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Anthropogenic impacts on riparian trees and shrubs in an eastern Mediterranean stream

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Abstract
This study contributes in listing and understanding the distribution of riparian species according to environmental and anthropogenic factors, recognizing the impact of these factors on biodiversity and tree growth and conducting an easy method for the assessment of habitat quality in a typical riparian ecosystem in the Eastern Mediterranean Basin. The methodology involved field assessment and the evaluation of riparian habitat quality by giving scores to different criteria, composing the habitat quality index. The results showed that river channel deviation is the most significant factor affecting riparian habitat quality. Non disturbed sites have significant higher scores, yet they are not classified as in natural conditions due to the effect of intrinsic environmental factors on habitat quality, namely bioclimatic conditions and river flow regime. An increase of biodiversity was recorded when habitat quality improved. Higher riparian habitat quality resulted in the presence of old growth trees, and climax species. This study allowed us to assess the requirements of major riparian species in terms of habitat quality, and to classify them based on their functional adaptation, in order to adopt appropriate ecosystem restoration and conservation plans.

Key words: anthropogenic impact, habitat quality index, Lebanon, riparian trees and shrubs.

Introduction

Riparian biotas are one of the most complex and diverse ecosystems; they constitute a transitional zone between aquatic and terrestrial biotas and include biotic and abiotic elements found near flowing water (Lowrance *et al*., 1985; Klapproth, 1999). Based on flow characteristics, rivers are grouped into “perennial” with a permanent flow, “intermittent” rivers with temporary flow in the stream channel and “ephemeral” rivers that flow for short periods after rainfall or snowmelt (Zaimes, 2007).

Nonetheless, these riparian ecosystems are of the most fragile ecotones (Camporeale & Ridolfi, 2006); declines in biodiversity are far greater in riparian ecosystems than in terrestrial ecosystems (Sala *et al*., 2000). The causes of disturbances vary from natural, such as floods and drought, or anthropogenic activities such as change of land use, water pollution, flow regulation, and dams construction. These disturbances can produce large-scale changes in the plant community and represent a persistent risk on the biodiversity and conservation of riparian ecosystems (Klapproth, 1999; Allan, 2004; Miserendino *et al*., 2011). The Red List of European habitats cites that “temperate and boreal hardwood riparian woodland” habitat is endangered, while the “Mediterranean and Macaronesian riparian woodland” is vulnerable according to the IUCN red listing assessment categories. Natural systems modification (i.e. hydrology) and climate change are listed amongst the main threats (European Commission, 2016).

Flooding can influence a riparian habitat; during inundation, soil becomes anoxic. Floods also affect species composition by removing pre-existent seedlings and creating bare spaces for more adapted species (Hook 1984; Naiman & Décamps, 1997; Bendix & Hupp, 2000).

When drought occurs for a long period, river flow is hindered; the moistened areas of the channel bed are limited to a series of ponds leading to the encroachment of the riparian vegetation into the stream channel (Zaimes *et al*., 2010). The removal of vegetation can modify flow characteristics, decrease infiltration and increase surface runoff (Walling & Fang, 2003; Miserendino *et al*., 2011). It can also alter the functioning of river ecosystems by increasing river sediment loads that can lead to shoreline erosion (Dudgeon *et al*., 2006) and thus an increase in nutrients leading to the overgrowth of algae, which alters habitat suitability for endemic species (Hall *et al*.,2001; Miserendino *et al*., 2011). Dams and channelization cause hydrologic regime alteration, disrupting riparian vegetation species composition and distribution, soil biogeochemistry, and sediment moisture retention (Naiman *et al*., 1998). Since food, nutrients, and shelter for aquatic life are no longer available in the same quantity as before some vulnerable riparian species will be eliminated downstream of the dam (Griggs, 2009). Water quality is also affected by the construction of dams as purification process will break off (Govorushko, 2007).

Many researchers rely on field assessment which allows not only conducting an inventory of species and

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estimating their growth and vitality, but also examines human disturbances in order to evaluate the habitat quality (Leonard *et al*., 1992; Baker *et al*., 2006; Barbour *et al*., 1999; Tharme, 2003).

Munnee *et al*., (2001) introduced the QBR index ("Qualitat del Bosc de Ribera" in English, "Riparian Forest Quality") a mean to assess the riparian habitat quality. This index is divided into four sections: total vegetation cover, vegetation cover structure, cover quality, and river channel alteration. Each section has a series of criteria to be assessed. Further, the values of scores for all criteria in each section are summed. The total of the four sections gives the final QBR index for each plot ranging between zero and 100. The plots are distributed in five quality classes according to their QBR score (Tab. 1).

Although riparian zones require continuous assessment and monitoring and even though water is a limiting factor in semi-arid regions, Mediterranean rivers are among the most impounded in the World (Grantham *et al*., 2010). Moreover, these areas are rarely studied in the Eastern Mediterranean Basin.

Lebanon has a typical Mediterranean climate with four dry months, during which the availability of water is limited. Therefore, riparian areas represent crucial ecosystems frequently affected by anthropogenic activities in addition to environmental factors. Until now, the ecological status of most rivers in Lebanon remains unstudied (Abboud *et al*., 2012). Abi Saleh *et al*., (1996) described some of the riparian vegetation series of Lebanon, and their distribution according to vegetation levels and the type of bedrock: the vegetation on limestone formed basically by *Platanus orientalis* L. and divided into lower level (near the riverbanks in the coastal areas where *Platanus orientalis* is usually accompanied by *Vitex agnus-castus* L., *Laurus nobilis* L., *Nerium oleander* L., *Salix alba* L.) and medium and upper level (where *Alnus orientalis* Decne., *Salix libani* Bornm. coexist).

The vegetation on sandstone is represented by *Rhododendron ponticum* var. *brachycarpum* Boiss. accompanied by *Alnus orientalis*, *Salix libani*, *Equisetum telmateia* Ehrh. and *Drosera rotundifolia* L.. Finally, the vegetation on talwegs is dominated by *Ostrya carpinifolia* Scop. and *Fraxinus ornus* L.

However, habitat quality as affected by both the physical environment and anthropogenic activities was never assessed.

This investigation aims at understanding the effect of the environmental factors and human interventions on the riparian ecosystems woody species distribution, diversity and vitality in an East Mediterranean stream. The study contributes in inventorying the tree and shrub riparian species along Nahr Ibrahim River, understanding their distribution and response to environmental and anthropogenic factors. A simple methodology is tested for the assessment of habitat quality in a typical riparian ecosystem in the Eastern Mediterranean Basin. These objectives aim to prioritize areas of intervention for biodiversity conservation and ecosystem restoration as well as provide solutions for water management policies.

Tab. 1 - Habitat quality classes according to QBR index.

Riparian habitat quality class	QBR
Riparian habitat in natural condition	>= 95
Some disturbance, good quality	75- 90
Important disturbance, fair quality	55-70
Strong alteration, poor quality	30- 50
Extreme degradation, bad quality	< = 25

Materials and methods

Study area

Nahr Ibrahim represents an important perennial stream flowing westward on the western slopes of Mount Lebanon, with a length of 30 Km and a basin surface of 330 km^2. The river watershed is mostly karstic, with few sandstone and basalt protuberance (Papazian, 1981). Nahr Ibrahim covers an altitudinal range from sea level to 1,980 m (Thermo Mediterranean to Mediterranean Montane) and has several tributaries, with many drying out in summer.

Nahr Ibrahim is renowned for its many cultural and historical values. With diversity in fauna and flora, this river was declared as an important natural site by the Ministry of Environment (MoE, 2010). Despite its cultural, historical and ecological values, Nahr Ibrahim River is threatened by different anthropogenic activities (industry, waste dumping, tourism, dam construction and agriculture expansion). Assessment and management of the river's riparian zone, which demonstrates a co-evolution between natural and anthropogenic characteristics, should be taken into consideration (Abboud *et al*., 2012).

Vegetation sampling

Twenty one plots were selected, covering all bioclimatic zones, soil and rock types, slope and flow regimes of the main river and its tributaries while taking into account accessibility to the plot, due to the steep slopes and dense vegetation of the valley. Ten sites out of twenty-one cross a perennial stream, five cross an intermittent stream, and six are located on ephemeral effluents.

The geographical coordinates of the sites are listed in the supplementary material table.

In order to assess the characteristics of the physical environment and to have an acceptable sampling size for trees (400 m^2), we used plots of 40 m length along the river, with 10 m width from each river bank, on both side of the streams to cover all the riparian zone in width.

The field survey was conducted between August 2014 and September 2015. In each plot, the physical environment characteristics; altitude, aspect and slope for both right and left side of the stream, soil and bedrock type and the number of dry months (NDM) were recorded. All trees and shrubs were identified and counted, including the non-riparian species. The canopy cover was estimated as well as shrub land coverage. The diameter at breast height (DBH) of trees was measured when DBH is superior to 10 cm. The type of disturbance (if present) was also described for each plot. The QBR index (Munnee *et al*., 2001) was applied to all plots in order to evaluate the riparian habitat quality, and habitat quality was classified accordingly (Tab. 1).

Data analysis

We calculated the equivalent Hill number (H) of Shannon-Wiener diversity index (Burton *et al*., 2005; Jost, 2006) to assess tree and shrub diversity in each plot, according to the following equation:

$$(H): Exp\ (-\sum p_i \log p_i)$$

Where, pi is the proportion of individuals found in species i ($p_i = n_i/N$, where ni is the number of individuals in species i and N is the total number of individuals in the community).

Statistical analysis allowed us to estimate the significance of Pearson's correlation between QBR from one hand and DBH of trees and biodiversity indices from another hand. Analysis of Variance (using Tuckey's test) was conducted to study the effect of vegetation level and river flow regime on the riparian habitat quality, and to study the relation between the type disturbance and QBR index, while chi-square test enabled us to study the effect of river flow regime and vegetation level on the density of the canopy cover. These combined analyses revealed the effect of both environmental and anthropogenic factors on the quality of the riparian habitat.

Results

According to the QBR index, the quality of the riparian habitat in all plots was not satisfying: only 3 plots were in good condition with some disturbances and none in natural condition. Three plots exhibited extreme degradation, and almost half of them showed important disturbance or fair riparian habitat quality. The physical characteristics of the plots are resumed in table 2. Plots were almost evenly distributed amongst vegetation belts. Canopy cover varied between dense forests (> 70%) to scrubland (< 10%).

The analysis denoted a weak correlation between the QBR and Shannon equivalent number of woody species (r = 0.491, with P-value = 0.024), and an increase of Shannon equivalent number when QBR augmented (Fig. 1). The QBR index values increased in the perennial stream, when compared to intermittent and ephemeral tributaries; however the differences were not statistically significant (Tab. 3).

Chi-square tests showed that canopy cover varied significantly according to vegetation levels: discontinued canopy cover with less than 10% is noticed in Mediterranean Montane sites. Oppositely, all plots within the thermo-Mediterranean level have significantly higher canopy cover (>70%) than in other vegetation levels. Plots located in the Mesomediterranean and Supra-Mediterranean levels have intermediate canopy cover (Tab. 4).

Oppositely, canopy cover was not significantly af-

Tab. 2 - Sites characteristics.

Sites	Vegetation level	NDM	Water regime	Canopy cover (%)	QBR	Shannon index	Diversity (Hill)
Nahr Ibrahim 1	Thermo- Mediterranean	0	Perennial	>70	25	0	1
Nahr Ibrahim 2	Thermo-Mediterranean	0	Perennial	>70	60	0.605	1.831
Nahr Ibrahim 3	Thermo-Mediterranean	0	Perennial	>70	75	0.784	2.190
Amez	Montane Mediterranean	2	Intermittent	<10	35	0.401	1.493
Ain El Ghwaybe	Mesomediterranean	0	Perennial	40-70	65	0.663	1.941
Afka	Supra- Mediterranean	0	Perennial	40-70	70	0.614	1.848
Nabeh El Rouwes	Supra- Mediterranean	1	Intermittent	40-70	55	0.534	1.706
Mghayre	Supra- Mediterranean	2	Intermittent	40-70	50	0.832	2.298
Bir El Het	Thermo-Mediterranean	0	Perennial	>70	70	0.686	1.986
Ain Aalaa	Montane Mediterranean	3	Ephemeral	<10	20	0.215	1.240
Artaba Charbine	Montane Mediterranean	2	Intermittent	<10	25	0.674	1.962
Mazraat El Siyad	Supra- Mediterranean	2	Intermittent	>70	55	0.456	1.578
Abboud	Supra- Mediterranean	3	Ephemeral	40-70	65	0.383	1.467
Hdayne	Mesomediterranean	0	Perennial	40-70	75	0.735	2.085
Yanouh	Mesomediterranean	0	Perennial	10_40	85	0.231	1.260
Jannet Artaba	Mesomediterranean	0	Perennial	40-70	35	0.703	2.020
Chouwen	Thermo-Mediterranean	0	Perennial	>70	70	0.786	2.195
Yahchouch	Mesomediterranean	4	Ephemeral	40-70	65	0.92	2.509
Ain El Lebne	Montane Mediterranean	3	Ephemeral	<10	50	0.613	1.846
Akoura-Jord	Montane Mediterranean	3	Ephemeral	<10	35	0.566	1.761
Mchete	Supra- Mediterranean	4	Ephemeral	40-70	55	0.91	2.484

Tab. 3 - Effect of flow regime on QBR index (One-way ANOVA test).

River flow regime	N	Average QBR	Standard deviation
Perennial	10	63	18.738
Intermittent	5	44	13.416
Ephemeral	6	48.33	17.795

Tab. 4 - Effect of vegetation level and flow regime on canopy cover (Chi square test).

		Canopy cover				Exact P	Chi 2
		<10%	10-40%	40-70%	>70%		
Vegetation Level	Thermomed	0	0	0	5	0.000***	37.33
	Mesomed	0	1	4	0		
	Supramed	0	1	4	1		
	Montanemed	5	0	0	0		
River Flow	Perennial	0	1	4	5	0.072	9.92
	Intermittent	2	1	1	1		
	Ephemeral	3	0	3	0		

fected by river flow regime, even if higher canopy cover was observed along perennial rivers, when compared to sites with ephemeral regime (Tab. 4).

However, when we associated the type of disturbances present in each plot to the respective QBR index values, we found that QBR values varied significantly with the main types of anthropogenic activities found along the river; channel modification is the principal disturbance affecting the QBR index negatively, followed by change of land use, waste dumping, embankments, and finally tree cutting, or grazing (Tab. 5).

Analysis of variance showed that *Salix libani* and *Tamarix smyrnensis* grow in sites with the lowest riparian habitat quality (respective QBR values 32.37 and 35.65) while *Salix acmophylla* and *Salix alba* are found in distorted sites (respective QBR values 40.74 and 53.93) and *Platanus orientalis* is found in fair quality classes (QBR value 62.6). *Nerium oleander* is found in a single site that is relatively undisturbed (QBR value 75) as shown in Table 6.

Tab. 5 - Effect of anthropogenic activities on QBR index (One-way ANOVA Duncan test).

Disturbance	N	QBR average values
Channel modification	3	36.67[a]
Change of land use	8	46.25[ab]
Solid and liquid waste dumping	5	55.00 [ab]
Embankments	4	57.50 [ab]
Tree cutting and grazing	2	62.50 [ab]
No disturbance	5	72.00[b]

Tab. 6 - Species distribution according to QBR (One-way ANOVA Tuckey test).

Species	N	QBR average values
Salix libani	76	32.37[a]
Tamarix smyrnensis	23	35.65[ab]
Salix acmophylla	54	40.74[abc]
Salix alba	248	53.93[abcd]
Platanus orientalis	365	62.60[bc]
Nerium oleander	10	75[c]

Figure 2 shows that DBH increased with a higher QBR index values exhibiting a weak correlation (r = 0.134; p-value = 0.001). Moreover, DBH is highly correlated to canopy cover density, and negatively correlated to NDM (Tab. 7).

Discussion

The influence of the bioclimatic conditions on vegetation cover is pertinent; higher altitude exhibit a diminishing canopy cover, while lower altitudes have a denser canopy. The presence of optimal temperature and humidity are reflected in lush dense tree canopy. In fact, the Montane Mediterranean level is occupied by ephemeral streams bordered by shrubs dominated

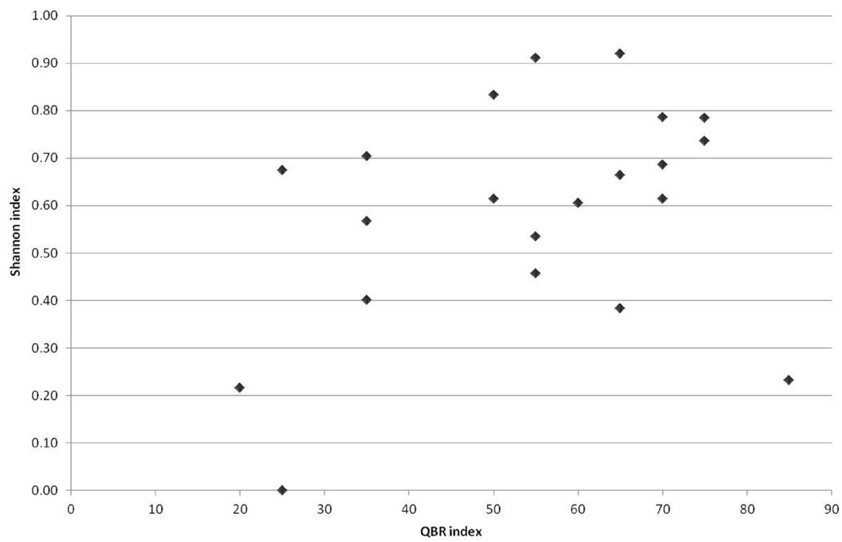

Fig. 1 - Shannon index distribution according to QBR index.

Tab. 7 - Effect of Canopy cover, QBR and number of dry month on diameter.

			NDM	Canopy cover	QBR
DBH	Pearson Correlation	1	-.088*	.152**	.134**
	Sig. (2-tailed)		0.023	0	0.001
	N	666	666	666	666

by *Salix libani* and *Rhododendron ponticum*, which explains the low percentage of canopy cover obtained in this level (Abi Saleh *et al*., 1996). In addition, the lower section of the river crosses a canyon with steep slopes which favors the development of a dense canopy cover that is a continuum to the adjacent non riparian woods (Angiolini *et al*., 2016). Hence, the riparian habitat quality is widely shaped by both canopy density and structure and by flow regime as expressed by Munnee *et al*. (2001), which explains why QBR values are significantly more affected by canopy cover that is part of the QBR test calculation rather than river flow regime.

Nonetheless, when we downscaled the analysis to the type of disturbances, it was pertinent that river channel deviation is the most significant factor affecting riparian habitat quality. In fact, channel modification may lead to river metamorphosis (a complete change of river's morphology) which explains its ponderous effect on riparian health (Gregory, 2006; Stella *et al*., 2012). As a result, non-riparian species may replace riparian species, leading to habitat fragmentation or loss. Such diagnosis could not be captured by the QBR values as the canopy cover was estimated for all trees combined, regardless of the dominance or not of riparian tree species.

Tree cutting and grazing lead to localized bank and channel erosion and decrease in vegetation cover. This effect is reversible once the source of disturbance has stopped, which explains its limited effect. Non disturbed sites have significant higher scores, yet they are not classified as in natural conditions due to the effect of intrinsic environmental factors on habitat quality (especially in high mountains with ephemeral streams).

Biodiversity of riparian species, as expressed by Shannon equivalent number is weakly correlated to riparian habitat quality. Although there was an evident increase of biodiversity when habitat quality improved, plots with lowest biodiversity are present in both plots with degraded or good habitat quality. The weak correlation of diversity and habitat quality was similarly denoted by Angiolini *et al*. (2016) who stressed on the effect of geomorphology and land use types on riparian plant communities assemblage. The bioclimatic conditions, geomorphology of the river, and the type of bedrock and the presence of alluvial soils largely affect spatial distribution of plant species in complex relation along with anthropogenic activities which rarely override natural factors (Engelhardt *et al*., 2012; Nucci *et al*., 2012; Gumiero *et al*., 2015). Another explanation is that perennial species such as trees and shrubs are not promptly affected by habitat degradation and disturbances as herbaceous species, and if some tree species are vulnerable to disturbances, they are soon replaced by shrubs. The spatial and temporal variability of the water regime induces a greater adaptation of the riparian species. In such habitat, species that require near permanent moisture and those that adapt to greater drought cohabitate, thus increasing the biodiversity of this habitat type (Nilsson & Svedmark, 2002; Gumiero *et al*., 2015). Moreover, the presence of substantial contiguous forests within the river watershed increase the resilience of riparian vegetation to biodiversity degradation (Von Behren *et al*., 2013).

For instance, *Salix acmophylla* and *Salix alba* were found in strongly distorted sites, this could be attrib-

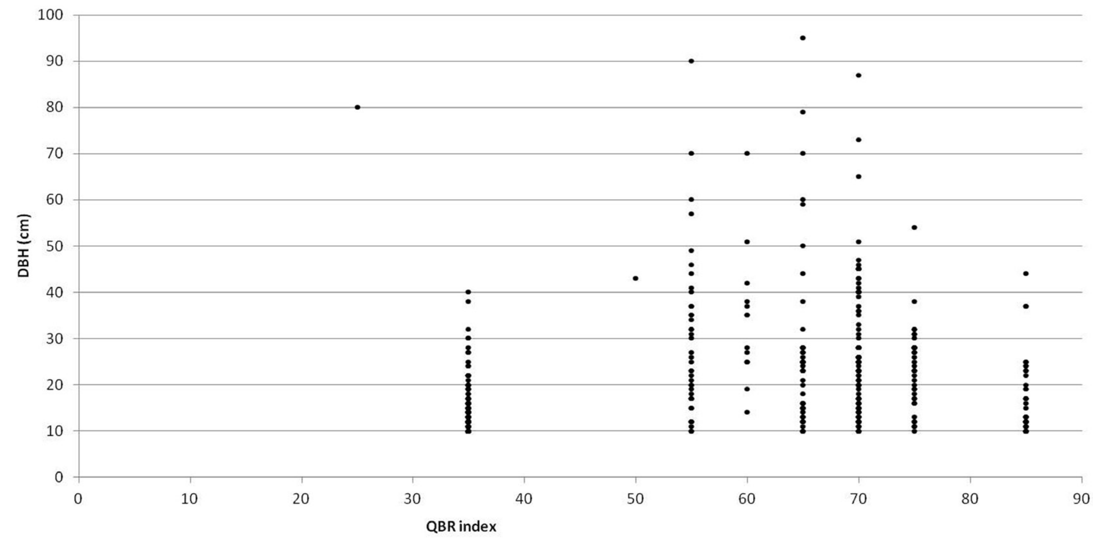

Fig. 2 - Diameter distribution according to QBR index.

uted to the fact that willow trees are pioneer species tolerating flood and low debris and colonizing remarkably affected sites through sexual and vegetative reproduction, which explains their presence in such sites (Friedman *et al*., 2006). *Platanus orientalis* being a climax species in eastern Mediterranean streams of low and moderate altitude (Abi Saleh *et al*., 1996) is more likely to be found in sites with lower disturbances and higher canopy cover. *Tamarix smyrnensis* is also known for its tolerance to drought (Bond *et al*., 2008) which explains its presence in sites with low QBR.

When we investigated the effect of riparian habitat quality on vitality aspects for each species, such as DBH of tree species, and their regeneration rate, only weak correlation values were found. This could be explained by the low regeneration count (in nested plots of 20 m^2 in each plot) and the heterogeneous distribution of tree species in our sampled plots (for instance, species are not found in all plots). However, when we combined all species together, it was obvious that tree growth (illustrated by DBH) is related to habitat quality, canopy cover and negatively affected by river flow regime (Gumiero *et al*., 2015). Higher riparian habitat quality resulted in the presence of old growth. Correspondently, this also explains that in such dense groves with old growth, regeneration rates are low, as observed during the survey (results not shown here).

Based on all results, we were able to classify riparian species according to their functional adaptations as per Naiman *et al*. (1998) (Tab. 8).

Conclusions

Our assessment proved that this riparian ecosystem is shaped by different environmental characteristics and anthropogenic activities. Channel modification has the strongest negative effect on riparian habitat quality. Nonetheless, tree and shrub riparian species show a relative resilience to the degradation of habitat quality, due to their intrinsic traits (like longevity), and the possibility to reiterate and reproduce asexually. This study allowed us to assess the requirements of major riparian species in terms of habitat quality, and to classify them based on their functional adaptation, in order to adopt appropriate ecosystem restoration and conservation plans.

The combined effect of anthropogenic impacts and natural distribution of riparian species along environmental gradients should be assessed in the future. Such investigation should be coupled with satellite imagery and remote sensing tools to assess riparian forest structure and composition and its degree of fragmentation. At a second stage, the riparian vegetation successions after disturbance should be considered in order to simulate the effect of climate change on riparian tree and shrub species distribution.

Tab. 8 - Riparian species classification according to environmental adaptations.

	Disturbance		
Species	**Anthropogenic**	**Drought**	**Shade**
Salix libani	Avoider	Resister	Avoider
Tamarix smyrnensis	Resister	Resister	Avoider
Salix alba	Invader, endurer, resister	Avoider	Resister
Salix acmophylla	Invader, endurer, resister	Avoider	Avoider
Platanus orientalis	Avoider	Resister	Resister

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Appendix I: Geographical coordinates (degree, decimal) and altitudes of the study sites.

Sites	X	Y	Altitude (m)
Nahr Ibrahim 1	34.059.167	35.639.500	10
Nahr Ibrahim 2	34.066.333	35.657.000	27
Nahr Ibrahim 3	34.082.833	35.683.500	109
Amez	34.051.333	35.797.500	1506
Ain el ghwaybe	34.085.167	35.878.500	962
Afka	34.072.167	35.887.333	1098
Akoura- nabeh el rouwes	34.109.167	35.907.000	1256
Mghayre	34.114.000	35.884.833	1245
Bir el het	34.077.667	35.724.500	284
Ain aalaa	34.134.167	35.877.333	1705
Artaba charbine-nabee el jered	34.122.667	35.858.000	1710
Mazraat el siyad	34.113.333	35.863.333	1386
Abboud	34.101.000	35.860.333	1234
Hdayne	34.088.167	35.867.333	805
Yanouh	34.095.500	35.896.167	987
Jannet artaba	34.078.667	35.830.500	756
Chouwen	34.081.167	35.775.833	407
Yahchouch	34.063.000	35.741.500	594
Akoura- ain el lebne	34.146.500	35.934.833	1766
Akoura	34.119.000	35.925.000	1521
Mchete	34.047.667	35.753.167	973