should find out the responsabilities according to the regulations. Any indifference to such violation is strictly prohibited.

DEFINING SUITABLE MANAGERS AND CERTAIN OUTLAY.

The man who is selected as the manager of the protected area should be the one willing to devote himself to the course of natural conservation, and is couragous in overcoming difficulties. A number of technicians, workers, and forest policemen must be assigned. The number of personal depends on the size, managed scope, and the development of the protected area. Protected areas are the national enterprises. It must obtain certain outlay in order to promote the development of the enterprise and must have a detailed program to meet the planned construction. Proper management will provide various incomes from which a part may be drawn for the construction of protected areas and gives some bonus to encourage the workers in order to accelerate the development of the protected area.

ESTABLISHMENT OF THE NECESSARY CONDITIONS FOR THE MANAGEMENT.

After making a decision for the establishment of the protected area, the necessary managerial stations must be established progressively. Adequate houses and related equipments should be built simply and thriftily according to the needs and possibilities. Roads should lead to the location of main managerial agencies as far as possible. Concerning with the daily life of the staffs and helping them to meet their requests for working, studying, life and recreation. Owing to the limited staffs and poor knowledge, it is difficult to complete all the arduous tasks assigned to them. There is urgent need to have a powerful backing. So, some related institutes or high schools must be invited to act as the consultants and a consultative committee of specialists should be organized, and work out a long-term program and concrete working plan relating to the management, scientific research, and training courses for the protected area.

GAINING A CLEAR UNDERSTADING ABOUT NATURAL AND SOCIOECONOMIC CONDITIONS OF THE PROTECTED AREA.

Any protected area ought to unfold a comprehensive survey related to the natural and socio-economic conditions such as geology, geomorphology, climate, hydrology, soil, flora, vegetation, fauna, biological and mineral resources, landscape, local residents and their productive situation, as well as historical changes, roads and communications around the protected area, etc, in order to provide detail research reports, correspondent maps and diagrams, are used as the basic informations of the protected area, providing a scientific base for the development and construction of the protected area.

WORKING OUT A LONG-TERM PROGRAM AND A PRATICAL WORKING PLAN.

For any protected area, a long-term managerial program should be worked out in order to have a clear objective for the staffs who have to know the real condition of the protected area and bring the initiative of the staff in full play; meanwhile, it is also necessary to work out a specific working plan according to the actual situation in order to meet the long-term objective. Of course, the major task of the protected area is conservation, but it can be combined with scientific research, education, production, and tourism, etc. in accordance with the actual situation. Therefore it is necessary to examine these tasks with a comprehensive consideration (WANG HUEN-PU, 1982).

A. Conservation: This is the most important task for the protected area. First, it needs to define the conservation tasks and key objects clearly. The lists of the endangered and protected animals, plant and their protective measures must be obtained to make all the people understand. To establish correspondent protected stations, observations towers, a capable professional protective contingent and mass protection networks according to the actual requirement and possibilities; allocate necessary equipments, such as various kind of cars, houses, field glasses, radio communication apparatus, fire proof equipment, and labour protection apparatus , etc. decide the managerial regulations concerning with conservation and firmly implement it; strengthen propaganda and educational works, such as, print and distribute the sloans; posters related to the natural conservation as well as maps and informations, etc.; explain and publicize the regulations to the masses in adequate time and places, strictly implement the related protected regulations, which are formulated by the government; commend and encourage the meritorious workers and units, who implement the protected regulations strictly; punish the workers and units who violate the protected regulations according to the laws, all these work has to be done.

b. Scientific research: The protected areas are the best bases for studying biology, earth sciences, environment sciences, agriculture and forest sciences. The consultative committee of protected areas should work out a long-term program for scientific research and annual working plan, and unfold the research work by organizing some related institutions and specialists, welcome other related units and experts come to work together. Do the best to create the necessary working conditions for them. In general, meteorological observation, environmental monitoring, integrated experimentals research of ecosystems and intermediate experimental demonstrations of agriculture and forestry production, etc. should be developed step by step and gradually perfect themselves. Herbarium and exhibition museum of biological and mineral resources may be established, therefore, in order to make people understand the significance and the role of the protected areas.

c. Education: Protected areas are also the best bases for teaching. One must provide convenient conditions for school to go there for a field trip, and to complete related research tasks depond on their strength. In the meantime, the protected area can provide special biological and mineral specimens, pictures, photographs, slides, films, and related informations to corresponding instructions for school, home and abroad. This will benefit the teaching task of institutions and schools, promote the scientific research works of the protected area, and increase to income for the construction and development of the protected area.

d. Production: Protected areas are not a productive unit, but they are managerial unit with land and natural resources. It must bring the superiority of the protected area into full play produce it own native products without detriment to the protection task so as to meet the social requirements. For example, it is necessary to provide special seed stock, nursey stock, scientific and technical research informations for related productive units. Meanwhile, it may be combined with experimental research and living requirement engaged in agricultural, industrial and commercial activities, provide certain production for the society and promote the development of natural conservation (BRATTON S.R., etc. 1980).

e. Tourism: Protected areas are better protected places of natural conditions in the region. It must be opened to the public without detriment to the protection task, especially the national park, not only as a tourist area, but it is also a good place for carry out patriotic and environmental education for the masses. It may foster people's knowledge and sentiments for loving nature, protecting nature and rational utilizing nature through observation and visit, also it will benefit the developmentof mass education and propaganda works of natural conservation. Of course, if a small region receives a great number of tourists, the destruction will certainly happend. So it must be planned beforehand certain limited regions for tourists, establish related managerial regulations in order to reduce the possible destruction, construct, necessary hotels, restaurants, shops, snack bars, snack counters, and supply centers of native products and to serve business meeting convenient to tourists and specialists. This will create a favourable condition for resolving the employment problems of workers' dependents in protected areas and increasing the income for the protected areas (WANG HUEN-PU, 1984).

If the above-mentioned different aspects are achieved, then naturally, the protected area will have an effective management but there are differences for various kind of protected areas or various regions. It must ascertain the way and different level or effective management based upon its own actual situation and requirement. Howeever, managers of the protected areas are required to have a long-term program with short-term arrangment; with its own plan for above mentioned problems; Avoid negative attitude to drift along. Thus, although the conditions are not provided, for some demands are not matterialized, it can still finds an opportunity to catch on the construction works, and aviod being in the passive mood of inertial ideas, firmly play their proper role and make a contribution to scientific and economic construction.

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ERRATA CORRIGE:

Pag. 130, Table 2, c) : Hrs-circumb

Pag. 144, Table 4 (nella didascalia) : ... Miyajima

Pag. 146, Table 7 : Empetrum nigrum var. japonicum; Solidago virga-aurea var. leiocarpa

Pag. 162, Table 1, 3. : Shurb-herb

Pag. 170, Fig. 2 : leaved forest

Pag. 179, Fig. 2 : ... *Myrica rubra*

Pag. 179, Fig. 3 : ... Fruits of *Myrica rubra*

Pag. 189, Table 2 (nella didascalia): ... environmental variables

Pag. 191 : ... relationship...

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