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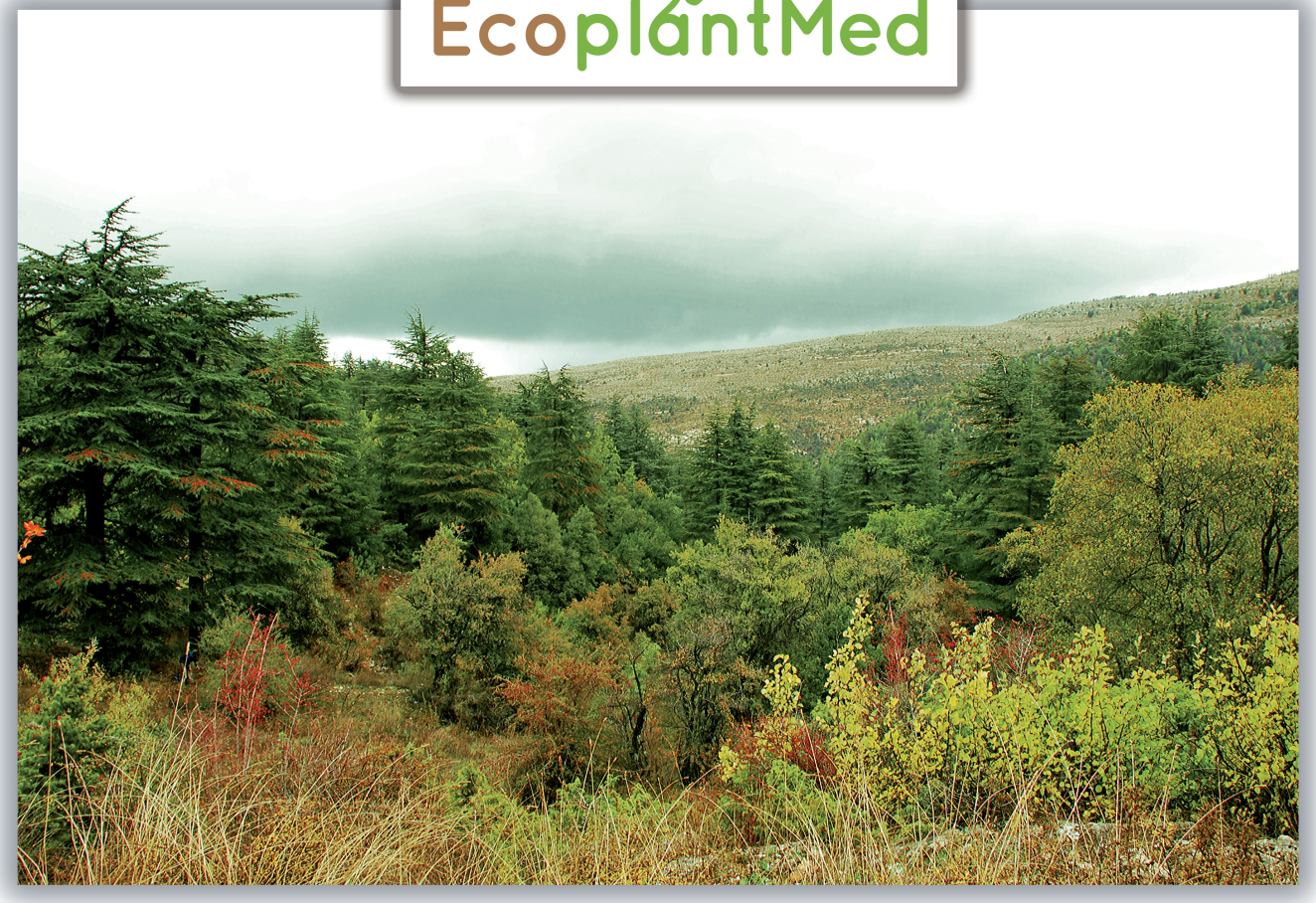

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Restoration against all odds: the case of coastal sand dunes in Ouzai

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Abstract
Substantial urban development (which has accelerated the effects of climate change), water and air pollution, as well as erosive forces have reduced natural habitats along the coast of Lebanon to less than 20%. One unique coastal ecosystem is the sand dunes, which once harboured rare and regional endemic plant species. Although sandy beaches currently occupy around 20% of the Lebanese shoreline, resorts, industries, commercial development and informal settlements have replaced the pre-existing, fragile dune ecosystems. The area under study stretches from the shores of Khalde in the south and the northern limits of Ouzai, the latter being an area dominated by informal settlements that have eroded and polluted the beach sand due to inadequate infrastructure. This has compromised and destroyed the highly specialised ecosystem and deteriorated its functions. Taking into consideration the beneficial functions and unique character of coastal sand dunes, this study presents a putative dune restoration plan that will essentially incorporate the nearby community in a self-sufficient, resilient landscape. A necessary change in the site's zoning plan, particularly in reference to land ownership and use, is needed prior to the implementation of the proposed restoration and integration program. Extensive environmental, spatial and social analyses allow the employment of several site-specific dune stabilisation techniques. The dune reinstatement methods will complement the establishment of a well-designed community in which human and environmental elements are integrated within designated spaces. These allocated interaction zones will act as a buffer between inaccessible dunes near the shore and the densely inhabited neighbourhood further inland. While the study focuses on the restitution of the coastal sand dune ecosystem, detailed design methodologies create a strategy for improving the living conditions within Ouzai. In light of the proposed design, the currently depreciated neighbourhood will experience more open space, enhanced infrastructure, cleaner air and a healthier environment.

Key words: bioswales, coastal sand dunes, ecological landscape design, informal settlements, rare and endemic species, spatial analysis, threatened ecosystem, urbanisation.

Introduction

The Coast of Lebanon

The coast of Lebanon is characterised by a narrow strip stretching across 230 km from the northwest to the southwest border, embraced by the Mediterranean sea and Mount Lebanon. Coastal zones occupy an area of 840km^2, or 8% of Lebanon's total surface area; they are distinguished by a sequence of headlands such as sandy beaches, cliffs, rocky capes and bays. There are approximately 20 sandy beaches in Lebanon covering a length of 49 km and representing 20% of the shoreline in areas such as Ras Beirut, Chekka, Batroun, Jbeil, Tyre and Ramlet el Bayda (MOE/GEF, 2016).

Remaining Sandy Beaches

This richly diversified coastline has become severely damaged by various factors including the effects of war, urbanisation, oil spills, industries, and quarrying, leading to the complete annihilation of many coastal natural habitats. Perhaps the most devastating disturbance of the coastal beaches and dunes is the continuous, rampant urban sprawl. Massive construction has left behind less than 20% of the pre-existent natural habitats, including coastal sand dunes (Fig. 1). Fifty five percent of the Lebanese population resides within the coastal zone, where informal settlements are now estimated to have approximately 594 inhabitants per km^2, in comparison to the overall population density of Lebanon, which is approximately 307 people per km^2 (MOE/UNDP/ECODIT, 2011). Furthermore, many beaches are facing permanent loss of sand and gravel (Makhzoumi *et al*., 2012). Between 1963 and 2003, 45.2% of shore sand has been eroded (MOE/UNDP/ECODIT, 2011).

Importance of Coastal Sand Dunes

An integral characteristic of sandy beaches is the formation of coastal dunes, fragile yet complex ecosystems with various ecological and social advantages. Sand dunes primarily serve as a barrier between sea and land by protecting the coast from erosive forces

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of tides and prevailing winds. They include rare and endemic species specialised to dune habitats. Moreover, they have been recognised as distinctive recreational areas often becoming the site of many human interactions. Since coastal dunes are distinct habitats with specialised physical and biological features, the environment created is capable of providing unique socio-cultural connections to the dune habitat heritage. Memorable activities such as walking, swimming, horseback riding and picnicking within coastal sand dunes tie people to the landscape. Furthermore, sand dunes are known to preserve archaeological sites along the coast, further enhancing the specialised heritage of the dune habitat (Everard *et al*., 2010).

For these purposes, the preservation and/or restoration of such ecosystems along Lebanon's coast is essential. However, sand dunes are the most negatively affected coastal ecosystems of Lebanon; they have been almost completely eradicated from every site where they once existed (NSW, 2001).

One case study that addresses the importance of coastal sand dune restoration in the Eastern Mediterranean is Kutiel (2001), which provides a platform for a restoration program within the Mediterranean context. While the scale of the study in Israel is larger and more complex, fundamental steps are established in the program that may be appropriately adapted to the case of Lebanon's coastal sand dune restoration program. The first step undertaken in this study was understanding the importance of the coastal habitat within its urban context. After thorough analysis, it was concluded that the sand dunes of Israel's coast do not only provide ecological benefits, but also social benefits such as recreation. This was highly emphasised in the restoration process, in which a program incorporating opportunities for recreational activities was proposed. Furthermore, high importance was given to the conservation of rare fauna and flora found in Mediterranean coastal dunes. Overall, the program established in Israel addressed multiple issues on different levels, something reflected by the development of heterogeneous landscapes. These landscapes took form as zones with varying accessibility to people. Less accessible zones were designated for biological and ecological conservation of the dunes, while more accessible zones were identified as areas for human activity (Kutiel, 2001).

The Site

In Lebanon, coastal sand dunes previously thrived along the shoreline, which stretches from Jnah to Ouzai (Fig. 2), an area directly south of Beirut currently occupied by informal settlements. The establishment of beach resorts on-site during the 1960s initiated the degradation, while the sprawl of informal settlements triggered by the Lebanese civil war caused most of the devastation. Due to poor infrastructural nature of the

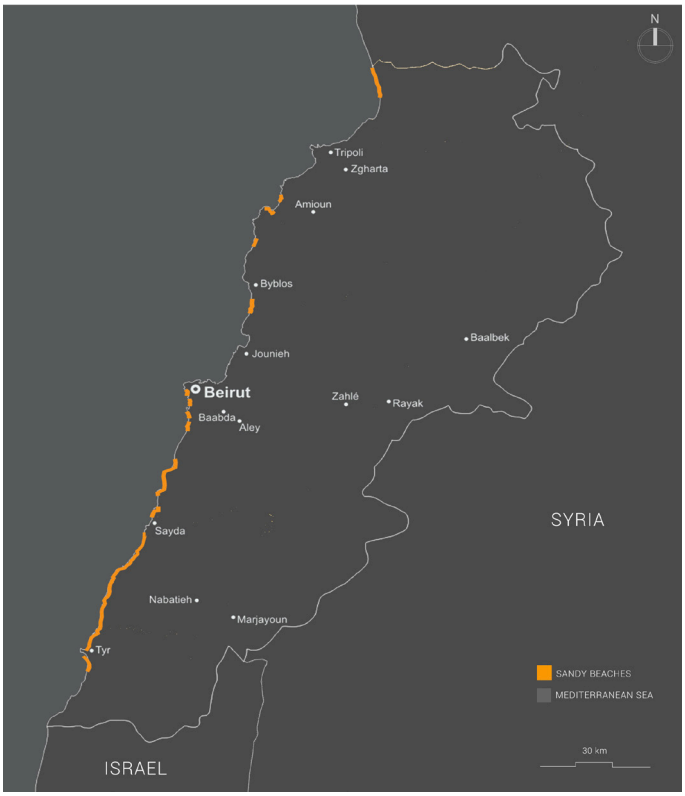

Fig. 1 - Sandy beaches along the coastline of Lebanon.

Fig. 2 - Location of the site under study.

settlements and improper development planning, the lack of adequate sewage networks and public services is further accelerating erosion and contamination of the Ouzai beach. Figure 3 illustrates the rapid urban expansion within the Ouzai strip since 1945 and the establishment of land embankments in the early 2000s.

The aim of this work is to analyze existing ecological, physical and social conditions of the Ouzai site in order to propose a restoration plan of the sand dune habitat without excluding people in the area.

Materials and Methods

General Methodology

Upon visiting the site, observations of ecological and social parameters were undertaken in an effort to present opportunities and constraints for the design process. The location and density of settlements was mapped (Fig. 4) which revealed how the sandy beach has been reduced to a narrow strip with a maximum width of 50 meters, miniscule in comparison to the previously, fully-formed sand dune. Proximity of settlements to the sea and the density of built elements have hindered any successful sand dune formation. This realisation pushed towards discovering possibilities of relocating settlements in specific areas. Site opportunities are affected by accessibility to the beachfront from the main highway. Figure 5 highlights several access points to the shoreline through the neighbourhood. These connections allow for pedestrian flow within the neighbourhood and along the beach, a prospect that may be enhanced in the design process.

Existing Site Conditions and Analysis

1. Activities on site

Regardless the exploitation caused by the development of settlements, which have affected natural habitats of the site, people inhabiting the Ouzai neighbourhood are directly connected to the seaside. Residents spend most of their time outdoors in the adjacent open market, in between narrow alleys of the settlements, and on rooftops. As a result, diverse activities have spawned along the shore where the improvised use of spaces is manifest through scattered tables and chairs set up as seating areas, as well as fishing boats or nets collected on-shore. All along the site, families gather on their rooftops overlooking the sea. On the beach, children swim and play with their dogs, young men gather in nearby abandoned buildings and fishermen occupy protruding rocky edges of the shore (Fig. 6). Although a systematic and comprehensive analysis of social activities on site needs to be undertaken using standard surveying methods, a quick observation of social patterns within the Ouzai strip yielded preliminary information that was used in this study. This approach was used primarily because of limited accessibility to reliable information sources within the strip.

2. Sewage-Trash Pollution

Assessment of potential restoration of sand dunes on-site draws significant attention to the effects of exposed pollution and sewage canals produced by the settlements, which run throughout the entire neighbourhood and into the sea. Figure 7 reveals four major, exposed sewage canals, each with areas affected by groundwater pollution. Aside from these main sewage streams, which are directed into the sea through concrete canals, pools of stagnant sewage are forming along the shore. Uncovered sewage lines prohibit rehabilitation of fragile dune ecosystems, and constitute major disease-risk factors for inhabitants of the site. Furthermore, a consistent strip of garbage accumulates in between the settlements and the sea (Fig. 8). Ironically, this is allowing sand to accumulate and ruderal and potentially invasive plant species to thrive, resulting in a linear landscape of 'garbage dunes'. Conta-

Fig. 3 - Historical timeline representing urban sprawl within site over time.

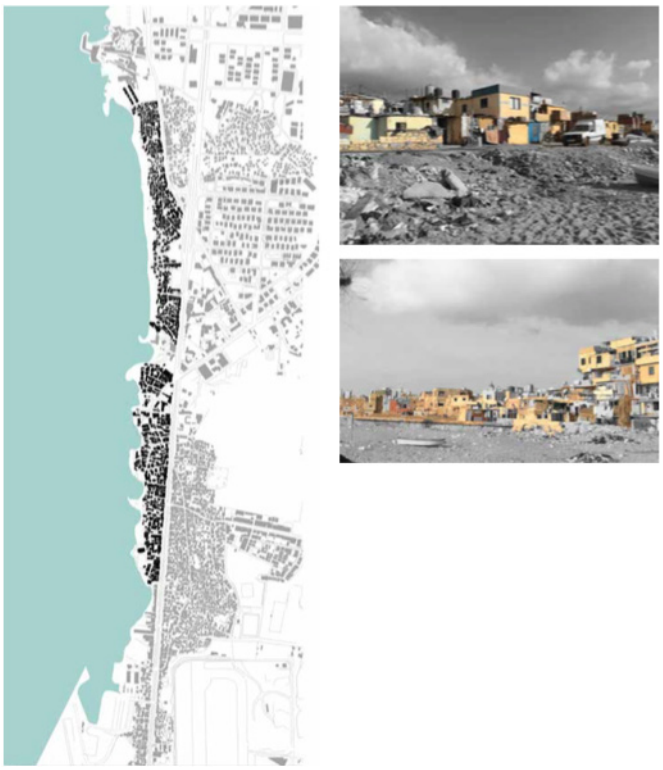

Fig. 4 - Density of the informal settlements.

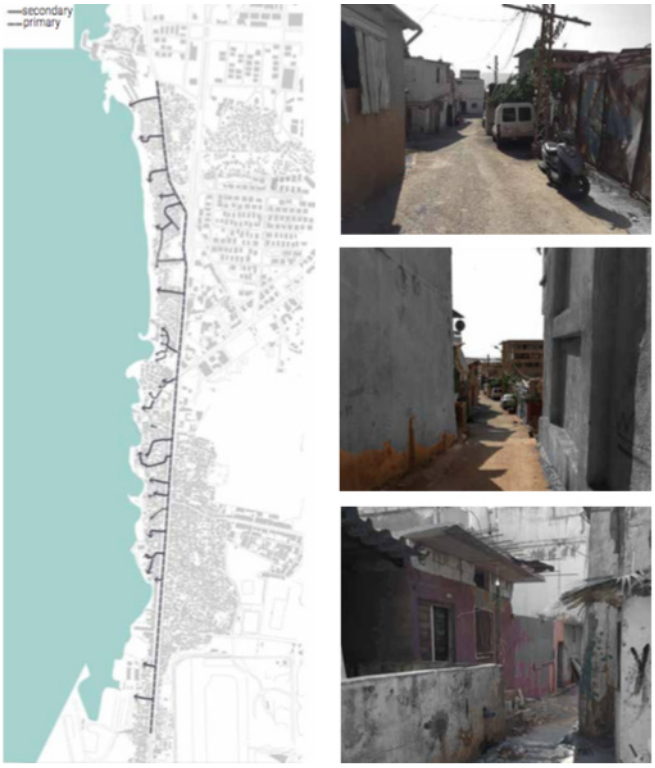

Fig. 5 - Access points from main road to shore.

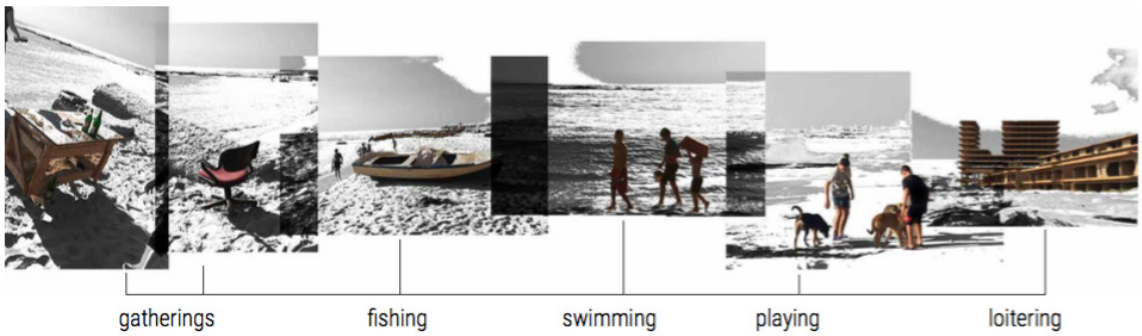

Fig. 6 - Different activities occurring on site.

mination of beach sand and groundwater due to sewage and pollution have created long-term, detrimental effects on the landscape and the living conditions of inhabitants. Proper treatment of sewage canals and removal of garbage should be addressed prior to further development of the site.

3. Sand Dune Zones

Sand dunes are considered to be highly mobile and responsive to disturbances. Consequently, processes of coastal sand dune formation will inform design decisions within this intervention proposal.

Coastal sand dunes are formed by the accumulation of sand on the shore due to deposition by waves or wind. This sand may be of terrestrial or marine origin. Terrestrial deposits, usually derived from quartz, silica, basalt, feldspar, or eroded animal skeletal material, are transported through rivers onto the coast, where the sand may also accumulate carbonates instigated from the sea. As a result of continuous sand deposition onto the shore from land and sea, dunes begin to advance into the sea and sand begins to accumulate as dunes of 5 to 10 meters, with the accumulation rate decreasing after reaching 10 meters. This deposition and the resulting formation of sand dunes with varying heights is dependent upon several factors including vegetation cover, climate change, local topography, prevailing winds, soil type, proximity to rivers, and embayment size (Greipsson, 2002)

Complex landscapes, which may be divided into different zones according to the level of stabilisation, vegetation cover and sediment cover, comprise the resulting formations (Fig. 9). The near shore zone, surf zone, swash zone and berm area all occur at the edge

Fig. 7 - Sewage canals polluting groundwater.

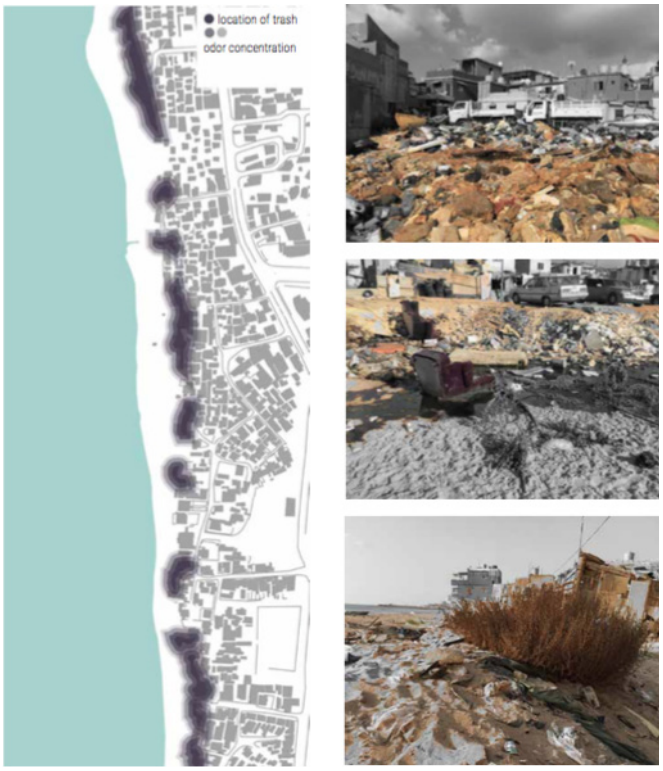

Fig. 8 - Trash and odor pollution along site.

of the shoreline. Since these zones interact with the sea waves, they tend to be the most active. Little accumulation occurs here, as wind and breaking waves cause the sand to be transported further up-shore to subsequent zones. Next, the primary vegetation zone consists of incipient dunes, small platforms where windblown sand begins to collect. Due to their location seaward, incipient dunes are directly exposed to wave erosion and are highly mobile, very often completely removed by waves. Despite the relative instability of incipient dunes, vegetation in the form of beach grasses or creepers occur in this zone, allowing the accumulation of sand. In contrast to high mobility of the primary vegetation zone, the secondary vegetation zone consists of foredunes, which are generally more stable, gathering larger amounts of sand than incipient dunes. These dunes' ability to withstand wind and wave erosion is due to the stabilising woody shrubs that thrive within. Foredunes are important features of the beachscape as their larger size along with the woody nature of their vegetation complement each other in creating dunes with greater heights than those surrounding them. Most inland is the tertiary vegetation zone inherent of the highly stabilized hind dunes, characterized by large trees and shrubs (NSW, 2001).

While these three main vegetation zones characterise typical coastal dune ecosystems, Lebanon's coastal dune formations differ in response to their direct environment, as is the situation in adjacent Eastern Mediterranean countries. These dunes exist as distinct, xeric ecosystems, their harsh physical environment caused by sand instability as well as low soil moisture and nutrient content, making it difficult for typical Mediterranean fauna and flora to thrive. Consequently, they harbor Mediterranean species that have undergone ecotypic differentiation. The harsh physical conditions, including sand instability, inhibit full formation of the three main dune zones, thus allowing only for incipient dunes and foredunes to be naturally established (Kutiel, 2001). Because of the specificity of Lebanese coastal sand dunes, particular criteria for dune re-establishment are used, allowing for the restoration of dune formations similar to the pre-existing ones. The site-specific dunes of the Ouzai strip, currently practically non-existent, once bordered rocky platforms at the base of rocky headlands, which may still be found on-site today. These rocky platforms will provide opportunity in the dune restoration process for the purpose of beach nourishment where sand may accumulate more easily (Northern Beaches Council, 2016). Low settlement density was also used as an additional criterion to delineate restricted zones within the restoration site.

In response to the missing benefits of specialised sand dune ecosystems, a conceptual restoration plan has been proposed. The master plan provides a strategy (Fig. 10), which will not only allow for the re-establishment of dunes in designated areas, but also include spaces of interaction where people of the neighbourhood may experience the sand dune habitat.

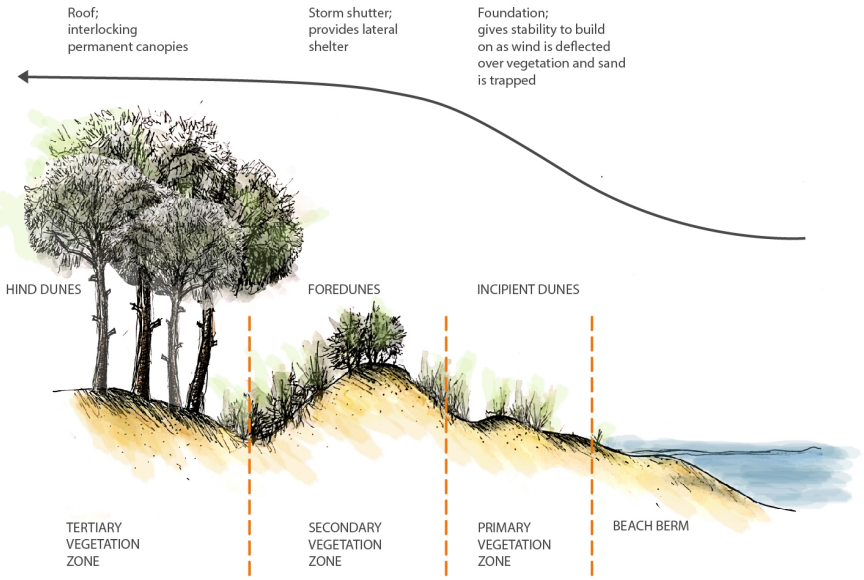

Fig. 9 - Profile of a coastal sand dune, presenting benefit as barrier.

The approach includes a zoning plan that designates the beachfront as restricted and non-restricted areas with specified uses.

Results and discussion

Restricted Zones

Three major restricted zones, denoted by points 1, 2 and 3 (Fig. 11), are allocated according to the following criteria: (1) areas with lower settlement density and (2) locations with rocky protrusions. Intensive restoration in these restricted zones will allow full development of the dune ecosystem with complete successive formations: the foredunes, incipient dunes and hind dunes.

1. Land Reclamation

In order to accomplish fully developed dune formations with primary, secondary and tertiary vegetation, land reclamation efforts along the shore will be undertaken in areas where rocky protrusions exist. The rocky protrusions will serve as natural bays allowing for increased sand accumulation and advanced dune development. Human disturbances will be prevented through the use of fences, pathways and signage.

2. Geo-textile Sand Tube Technique

Based on the design proposal (Fig. 11), zones 1, 2 and 3 will be restored using the geo-textile sand tube technique (Fig. 12). The method, which is highly effective and provides immediate results, especially in extremely disturbed situations, artificially reconstructs sand dunes by collecting local sand into tubes with geo-textile layering and manually planting the dunes. Incorporation of the geo-textile layer into tubes acts as a protective layer from possible polluted groundwater and the disturbed sand surface.

Material used for the geo-textile tube technique include geo-textile sand containers, local sand, and planting grids.

Geo-textile container implementation takes place shortly before the planting season, since placement of the sand tubes long before that will expose the sand to erosion in the absence of plants. Therefore, the use of provisional stabilisers might be necessary in the period between reconstruction and re-planting. The geo-textile tube-shaped sand containers will be fabricated off-site. During manufacturing, tubes will have been gauged to certain temperatures and humidity levels as to handle the harsh and unfavorable coastal environment. These tubes can be very large in size reaching 20 meters in length by 1.6 meters in width, creating sturdy material that can withstand the forces of wind and waves (Carmo *et al*., 2006). Manufactured containers will be placed at the hydrographic zero (2 meters below sea level) and subsequently filled *in situ* with a blend of local sand and water to eventually allow the water to drain. A one-meter layer of sand should cover the containers, ultimately creating the profile of a sand dune. The planting phase will take place the spring following implementation. Planting in the geo-textile containers is a process that begins with laying out a 50 cm diagonal grid and transplanting within the same day for maximum efficiency (Carmo *et al*., 2009). Application of fertilisers as well as transplantation every few years will ensure continued stabilisation of the dunes.

Non-restricted Zones

Non-restricted zones, accessible to people, will be

Fig. 10 - Proposal showing settlements to be relocated, suggested relocation sites, and reclaimed land locations.

Fig. 11 - Three major zones (1, 2, 3) open to public and four zones (a, b, c, d) not open to public.

located at points a, b, c and d (Fig. 11). They incorporate less intensive restoration techniques and focus on the development of foredunes and incipient dunes. Since these non-restricted zones will act as venues of human interaction, treatment of sewage, pollution and reduction in settlement density becomes crucial. Consequently, a program of settlement relocation, sewage/pollution treatment using bio-swales and finally dune-building fencing will be undertaken in these zones.

1. Settlement Relocation

Zones a, b, and c (Fig. 11) are areas in which settlements will be relocated since land reclamation in these areas is inefficient given the lack of rocky protrusions. Zone d is a stretch formed of rocky cliffs that will accumulate sand more easily and allow for the formation of dunes. A total number of 86 houses, covering an area of 13,400 m^2, will be relocated to the nearby zone highlighted in light grey (Fig. 13). The highlighted areas represent 31,000 m^2 of abandoned land north of the neighbourhood. An area of 14,200 m^2 will be developed to accommodate the relocated settlements. This relocation will significantly decrease disturbances in the non-restricted zones.

2. Bio-swales

The removal of settlements offers opportunities for treatment of soil and groundwater affected by major sewage canals. Once the settlements are relocated, soil and groundwater treatment will be addressed through phytoremediating bio-swales (Fig. 14).

Sewage canals coming from the Ouzai neighbourhood will be redirected into the proposed bio-swales, which treat wastewater as well as prevent groundwater infiltration and soil contamination, significantly reducing the unsanitary conditions (Hooda, 2007). These bio-swales use phytoremediating plant species, which degrade wastewater contaminants. While many native species may have a great potential in phytoremediation, such species are either unknown or unavailable on the market, thus the need to use non-native species with such potential.

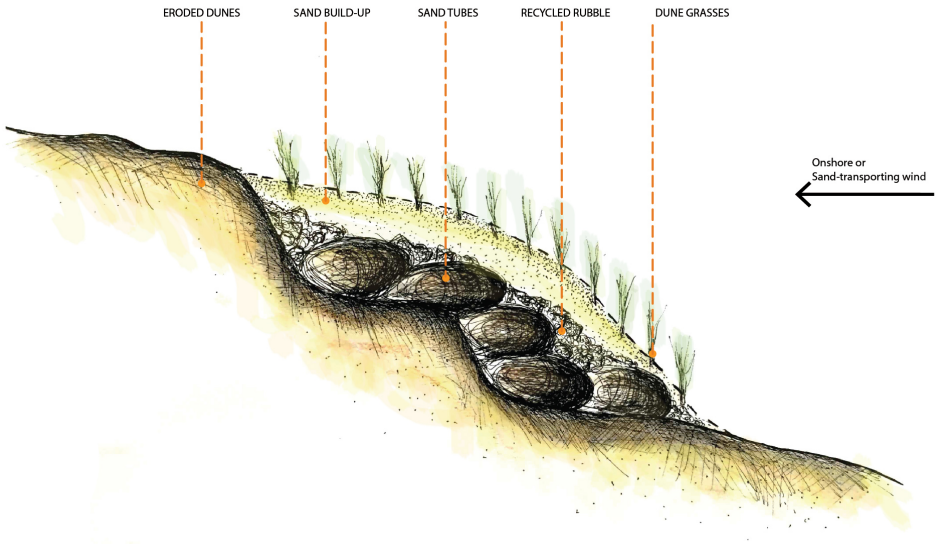

Fig. 12 - Sand dune container method, which will be used in the restricted sand dune accumulation and restoration zone.

Materials used to construct the bio-swales consist of three layers: a base layer consisting of geo-textile lining; a secondary layer of soil/compost mixture; and a recycled rubble/gravel layer.

The soil-compost layer lies between the base and rubble/gravel layer to prevent the rupturing of the geo-textile layer. Rubble recycled from settlements, which have been relocated, may be used. Once the recycled rubble/gravel has been installed, selected plants species may be introduced. The combination of rubble/gravel with plants will reduce water flow and allow for sedimentation, which removes waste. Continuous maintenance of the bio-swales through plant replacement and removal of accumulated sediments should be undertaken periodically.

3. Fencing Technique

In accordance with the design masterplan (Fig. 11), zones a, b, c and d will be subjected to the non-restricted sand dune restoration method (Fig. 15). This simple technique introduces fences or wooden posts placed into the soil to allow for sand accumulation and gradual establishment of dunes and consequently plants. Dune-building fences are multi-functional, as they are capable of controlling wind-blown sand, accumulating sand and creating boundaries to prohibit access to protected dunes. Generally, dune-forming fences are installed during the pre-planting phase in order to allow for sand build-up.

Three elements comprise the structure of dune-building fences:

1. Porous material such as woven synthetic cloth. Porosity of the material should be 40%, allowing sand entrapment (NSW, 2001). The woven, synthetic cloths should be durable and flexible.

2. Wires capable of supporting the synthetic cloth

3. Wooden posts

Synthetic cloth, attached to wires with ring fasteners, should be oriented in the direction of prevailing winds, most effectively at approximately 90°. Initial installation requires digging 20 cm into the sand (NSW, 2001). Fences are set up parallel to each other, 2 to 5 meters apart, guaranteeing maximum sand accumulation (NSW, 2001). The dune-building fences act as anchors for sand accretion and will inevitably be buried by sand over time. Eventually, vegetation should begin to grow on the accumulated sand. While dune-building fences have been proven to successfully establish sand dunes, the slow rate of the technique must be recognised and taken into account in the restoration program. Complementing this dune-building fence technique is the use of wooden pathways. Such pathways are simple and cost-effective, which will direct and orient human activity (along with the fences). The pathways protect the top layer of sand from being removed while also allowing constant circulation along the site.

Vegetation

Dune grasses like *Ammophila arenaria* (L.) Link, will be planted using propagated clonal offsets, and fertilisers will be applied. *Ammophila* grasses are indigenous species to dune ecosystems and generally encourage the symbiotic relationships of Arbuscular Mycorrhizal Fungi (AMF) with their roots. Therefore, the establishment of vegetation on fore-dunes will increase the likelihood of dune restoration success in the long run. Naturally, grasses native to Lebanese dunes should be used. A survey of Mouterde (1966-1984) yielded at least 16 species of native grasses (*Stipagrostis* spp., *Cutandia* spp. and *Vulpia* spp. for example) that could have been found on the dunes under study. However, these grasses are mostly unavailable in the

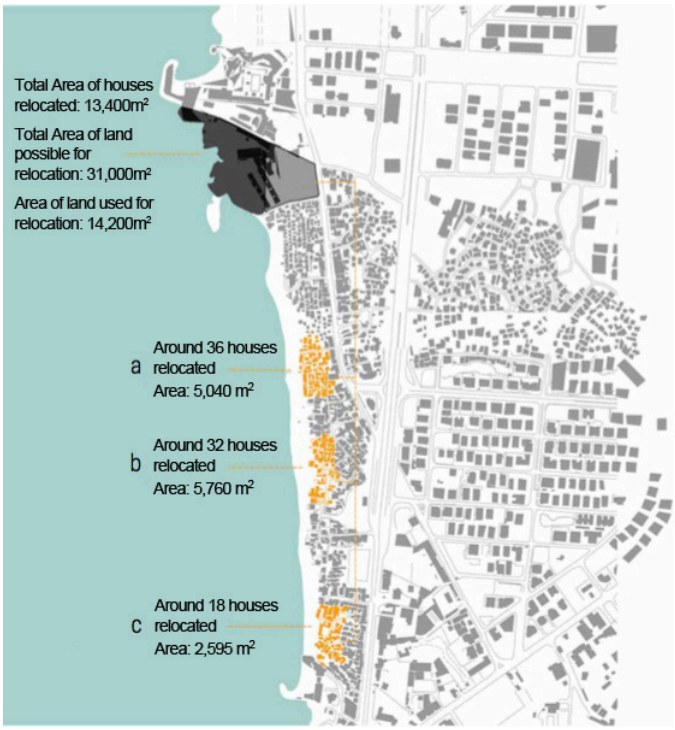

Fig. 13 - Number of settlements to be relocated, with proposed relocation site.

local market and therefore would have to be propagated specifically for this restoration effort or replaced with non-native, ecologically suitable species such as *A. arenaria*. Research to verify the optimal distance from sea and the optimal density for planting *A. arenaria* on the restored sand dunes would be needed (De Lillis *et al*., 2004).

Further methods to ensure dune protection would be to plant large trees on and behind the hind dunes, near the adjacent vehicular road, to act as a double-sided buffer zone. Not only will this buffer zone protect the coast from wind and sea wave erosion, but it will also protect the foredunes from disturbances coming from the road and the development beyond. In addition to ecosystem reconstruction and protection, the restoration program must take into consideration the use of the site, whether as completely protected zone or partially accessible area (Nordstrom & Jackson, 2013).

The list below is a small selection of potential native plants that may be used to achieve the coastal sand dune profile. A few options will be selected for bioswales as well.

1. Hind Dunes

Pinus pinea L.; *Pistacia lentiscus* L.; *Ceratonia siliqua* L.

These woody species will be used primarily for the stabilization of the hind dunes.

2. Foredune

Convolvulus secundus Desr.; *Euphorbia peplus* var. *minima* DC; *Euphorbia paralias* L.; *Ammophila arenaria* (L.) Link; *Ipomoea imperati* (Vahl) Griseb.; *Drimia maritima* (L.) Stearn.

3. Incipient dune

Pancratium maritimum L.; *Desmazeria philistaea* (Boiss.) H. Scholz; *Cutandia maritima* (L.) Benth.; *Matthiola tricuspidata* (L.) R. Br.; *Cakile aegyptiaca* (L.) Maire et Weiller.

4. Bioswales

Spartina alterniflora Loisel.; *Salicornia bigelovii* Torr.; *Miscanthus sinensis* Andersson.

Once the restoration techniques are applied, the site will serve as habitat for coastal vegetation unique to sand dunes, and as an open public space for site residents. Having dealt with the treated groundwater,

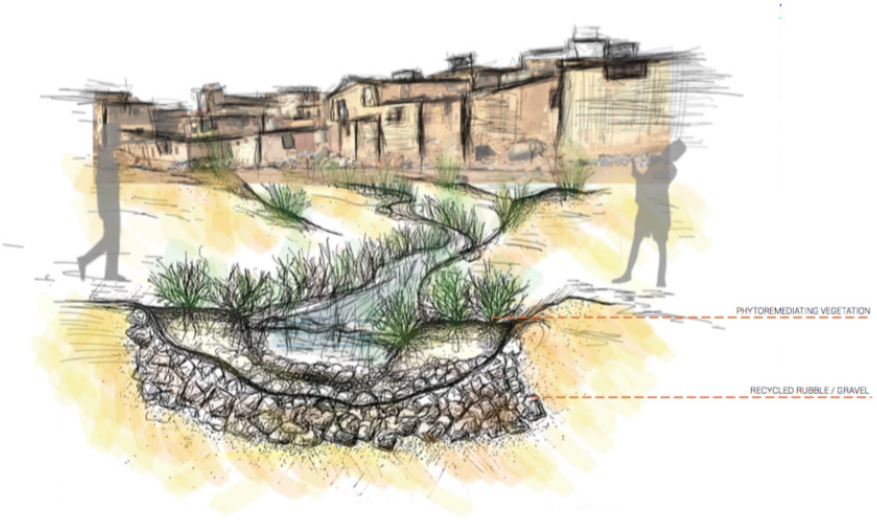

Fig. 14 - Goal of bioswales and section view.

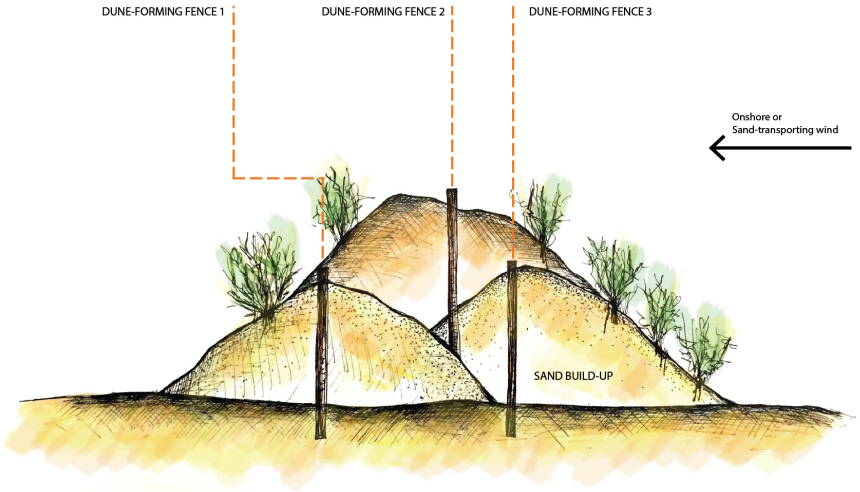

Fig. 15 - Goal of dune fencing method, to be used for non-restricted sand dune accumulation and restoration zone.

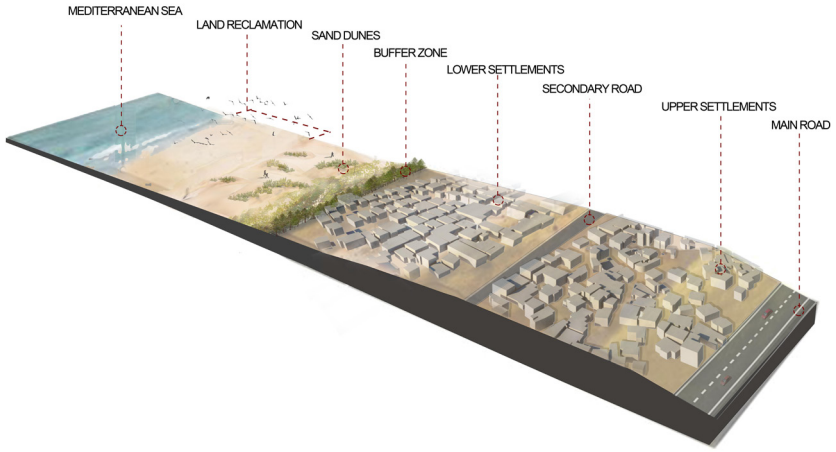

Fig. 16 - 3D representation of proposal vision.

sewage canals and the garbage along the shore, the interaction between the people and the landscape will increase in a safer and more sustainable environment.

Conclusions

Sand dunes are important features of the coastal landscapes since they serve as a buffer against the impacts of wind and sea waves. Stabilised dunes prevent sand from inundating nearby lands and provide a source of sand for the beach. Moreover, coastal sand dunes are valuable natural habitats with important ecosystem services, high amenities and recreational value. Sand dune ecosystems support high biodiversity, their unique conditions providing specialised habitats for rare and endemic species. Dune formation consists of several factors working interdependently to create stable and mobile sands in different zones. Continuous succession and mobility of ecosystem elements renders it sensitive to disturbances such as human activity.

Coastal dunes that once existed in Ouzai, Lebanon, have been completely destroyed. The planned program of reconstruction of the dunes discussed in this paper provides a platform for future restoration projects. In-depth studies of the site's soil types, erosive forces, surrounding disturbances and sources of sand and vegetation should be conducted prior to successful implementation. Reconstruction and management of such habitats is an important initiative, which should be applied to the many different and unique landscapes and ecosystems of Lebanon.

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References

Carmo J. A.D, Reis C. S. & Freitas H., 2006. Successful rehabilitation of a sand dune system. WIT Transactions on Ecology and the Environment: 88: 195-204.

Carmo J. A. D., Reis C. S. & Freitas H., 2009. Rehabilitation of a geotextile-reinforced sand dune. Journal of Coastal Research Sl 256: 282-286.

De Lillis M., Costanzo L. & Bianco P. M., 2004. Sustainability of sand dune restoration along the coast of the Tyrrhenian Sea. Journal of Coastal Conservation 10 (1): 93-100.

Everard M., Jones L. & Watts B., 2010. Have we neglected the societal importance of sand dunes? An ecosystem services perspective. Aquatic Conservation: Marine and Freshwater Ecosystems 20 (4): 476-487.

Hooda V., 2007. Phytoremediation of toxic metals from soil and waste water. Journal of Environmental Biology 28 (2): 367-376.

Kutiel P., 2001. Conservation and management of the Mediterranean coastal sand dunes in Israel. Journal of Coastal Conservation 7 (2): 183-192.

Makhzoumi J., Chmaitelly H. & Lteif C., 2012. Holistic conservation of bio-cultural diversity in coastal Lebanon: A landscape approach. Journal of Marine and Island Cultures 1 (1): 27-37.

MOE/GEF, 2016. Updating the 2002 SAP-BIO National Report for the Country of Lebanon. Prepared by Nader M., and Talhouk S.

MOE/UNDP/ECODIT, 2011. State and Trends of the Lebanese Environment.

Mouterde P.S., 1966-1984. Nouvelle flore du Liban et de la Syrie. Tome I-III. Editions de l'Impr. Catholique, Beyrouth.

Nordstrom K.F. & Jackson N.L., 2013. Foredune restoration in urban settings. In Martinez L.M., Gallego-Fernandez J.B. & Hesp P.A. (Eds.), Restoration of coastal sand dunes: 17-31. Springer-Verlag, Berlin Heidelberg.

Northern Beaches Council, 2016. Rock Platforms. (n.d.). Retrieved August 29, 2016, from http://www.pittwater.nsw.gov.au/environment/coastal/rock_platforms

NSW Department of Land and Water Conservation, 2001. Coastal Dune Management: A Manual of Coastal Dune Management and Rehabilitation Techniques, Coastal Unit, DLWC, Newcastle

Greipsson S., 2002. Coastal Dunes. In Perrow M.R., & Davy A.J. (Eds.), Handbook of Ecological Restoration. Vol. 2: 214-237. Cambridge University Press, Cambridge.