Journal of Innovations in Pharmaceuticals and Biological Sciences
www.jipbs.com

JIPBS

ISSN: 2349-2759

Review article

Biological method in stabilization of sand dunes using the ornamental plants and woody trees: Review article

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Abstract
Sand dunes are considered one of the most obstacles that face the horizontal or vertical expansion of agriculture in the desert. Sand dunes are a collection of a loose grouping of sand on the land surface in the form of a pile with top. In the recent years, increasing attention has been taken to cultivate the timber trees and ornamental plants in a narrow range to combat the desertification, sand encroachment and sand dunes. The climate factors are characterized by high temperature, strong winds laden with sand and sandy dunes, lead to soil erosion and remove the fertility soil in the surface layer, and destroying cultivated lands. Therefore, it's important to planting windbreaks and stabilization sand dunes to reduce the damage and loss of all areas of development aspects. The methods used for combating the sand dunes can be classified into two types; biological methods or plant measure and the second are the mechanical methods or engineering measure. We will focus in this article on the biological methods where the trees, shrubs and grasses are planted. The desert plants should have some criteria. Some successful biological measures were used for combating desertification in different land, such as agricultural areas, highways, railways, roads, cities, industrial factories and mining areas. There are environmental and economic importance of the cultivation of the dunes such as installations and afforestation of sand dunes to maintain the ecological balance and the stability of life, providing employment opportunities and timber production for fuel, or for animals feed.

Key words: Desert plants, Desertification, Afforestation, Petroleum chemicals, Combat.

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1. Introduction

Sand dunes constitute a constraint in urban development and agricultural expansion. Sand dunes are defined as a collection of sand, which is a loose grouping of sand on the surface of the earth in the form of a pile with top. Sand

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dunes formed by erosion, a desert rock interaction with extreme temperatures and wind blowing continued, leading to the dismantling of the rocks and fragmentation to a different size and shape sand granules..

Since pharaonic times mobile sand has been stabilized through plantations, while conversely fields and woodland have been devastated by wind-driven erosion and coverage of sand. This ancient fight between vegetation growth and Aeolian surface mobility has evidently enormous impact on the economy of semi-arid regions, on coastal management and on global ecosystems [1].

Trees, shrubs and ornamental plants are represented permanently important group in windbreaks and play an important role in combat sand dunes. In recent years, increasing attention to the cultivation of timber trees in a narrow space for combating the desertification, sand encroachment, sand dunes and overcome the harmful of climatic changes and protect the environment from pollution, as well as its have a role in addressing the big problems that result from the movement of sand dunes and its threat to the installations of industrial and population, roads and farms, etc.

High temperature, strong winds caused the sandy dunes, which lead to soil erosion and remove the surface layer rich; lead to cover the land and destroying a cultivated area, soil becoming poor in organic matter and nutrients. This prompted many interesting countries to planting windbreaks and stabilization the sand dunes to reduce the desertification, land degradation, particularly in arid and semiarid regions [2,3]. Sand dunes without vegetation can be moved by wind and this process can cause major damage to the landscape [4,5].

Sand dunes and other aeolian forms cover about 17% of the whole Egypt country, while cover approximately 6% of the global land surface area [6].

Morphologically these landforms are subdivided into sand seas (ergs), isolated dunes, dune fields, sandy plains and sheets. At several locations, sand encroachment causes hazards to farmlands, highways, population centers and other infrastructures. Remote sensing techniques could be use effectively to monitor sand dune movements through comparing the multi-temporal satellite images according to [7].

Sand encroachment in Egypt can be classified into two categories:

1. Severe dune migration (> 15 m $year^{-1}$). It occurs in South Al-Bardaweil (North Sinai). It prevails in Central Sinai, east of the Suez Canal, Siwa, Abu Mongar, Farafra, Bahariya and El Rayan.
2. Slight dune migration (< 5 m $year^{-1}$). It occurs on both sides of the Nile Delta, northern coast of the Nile Delta and along [8].

In Egypt, the main constraints for sustainable agricultural in Sinai is, essentially, the migration of sand dunes that occupy about 5000 Km^2 of the coastal zone This adversely affects on the cultivated lands and the newly reclaimed areas. It is subject to sand dune encroachment. The movement of sand dunes causes severe damage to the buildings, roads, irrigation and drainage canals. Migration of aeolian sands results in the migration of longitudinal dunes at a rate of 2.25 m/y for that south of Bir El Abd and 13 m/y at Wadi El Gady [8].

Sand dunes are known to be (1) free of vegetation and active, (2) partly vegetated and active and (3) fully vegetated and fixed. It is customary to conclude that the stabilized sand dunes of the world indicate mobility in the past, probably under more xeric climate regimes [10]. Many geologists and geomorphologists relate the mobility of sand dunes during the Upper Quaternary to an increase in aridity while stability by vegetation occurs during wet phases [11,12]. It is obvious that all fixed dunes were active in the past and became stabilized when their climate changed. Most scientists refer to climate change as a change in rainfall and temperature, which are the two important climate elements that affect vegetation growth [13].

For this reason, it`s expected that sand dunes in hot deserts would be devoid of vegetation and active, while the dunes along the coasts of humid areas would be vegetated and stabilized. However, there are many examples of active sand dunes in humid areas and stabilized dunes in arid areas [14].

Sand dune fixation is designed to prevent the movement of sand long enough to enable either natural or planted vegetation to become established. In the arid and semi arid regions, various species of trees, shrubs and grasses can be used for dune fixation [15]. *Atriplex spp.* and *Acacia spp.* are among the effective plant species used for the control of shifting sand dunes [16].

In El-Shaikh Zuweid (Egypt), [17] used biological fixation of coastal sand dunes (Moghat, Liquorice, Sisal and Opuntia). Ndiaya *et al.* [18] cultivated *Casuarina eqisetifolia* for the control of the coastal sand dunes of Senegal. Moreover, the monitoring of four plant species grown for sand drift control in India showed that, the growth and the survival of such plants were best on the dune crest and leeward slopes [19]. Furthermore, the most popular cultivated plants tolerated the stress conditions under sand dunes in Egypt are: *Acasia saligna, Prosopis pallid* and *Atriplex nummularia* [17,20].

The sand dune fixation has been carried out in the Sahel [21,22] in many areas in the world. In all cases, the use of plastic sheets, plant residues, bitumen, and elemental sulphur, lead to improved chemical properties of dune sand. This was reflected in significant increases in plant height, number of branches, crown cover and crown volume. As a result, the shifting sands were sharply decreased by 47.2 to 96.7% in the stabilized areas. Planting of natural wind breaks/shelter belts, stabilization of sand dunes, minimum tillage, and conservation of rainwater are some of the measures found effective in checking wind erosion. Reduce to advanced erosion and planned performing wind breaking the prevailing winds in the direction perpendicular to wind prevent devastating effects (wood and bamboo curtains (reed), shrubs, fences, rocks, etc.).These measures are extremely effective against wind erosion and to stop sand dune in order the move and keep in the place [23].

It can be classify the methods used to control sandy desert into two types: One is to the extant vegetation on the sand dunes or, where such vegetation has deteriorated, to plant trees, shrubs and grasses. The materials used in this type of method are living. This type is known a biological methods or plant measure for desert control. The second is to set up barriers used in this type are non-living, such as wheat straw, branches of trees, bamboo, reeds, sorghum stalks, clay, cobblestone, petroleum chemicals and so on. This type, called a mechanical methods or engineering measure for desert control.

In this article we will focused only on the biological methods, particularly role of ornamental plants and woody trees in the stabilization of sand dunes.

Biological methods for combating the sand dues

Some successful biological measures were suggested for combating desertification in different land uses such, as agricultural areas, highways, railways, roads, cities, industrial factories and mining areas. Suitable plant species were chosen on the basis of their capabilities in these kinds of harsh environments. Plantation techniques and the seed treatments like sowing, seedling and air seeding were successfully used for protecting the properties of people that are living in the desert areas of China. Shelterbelt systems and practical models for the hilly and flat desert areas are applied [24].

Criteria of desert plants

Desert plants usually call on the plants, which grow in a sandy dune with loose texture or sandy beaches; they include grasses, shrubs and trees. These plants must be able to tolerate rapid sand accumulation, flooding, salt spray, sandblast, wind and water erosion, wide temperature fluctuations, drought, and low nutrient levels. In spite of the severe limits these requirements place on the plant species, plants capable of stabilizing coastal dunes can be established in most coastal regions with enough rainfall to support plant growth [25,26].

The six primary criteria of desert plants include:

1. Cold resistance and heat resistance: Most desert plants such as *Ammopiptanthus mongolicus* could resist severe cold of 25°C and can tolerate over 60°C land temperature and 70°C surface temperature.
2. Strongly favor sunlight: *Atraphaxis bracteata*, *Calligonum caput-medusa* trees grow very well under sand dune desert condition.
3. Sand bury-resistance and wind erosion-resistance: Twigs of many desert plants are buried by moving sand, if the twigs meet water, they can grow adventitious roots, and can grow new plants on the twigs rapidly, such as *Nitraria sp*. Some roots are exposed because of strong wind erosion, and they still grow tenaciously, such as *Haloxylon* and *Calligonum*.
4. Root developed strongly: Main root usually can reach underground water layer, the longest roots are over ten meters. *Haloxylon* plants, main root can reach as 13 meters, *Alhagi sparifolia*, its main root can reach 5 meters deep, such as *Calligonum mongolicum*; its lateral root can reach 25 meters.
5. Drought and barren resistance: When the water content rate no more than 2 % in the sand dune, the nutrition of the soil is a worse desert plant can still grow well, such as *Limonium aureum* can still grow and blossom strongly in 1.68% water content. The endemic plants have mechanisms to adapt the drought conditions [27].
6. Sprout early, the growth period is long: Desert plants usually sprout in early April and blossom in May to July. Desert plants grow more vigorously, after September their growths go down gradually.

It is not suitable to raise seedlings with seeds for desert plant in clay; the most suitable place is in the sand-loam.

Introduction of species in the sand regions

There are four main factors affecting the introduction of desert plants:

1. Zonal, for example, when *Salix goredjeveii* when grow in the steppe area was introduced into the steppe, desert regions, the species can survive and grow because of its roots. On the contrary, the two species *Aryemisia halodendron* and *A. Wandanesis* cannot grow and survive in the dry season and dry year because of their sallow roots. When the desert plants were introduced into steppe or steppe, desert region, some could grow and other could not grow well because of more rainfall than that of the desert region.
2. Temperature especially if we introduced the plants from abroad the temperature should be considered as a major factor.
3. Ecological series: There are four ecological series that are the xeromorphy, hydrophyte, halophyte and psammophyte in the sand regions. *Elaeagnus angustifola* and *Populus euphatic* usually grow in the regions where the ground water available. While we introduce the *species into the san*d reg*ion where no gro*und water is supplied, the species won't grow good *Hedysarum scaparium* and *Caragana korshinskii* are the xeromorphy plants, if we introduce these plants into regions where the grou*nd water level is h*igh, *the roots of these p*lants will be rotted species.
4. Sand dune sector: The sand covering can accelerate the growing of pasmmophyte. However, some plants can resist available sand covering and other have some resist strong sand covering. However, it is important to consider that planted positions of introducing on the sand dunes.

Environmental factors affecting the growth of sand dune desert plants

The success of the fixation is still dependent on several other factors, even with a sufficient supply of planting stock for stabilization sand dunes.

The important affective factors on the distribution of vegetation and growth are [28]:

1. Sufficient soil moisture: is an essential component for the establishment of dune grasses, and the low water holding capacity of sand can cause failure of plantings [29]. However, compensating factors in the dune system such as high water tables often make it possible to work around this problem. Also, dune plants have various specialized adaptations for surviving long periods of low moisture. For these reasons, irrigation of restored sites is not generally worthwhile [25].
2. Salinity concentrations: Salinity is a potential inhibitor to dune plants growth through factors combination of nutritional, toxic and osmotic nature [30].

   Fortunately, the likelihood of salt damage to dune plants is greatly diminished by the rapid leaching of salts from the dune sands. These sands have almost no retentive capacity for salt and only a small amount of rainfall is needed to remove salt from the plant zone. Also, all dune plants are tolerant of moderate salt concentrations and most seeds can withstand salinities as high as full strength sea water [31].

Physical and chemical characteristics of soil such, humidity, salinity and acidity were the effective factors on the habitat homogeny, which control the pattern of plant community's distribution [32].

3. Available nutrients: can also influence the success of the dune grass establishment. Dune sands undergo extensive leaching during accumulation, transport, and deposition of sand grains, leaving them very low in most nutrients essential to growth of plants [29]. Dunes are equally suitable for growing trees, shrubs and crops, but their fertility and high permeability appears to be a limiting factor. Under sand dune stabilization process conditions, nitrogen was the most important plant nutrient required for establishment and rapid early growth of horsetail she-oak seedlings [33]. Increased spinifex growth was obtained by increasing the rate of application of nitrogenous Fertilizer up to 934 kg N ha^{-1} in 5 equal split applications over 15 months [34].

   Under global change scenarios, increased nutrient input could alleviate nutrient stress in *S. virginicus*, enhancing clonal expansion and productivity, but this benefit could be offset by increased sand accretion levels equal or exceeding 100% of plant height. Depletion of stored reserves for emerging from the sand could increase plant vulnerability to other stresses in the long-term. The results emphasize the need to incorporate statistical designs for detecting non-independent effects of multiple changes and adequate spatial replication in future works to anticipate the impact of global change on dune ecosystem functioning [35].

   Experiences have shown that, the selection of plant species and adequate maintenance such as irrigation or fertilization are the key factors of successful transplant vegetation [36].

4. Spacing: Soil moisture, salinity, and fertilization will affect the success of dune grass establishment once the grass has been planted, but there are also certain standards that need to be followed when planting the vegetation. For most species of dune grasses and plants, planting is typically done by hand on small areas and on rough or steep slopes, and by machine on larger, flatter sites [37]. The depth and date of planting vary between geographic regions and among species of dune grasses. In general, the depth is typically 20 to 30 centimeters, and date of planting is dependent upon favorable soil moisture conditions [38]. The spacing and pattern of planting is also important to consider. Spacing that is too close is more costly and wasteful, and spacing that is too wide will usually result in total failure [25]. The spacing and pattern should be determined by the conditions of the site and the objectives of the planting. In general, plants should be spaced about 18 inches apart, and in a strip pattern with 36 inches between rows [39].

Vegetation was destroyed due to different factors in arid and semi-arid areas of sand dune formation and going harmful movement (such as Karapınar-Konya sand dunes). A different plant occurs rarely constantly changing on the dunes as other than shrub or tree. Because, plants cannot be developed at the surface of the dry dunes in the dry season [40]. Wind curtain statement was used to protect to buildings, gardens, fields and other facilities from wind damage for the purpose of the mechanical and plants were used all kinds of obstacles. The young vegetation disappeared without forming vegetation without creating any blocking effect of wind moving through the sand dunes planted. Therefore, vegetation grown the direction perpendicular to the wind one side by cutting the material to keep the speed, on the other hand prevents further removal of material [41].

Plant growth and development are control by internal regulators, which are modified according to environmental conditions [42]. The most ecologically important environmental factors affecting rangeland plants growth and distribution are topography (slope, aspect, and elevation) and soil properties [43]. Thus, according to the role of plant on the equilibrium of ecosystem and human interest, the relation between vegetation and environmental factors for stability and sustainability is vital, showed that the vegetation distribution and establishment of plant communities depended on the soil and climate variable [44, 45], the altitude, slope, soil texture and depth [46].

The relationship between environmental factors and distribution of plant studies indicated that slope, altitude, texture, depth of soil and nitrogen had a high effect on the distribution of species [47]. As regards the plants, existence in different region is due to environmental factors and some of these factors had higher effect on the plants existence in an area, and effective factors on plant distribution.

Species selection

Natural conditions in various desert areas are quite different and they are a key to select suitable species based on local conditions. Plants should be preferred suitable for dry and wind-resistant deep-rooted fast-growing, branching from the bottom of a certain size and long-lasting ones which wood pitch for the establishment of the selected trees and shrubs of the region's climate and soil characteristics [48]. When selecting suitable species, the following items should be taken into consideration:

1) Selecting the species which grow well from nearby area; 2) Selecting local species; 3) Selecting the species with high economic values; 4) Selecting the species that are strong in sand fixing; and 5) In other places, vegetation was removed from dunes as a result of over-grazing and cutting. In these cases, the reverse of the stabilization process took place, in which sand-shifting increased. There are researchers who understand this destruction process as part of the desertification process [49,50].

This process too causes changes in the natural landscape and affected in species selection. So, we have been selecting the species that have rapid growth for over grazing and cutting.

In various places in the world, great efforts have been made to stabilize coastal dunes and sand dune of desert in particular and fore dunes in general. In most cases exotic species were used, such as the Australian acacia (*Acacia saligna* and *A. cyclop*), various species of tamarisk, pine, and perennial grasses, such as maritime grass (*Ammophilla arenaria*) [36]. These plants are rapid growers, have low demands on their habitats, and are able to cope with high-speed wind regimes and seawater spray close to the coast, as well as the harsh conditions typical of sand. Over time, some of these plants have expanded and covered broad areas, thereby, stabilizing the sand and modifying the landscape in both geomorphic and biological sense. In many cases this has caused nature conservation problems [51,52].

Recently, tree and shrub plantings have been applied to control shifting sand [53,54]. For example: *Populus euphratica, Populus alba, Callegonum spp, Tamaix spp Artemisia arenaria, Zygophllum xanthoxylum, Atraphaxis bracteates* ect. These species, selected from practical experience through many years have relatively, strong adaptive faculty and have been utilized in desert areas. The *Populus euphratica* tree grows on the sand dunes that surround certain wells at the western stretches of Siwa (Egypt) Oasis [55] and had been introduced to Siwa Oasis to fix the sand dunes during the Alexander the Great Period [56].

Famous plants which used in the stabilization of sand dunes are Deciduous (Table 1)

1. Trees (*Taxodium distichum, Quercus alba and Quercus robur*).
2. Evergreen trees (*Pinus mugo, Juniperus chinensis and Juniperus horizontalis*).
3. Shrubs (*Caragana arborescens, C. fruticosa, Hydrangea spp., Rhus glabra, Rhus typhina and Rhus aromatica*).
4. Herbs (*Helianthus sp, Methiola incana, Vinca rosa and Limonium latitolium*).
5. Others Species plants (*Tamarix aphylla, Prosopis juliflora, Acacia saligna* and *Atriplex nummularia*).

Table 1: Suitable plant species for different desert types desert [24].

Location	*Suitable Species*
Desert	*Populus euphratica, Populus alba var. pyramidalis, Populus gansuensis, Reaumuria soongorica, Elaeagnus angustifolia, Caragana korshinskii, Hedysarum scoparium, Haloxylon ammondendron, Calligonum sp, Tamarix spp. Artemisia arenaria, Zygophyllum xanthoxylum and Atraphaxis bracteata.*
Sand dunes	*Haloxylon ammodendron Bge., Tamarix ramosissima Ledeb., Hedysarum scoparium Fisch.et Mey., Caragana korshinskii Kom, Calligonum arborescens Litv., C. caput medusa Schrenk and C. mongolicum Turcz.*
Arid area	*Haloxylon ammodendron, Hedysarum scoparium Caragana korshinskii.*
Semi arid area	*Salix matsudana, Populus canadensis, P. simonii, P. nigra var. italica, P. alba var. pyramidalis and P. nigra var. thevestina.*

Environmental and economic importance of dunes cultivation

Rapid population growth is an important driving force to increase the pressure on the land resource, because a larger population must induce more activities for needs of life [57]. In the last 50 years, the population in this zone has doubled. The available cropland per capita and rangeland per sheep unit has decreased by a factor of three. A series of unwise activities, such as overgrazing, over the expansion of cropland, abuse of water resource, removal of shrubs and trees for fuel wood gathering, etc., has caused wide spreading of desertification. Urbanization, traffic infrastructure construction, mine exploitation, as well as recreation, have also disturbed the land and the vegetation. Installations and afforestation of sand dunes of the most important factors that maintain the ecological balance and the stability of life in these areas, and contribute to providing employment opportunities for citizens as a factor of the limiting factors of desertification, and contribute to providing employment opportunities for the citizens living in these areas and timber production for fuel, some industries and securities which can be used as feed for animals such as leaves *Acacia sjanovila* and other leads to economic growth and social development in these areas generally.

Environmental benefits

The environmental benefits of using the biological methods for combating the sand dunes is the stability of the soil surface which becomes suitable for the cultivation and growth of trees which leads to the development of environmental and improve soil properties, according to the accumulation of leaves and twigs of deciduous trees, plants and organic materials, which in turn activate objects microbiological existing soil *Cabactrella rizbayoum.*

The economic benefits

The installation process and repel wind does not stop for the importance of the installation process on the preventive side only, but goes beyond that to include what can be supplied from production directly and indirectly in terms of

A. Providing grazing areas or supplemental feed sources.
B. Wood production (fuel industries) of economic value.
C. Contribute to raisimg the rates of productivity in agricultural areas that are protected from the wind and sand.
D. Limit the degradation of areas of new production from the impact of the movement of sand creeping and must focus on the need to build a sustainable policy in the afforestation of sand dunes and species selection multipurpose. In this, regards [58] reported that trees and forests had a role in increasing food security and reducing poverty is gaining recognition. A large proportion of the dry land inhabitants depend on forests for subsistence or income. They use trees, in natural forests or on the farm, to generate food or cash. In the absence of trees, the harsh environmental factors of wind and water runoff become strong forces eroding the soil. Hence, land degradation, productivity decline, per capita grain production decline and the increase in poverty level as well as an increasing number of people living in extreme poverty are becoming frequent.

Elsiddig *et al.* [59, 60] reviewed the literature on shelterbelt influences, design and related it to conditions in Sudan. They have emphasized the benefits in terms of amelioration of the environment, savings of irrigation water and enhanced crop production that would result from the more widespread local use of shelterbelts. Strong opinions, which are not always well founded, are frequently expressed concerning a number of drawbacks attributable to shelterbelts.

The potential benefits of shelterbelts

Irrigated forest plantations in the form of shelterbelts or woodlots under Gezira conditions are competitive with agricultural crops and are important in meeting essential needs and national objectives [61]. The non-wood values in the form of reducing rural depopulation, creation of the jobs, amenity, environmental and crop protection, saving of irrigation water and increasing of agricultural yields are appreciable. They have not been included in the financial analysis. Efforts should be made to include these non-wood benefits in future assessments of profitability, as they will definitely boost them greatly [62,63,64].

Biological Dune Fixation Operations

The first step in stabilizing dunes is temporary stabilization by any material that stops surface sand movement. The second step is biological stabilization, which consists of establishing a permanent vegetative cover [65]. That is no easy task because of the character of the soils and because the winds tend to uproot young plants or bury them with drifting sand. Temporary stabilization of the soils is necessary in order to protect young plants until they become sufficiently large to maintain themselves against the drifting sand.

Over the years, a variety of measures have been used effectively to build up, and to stabilize dunes, or to prevent the erosion of dunes and beaches. Devices that have been effectively implemented to trap the aeolian sand are fences, nylon nets, and rugged materials [66, 67].

Once the dunes have been stabilized, they can then be fixed definitively by installing perennial grassy and woody vegetation (figure 1). For each planting season, planting and restocking start as soon as the first rains fall. The ideal is to plant as soon as the new and residual soil moisture meet, which takes place a few days after a good rain. A well-moistened soil means that the time taken in planting is reduced to a minimum and the seedlings take root well, thus reducing the planting costs per hectare. In the case of insufficient rainfall, supplementary water must give to each seedling in order to make up for the depth of residual moisture. The positioning of species on the ground is a very important factor for successful planting.

Plantation Phase: Based on previous experience of local sand dune stabilization, the planting strategy of the scheme depended on the following factors:

A. Irrigation of trees and shrubs by fresh, brackish and/or salinity water. The water is pumped from a main drain close to the plantation site;
B. Reduction of the rates of drifting sand through biological dune fixation. Among the ten plant species, *Tamarix aphylla, Prosopis juliflora, Acacia saligna* and *Atriplex nummularia* show high rates of growth and significant survival rates [8].

Sand dunes formed through fencing are unstable and can become deteriorated rapidly. The most common practice is to stabilize them by vegetation [68]. However, the dunes close to the coastline are in a very harsh environment for the plants. Limited amounts of fresh water, constant salt spray, sand blasting or burial caused by the wind, and additional disturbance due to human activities, all these can be hostile to the vegetation. In this way, not only can the dunes be stabilized by vegetation, they can also be attractive habitats for some shore-dwelling animals [69].

Purposes and practical applications of the process of stabilization of sand dunes

Establishing shelterbelts as a part of dune fixation Shelterbelts for farmland Definition

An artificial forest comprising of belts to protect farmland is called shelterbelt for farmland. In addition, all shelterbelts, which are planted along the roads in farmland, river banks, ditches and the fringes of deserts close to the farmland, are also included in the same category each shelterbelt for farmland is called a protective Frostbelt, or a forest belt. The forest belts, which crisscross each other, are called networks of shelterbelts for farmland or network of forests. The purpose of the shelterbelts for farmland:-

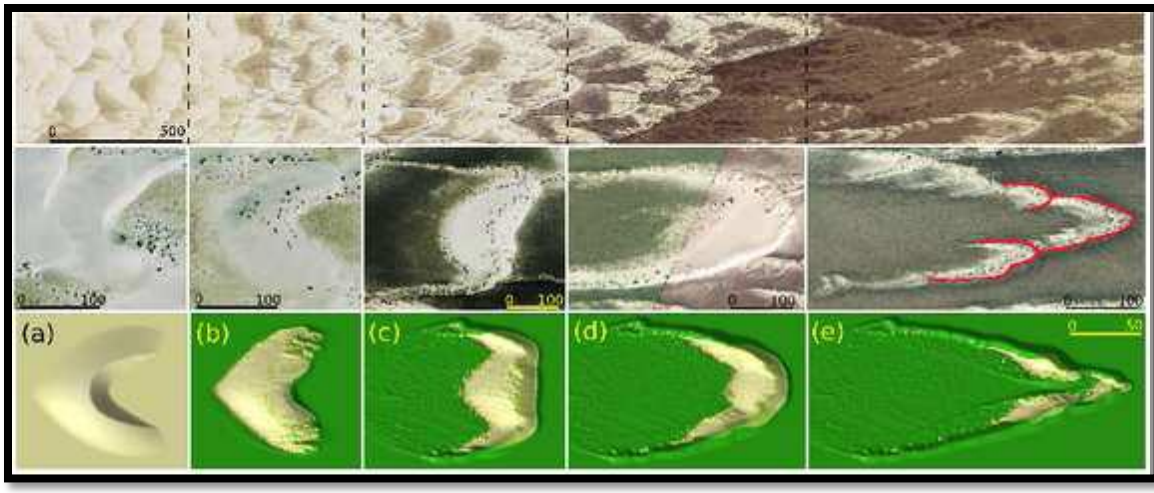

Figure 1. Deactivation of migrating dunes under the influence of vegetation. On top, a dune field in White Sand, New Mexico that shows barchanoid ridges on the left, where vegetation is absent, developing towards a mixture of active and inactive parabolic dunes on the right (wind blows from left to right). Dark green regions indicate abundance of vegetation. This suggests a transition between both types of dunes when the vegetation cover increases. This transition is illustrated with various dune types found in the White Sand dune field (pictures in the middle), reinforcing the idea of their common evolution from a crescent dune. Satellite images taken from Google Earth. Below, same transition obtained by the numerical solution of a model that accounts for the coupling between sand transport and vegetation, with fixation index _ = 0.22. The vegetation cover is represented in green (grey) [1].

The main purpose of the shelterbelts for farmland is to protect farming crops from natural disasters, particularly from the meteorological disasters, and to improve the farming eco-environmental conditions.

The establishments of shelterbelts for farmland not only declines blown sand encroachment, such as sand beating, cutting and piling in the farmland, but also to improve the quality of the whole environment and to increase the productivity in the oases and farmland.

Desert control and afforestation

Desert control and afforestation are the two elements of interaction. Before planting trees on sand dunes, the mobile sand dune must be fixed. At present there are many measures for desert control and the main ones are clay barrier, wheat-straw barrier, barriers made with gravel and oil felt rug, mechanical and chemical measures, such as petroleum emulsion, etc. The details will not be discussed in this article.

Research on the characteristics and sheltering effectiveness of shelterbelts and forests is quite limited. Recent review papers on shelterbelt modeling [70] and worldwide applications of shelterbelts [71] make no mention of coastal applications.

Zhu *et al.* [72] provide a model for winds within a coastal forest canopy, windbreaks consisting of shelterbelts (one or two rows of trees) and forest belts (multiple rows) are commonly used (figure 2) at inland locations as natural barriers to reduce wind speed, modify the microclimates of small regions and suppress the movement of snow, pollen, dust, sand and odors. They are most widely used in agriculture in regions of high wind speed such as Australia, New Zealand, the Russian Federation, China and the Great Plains of the United States. Therefore, the methods used and results derived from studies of agricultural shelterbelts can be applied to coastal shelterbelts and forests as well. In this section, we discuss the knowledge base on shelterbelt design and application as it has been established through research on agricultural shelterbelts.

Figure 2. Wind-breaking trees bands and stripped cultivation method applied way in the agriculture land [73].

In regions where the annual precipitation is over 200 mm, bushes and herbs can be planted to further improve the windbreak and sand dune fixation qualities. After establishment, the straw gradual laid rots to become soil organic matter. Scientists devised this technique in 1957 [74]. It is widely used for dune fixation in arid and semi-arid regions of China [75]. It is used to prevent the burial of the railway and highway by sand.

Afforestation on sand dunes

At present, the annual species such as *Halaxylon ammodendron calliganum spp*, *Atraphaxis bracteata*, *Nitraria tangutorum*, *Artemisia arenaria* etc. are used for sand dune afforestation. Before afforestation, sand barriers need to be set up to stabilize the shifting sand.

In order to make the afforestation play its role of sand stabilization as soon as possible, trees can be planted with a density of 2m x 2m (spaces between plants and rows).

The planting site should be about 50-60 cm for away from the lee side of barriers and no tree is allowed to be planted in the centre of the barriers.

Generally, dig holes to plant trees. When digging holes, move the dry sand on the surface firstly, then dig the hole, putting the wet sand from the hole beside it for later use. The trees should be planted as deep as that 5 cm of root system has been covered and with the root system unfolding. The wet sand (no dry sand is allowed to be filled in the hole) to fill the hole needs to be pressed tightly. If the seedlings are too big, some branches can be cut to reduce moisture loss from seedlings. No irrigation is needed in those areas where the rainfall is plentiful or where the moisture in the sand is sufficient. But, for those areas where the moisture is insufficient, about 5-10 kg of water is needed for every hole. After infiltration, cover the surface with a layer of dry sand to prevent the moisture from evaporation. In those areas where the layer of dry sand is too thick and the moisture in the sand is insufficient, it's not suitable to plant trees.

Afforestation in the depressions among sand dunes

The depressions among sand dunes are the relatively smooth places. In the areas where the water for irrigation is available and the soil is clay, arbour can be planted with a density of 3 x 3m for timber production.

In the areas where there's no available water for irrigation, it's suitable to plant some drought resistance arbour trees, such as *Caragana korshinski, Hedysarum scaparium, Tamarix spp. And Nitriria tanutorum* ect. The density is 2m x 2m, 2m x 3m or 3m x 3m after planting, water the trees (8-10 kg of water in every hole).

Some successful models which have been employed are shelter forest system (Model Biosphere):

The land uses that are suffering most from desertification are agricultural areas, highways, railways, roads, cities, industrial places and mining areas. The important plant species used for combating desertification and moving of sand dunes are *Hedysarum laeve, H. scoparium*, *Amorpha fruticosa*, *Lespedeza bicolor*, *Caragara microphylla*, *C. korshinskii, Artemisia halodendron*, *A. sphaerocephala*, *Astragalus adsurgens*, *Ulmus pumila*, *Hippophae rhamnoides, Haloxylon ammodendron*, *Calligonum mongolicum* [24]. *Elaeagnus sp., Fraxinus sp. Robinia pseudeaccucia,* etc.), which dry and hot-resistant plants were selected plantations [48].

Transplanted seedlings, direct sowing, use of cutting, and air seeding techniques were used for greening areas degraded by wind and water erosion. Different models have been applied for protecting agricultural areas, cities, highways, railways and roads, industrial or mining and reservoir properties. As soon as the dune is stabilized and moving sand is suppressed, seedlings of woody perennials such as shrubs and trees may be introduced. Establishing the shelterbelt on dunes or protective dykes serves multiple purposes [76].

There are some successful models which have been employed are shelter forest system in oases, shelter system for sand fixation in agricultural areas, transportation, industrial or mining and reservoir properties [24]. Also [77] revealed that, there are generally three major types of severely decertified land. Each different type has its own cause of desertification and characteristic fragilities, and needs a specific model for transformation. In the regions where sand dunes are densely distributed, desertification reversion is very difficult to achieve. Through several years of experiments and demonstration services an eco-model named ‘small biosphere’ was developed, which can promote the above-mentioned theoretic approach to be realized (figure 3).

The small biosphere model consists of three small circular zones. The ‘core zone’ is arranged in the center part, occupying about 1 to 4 ha of wetland, equipped with one or two wells and pumps for irrigation in drought season and cultivated with productive crops such as wheat, maize, rice and fodder crops. It is used for food and fodder production. The out-fringe of the core zone is a ‘protective zone’, covering about 10 to 20 ha of sandy land or sand dunes, where shelterbelts and windbreaks are planted, and some psammophytic shrubs planted for fuel materials as well as for sand control. The houses and the animal yard are also arranged in the protective zone [57]. Outside of it is a circular shaped 'buffer zone', occupying about 100 to 200 ha of sandy land or dunes. As a transitional belt between the protected zone and the bare drifting dunes, this buffer zone is used for light grazing, allowing 0.2 to 0.3 sheep units in one ha, or even forbidding grazing in the beginning of the small biosphere construction for vegetation establishment and to reduce the movement of sand. With the increase in crop and fodder production in the core zone the stocking rate on the surrounding sandy rangeland can be decreased gradually. This model can both reduce poverty and protect vegetation. Each small biosphere is managed by one family, which consists of 4 to 6 people. This way the income of the family has increased from less than 5,000 RMB yuan to more than 40,000 yuan in 5 years; the rangeland resource has been restored and the environment improved [78].

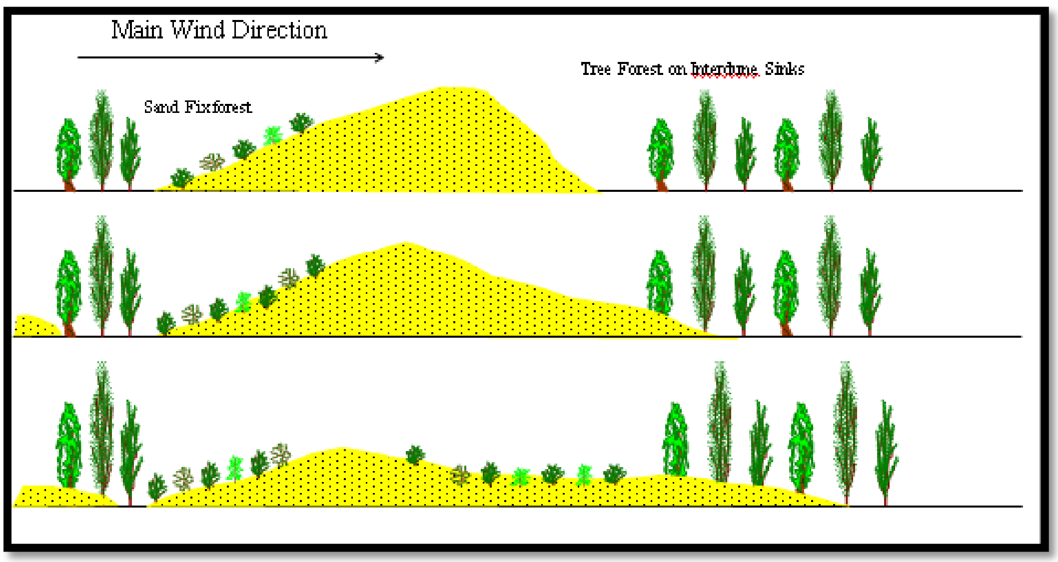

Figure 3. Blocking Shifting Sang Dunes at Front and Dragging at back in Wushenqi [24].

References

1. Mahsud, MA J, Khan A, Hussain J. Hematological changes in tobacco using type 2 diabetic patients. Gomal. J Med Sci. 2010; 8:8-11.
2. Duran O, Herrmann HJ. Vegetation against dune mobility. Phys. Rev; Let., 2006, 97, 188001.
3. Wang T, Wu W. Combating desertification in China. In: Proceedings of the International Symposium, New Technologies to Combat Desertification. Tehran, Iran., 1998, 1:49–64.
4. Wang HJ. West Development and Ecological Construction. Beijing. China Forestry Publishing Houses, 2001, 17-26.
5. Pakparvar M. Desert research and control desertification in Iran. In: Proceedings of the International Symposium, New Technologies to Combat Desertification. Tehran, Iran, 1998, 1:25–34
6. Xia XC, Fan SY. Research progress of desert science in China. Chinese Sci. Bull., 2000, 45(24): 2209–2213.

7. Pye K, Tsoar H. Aeolian Sands and Sand Dunes. Springer-Verlag, Berlin- Heidel burg, 2009.
8. Islam AEM, Osman H, Sayed A. Quantification of Sand Dune Movements in the South Western Part of Egypt, Using Remotely Sensed Data and GIS. J. Geographic Inf. Syst.2013, 5: 498-508
9. Misak RF, Draz MY. Sand drift control of selected coastal and desert dunes in Egypt: case studies. J. Arid Environ., 1997, 35:17–28.
10. Philip G, Attia OEA, Draz MY, El Banna MS. Dynamics of sand dunes movement and their environmental impacts on the reclamation area in NW Sinai, Egypt, Proc. of the 7th Conf. Geology of Sinai for Development Ismailian, 2004, 169-180.
11. Tsoar H. Sand dunes mobility and stability in relation to climate. Physica A: Statistical Mechanics and its Applications, 2005, 357(1): 50-56
12. Magaritz MY. Enzel, Clim. Change, 1990,16:307.
13. Arbogast AF, Packman SC. Middle-Holocene mobilization of aeolion sand in western upper Michigan and the potential relationship with climate and fire. Holocene, 2004, 14:464-471.
14. Houghton JT (Eds.). Climate Change. The Scientific Basis, Cambridge University Press, Cambridge, 2001.
15. Tsoar H, Moller JT. In: W.G. Nickling (Ed.), Aeolian Geomorphology, Allen and Unwin, Boston, 75, 1986.
16. Kaul RN. A forestation of dune area. In: Sand dune stabilization, shelterbelts and afforestation in the dry zones. FAO Conservation Gudie, 1985, 10:75- 85.
17. Draz MY, Ahmed AM, Afify MY. Studies on sand encroachment in Siwa Oasis, Western desert, Egypt. II- Feasibility of sand dune fixation measures. J. Eng. and Appl. Sci., 1992, 39 (4):723 – 725.
18. Gad MRM. Environmental conditions affecting the growth of plants used for the stabilization of sand dunes (Siwa Oasis, Case Study). M.Sc. Thesis in Environmental Science. Environmental Studies and Research, Ain-Shams Univ. Egypt, 1999.
19. Ndiaya P, Mailly D, Pineau M, Hank AM. Growth and yield of *Casuarina equistifolia* plantations on the coastal sand dunes of Senegal as a function of microtopography. Forest Ecol. and Manage., 1993, 56:13- 28.
20. Kumar S, Shankaranarayan KA. Aerial seeding on sand dunes:seedling survival and growth. J. Tropical Forestry, 1988, 4 (2): 124- 134.
21. Draz MY, El-Maghraby SE. Impact of different plant species on the properties of dune sand soil in Siwa Oasis (Western Desert, Egypt). Egypt. J. Appl. Sci., 1997, 12 (3) 308-317.
22. El Maghraby SE, Draz M, Wassifi MM. Chemical, mechanical and Biological stabilization of Siwa Dune and Its relation to soil conditioners. University of Hohenheim; Centre for Agriculture in the Tropics and Subtropics in Wind erosion in West Africa, 1986, 181-190.
23. Gupta JP, Rama P. Wind erosion and it control in hot arid areas of Rajasthan, India In Buerkert, B. Allison, BE, MV Oppen (Ed). Proceedings of International symposium. "Wind erosion" in West Africa.The problem and its control. University of Hohenheim, 5-7th December 1994. Margraf Verlag, Weikersheim, Germany, 1996.
24. Anonymous. Çölleşme ile Mücadelede Türkiye Ulusal Eylem Programı. T.C. Çevre ve Orman Bakanlığı. Ankara, 2005.
25. Heshmati AGA. Biological Models for Protecting Different Land Use in Arid Areas China. J. Rangeland Sci., 2011, (1): 2.
26. Woodhouse WW Jr (1978). Dune Building and Stabilization with Vegetation. U.S. Army Corp of Engineers, 3: 9-104.
27. Olafson A. Stabilization of coastal dunes with vegetation. Restoration and Reclamation Rev., 1997, 2 (5) 1-7.
28. Gad MRM, El-Hadidy MEA, El-Nabarawy AAA (2012). Comparative study on the adaptation of some natural plants grown under macronutrients limitation at North

Sinai sand dunes (Egypt). Ann. Agric. Sci. 57:81-90.

29. Seyedeh ME, Gholamali H, Reza T. Effect of some environmental factors on plant distribution using LFA method (Case study: Valuyeh summer rangeland of Mazandaran province). J. Bio. and Env. Sci., 2015, 6 (1): 62-68.
30. Chapman VJ. Coastal Vegetation. 2nd Ed. Pergamon Press. Oxford, England,1976, 150-217.
31. Cordazzo CV. Effects of salinity on seed germination, seedling growth and survival of *Spanina ciliata* Brong.). Acta boI. Bras., 1999, 13(3): 317-322.
32. Seneca ED. Germination Response to Temperature and Salinity of Four Dune Grasses From the Outer Banks of North Carolina. Ecology,1968, 50 (1): 45-53.
33. Yibing Q. Impact of habitat heterogeneity on plant community pattern in Gurbantunggut Desert. Geographical Sci., 2008, 14:447-455.
34. Rouhipour H. Investigation of crop production in stabilized sand dune using amb layer associate with drip irrigation System. Sociedade & Natureza, Uberlândia, Special Issue, 2005, 615-627.
35. McKenzie JB, Barr DA. Research in southern Queensland into management of coastal sand dunes. 17th Intern. Coastal Eng Conf. Sydney. 1980, https://icce-ojs-tamu.tdl.org/icce/index.php/icce/article/viewFile/3517/3198
36. Frosini S, Lardicci C, Balestri E. Global change and response of Coastal Dune plants to the combined effects of increased sand accretion (Burial) and nutrient availability. PLoS One, 2012, 7(10).
37. Nordstrom KF. Beach and Dune restoration. Cambridge University Press, New York, 2008, 200pp,
38. Wilcock F. The formation and erosion of sand dunes. In: Young R (ed) Planning for the use of Irish sand dune systems. Conference Proceedings, An Faras Forbatha, Wexford, 1977, P.145
39. Hawk VB, Curtis SW. Sand Dune Stabilization Along the North Atlantic Coast. J. Soil and Water Conservation, 1967, 22(4):143-146.
40. Zak JM. Sand dune erosion control at Provincetown, Massachusetts. J. Soil and Water Conservation, 1965, 4:188-189.
41. Çetik R. Vejetasyon Bilimi, Ülkemiz Matbaası. Ankara, 1973, No. 103.
42. Akalan I. Toprak ve Su Muhafazası. Ankara Üniv. Ziraat Fak. Yayın. Ankara, No: 532, 1974.
43. Manske L. Effects from environmental factors of light, temperature, and precipitation on range plants in the Dickinson, North Dakota, Region. NDSU Dickinson Research Extension Centre. Range Research Report DREC Dickinson, 1997, 11-14.
44. Jafari Z, Chahouki M, Tavili A, Azarnivand H, Zahedi AG. Effective environmental factors in the distribution of vegetation types in Poshtkouh rangelands of Yazd province (Iran). J. Arid Environ., 2004, 56: 627-641.
45. Eldridge D J, Tozer ME. Environmental factors relating to the distribution of *Terricolou sbryophytes* and lichens in semi-arid eastern Australia. The Bryologist, 1997,100: 28-39.
46. Jin-Tun Z. A study on relation of vegetation, climate and soil in shanxi province. J. Plant Ecol.,2002, 162: 23-31.
47. Moradi H, Asri Y, Kashipazba M. A survey of some ecological factors of plant association in Baghshad region. J. Rangeland, 2008, 2:225-236.
48. Armaki M. A., A. Jahani, H. Goshtasb. Investigation of environmental effective factors to distribution of *Salvia officinalis* (Case study: Ghohroud watershed in Kashan, Iran). J. Bio. & Env. Sci., 2015, 7 (1): 113-119, 2015.
49. Acar R, Dursun S. Vegetative methods to prevent wind erosion in Central Anatolia region. Int. J. Sustainable Water & Environ. Syst., 2010, 1: 25-28.
50. Kumar M, Bhandary MM. Impact of human activities on the pattern and process of sand dune vegetation in the Rajasthan

desert. Desertification Bull., 1993, 22:45–54.

51. Barth HJ. Desertification in the eastern province of Saudi Arabia. Arid Environ., 1999, 43: 399–410.
52. Witkowski ETF. Growth and competition between seedlings of *Protea repens* (L.) L. and the alien invasive, *Acacia saligna* (Labill.) Wendle. in relation to nutrient availability. Function. Ecol., 1991, 5:101-110.
53. Barrere P. Dynamics and management of the coastal dunes of the Landes. Gascony, France. In: Carter, RWG, Curtis, TGF, Skeffington MJS (Eds.), Coastal Dunes. Balkema, Rotterdam, Brookfield, 1992, 25–33
54. Zhao HL, Zhao XY, Zhang TH, Wu W. Desertification Processes and its Restoration Mechanisms in the Horqin Sand Land. China Ocean Press, Beijing (In Chinese), 2004, 202-205.
55. Zhao HL, Zhou RL, Su YZ, Zhang H, Zhao LY, Drake S. Shrub facilitation of desert land restoration in the Horqin Sand Land of Inner Mongolia. Ecol. Eng., 2007, 3:1–8.
56. Abd Elghani MM, Fawzy AM. Plant diversity around springs and wells in five oases of the Western Desert, Egypt. Int. J. Agri. & Biol., 1996, 8 (2) 249–255.
57. Zahran MA. On the ecology of Siwa Oasis, Egypt. Egypt. J. Bot., 1972, 15: 223–42
58. Liu X, Zhao XY. Transformation of decertified land in the Grazing-farming interlaced belt of Northern China. Institute of Desert Research, Chinese Academy of Sciences, Lanzhou. RALA Report No. 200, 2000.
59. Talaat DA, Diab IE. Environment and Desert Research Institute, National Center for Research Shelterbelts for Dry Land Development of Sudan. J. Forest Prod. and Industries, 2014, 3(3):118-123.
60. Elsiddig EA, Abdel Magid TD, Mohamed AG. Forest Plantations/Woodlots in the Eastern and North-Eastern African countries of Kenya, Tanzania, Uganda, Burundi, Rwanda, Ethiopia and Sudan. Sudan Report. African Forum for Forestry, 2011.
61. Elshiekh, HKO. Shelterbelt effects on soil temperature and moisture in the River Nile State – Sudan. MSc Thesis, Desertification and Desert Cultivation Studies Institute, University of Khartoum, 2010, 14-16.
62. Ali GE. Economic of irrigated plantations in Gezira province, Sudan FNC and FAO, Fuelwood Development for Energy in Sudan, 1986, 265.
63. Bayoumi A. Renewable natural resources management and desertification in Sudan. Sudan J. Desertification, 1985, (2): 1- 4.
64. Bayoumi AM, El Houri AE, Badi KH, Abd Elmagid TD. A century of Sudanese Forestry. A book prepared by FNC and Arab Organization for Agric. Development, 2001,(In Arabic).
65. Gafaar A. Forest plantations and woodlots in Sudan. African Forum for Forestry, 2011, P.16.
66. Troeh FR, Hobbs JA, Donahue RL. Soil and water conservation for productivity and environmental protection. 3rd ed. Prentice Hall: NJ, USA, 199; 115–125.
67. Neves LD, Gomes FV, Lopes MDL. Coastal erosion control using sand-filled geotextile containers: a case study from the NW coast of Portugal. Coastal Eng., 2004, 1(4): 3852–3864.
68. Hotta S, Harika S. State-of-the-art in Japan on controlling wind-blown sand on beaches. Proc. 32nd Conf. on Coastal Engineering, Shanghai, China, 2010, pp. 1-13.
69. Khalil SM. The Use of Sand Fences in Barrier Island Restoration: Experience on the Louisiana Coast. ERDC TN-SWWRP-08-4. U.S. Army Engineer Research and Development Center, Vicksburg, MS., 2008
70. Wei PH, John ZY. Sand dune restoration experiments at Bei-Men Coast, Taiwan. Ecol. Eng., 2014, 73:409–420
71. Wang HJ, Takl ES, Shen J. Shelterbelts and windbreaks: mathematical modeling and computer simulation of turbulent flows. Ann. Rev. Fluid., 2001, 33:549-586.
72. Brandle JR, Hodges l, Wight B. Windbreak practices. In: H.E. Garrett, WJ Reitveld & RF Fisher, eds. North American

agroforestry: an integrated science and practice. Madison, WI, American Society of Agronomy, Inc. 402, 2000.

73. Zhu JJ, Gonda Y, Matsuzaki T, Yamamoto M. Modeling relative wind speed by optical stratification porosity within the canopy of a coastal protective forest at different stem densities. Silva Fennica, 2003, 37:189–204.
74. Anonymous, Yeşeren Çöl Karap ınar. Köyhizmetleri Genel Müd.Yayın No:7.Ankara. In: Acar and Dursun [48].
75. Liu Y. Establishment and effect of a protective system along the Bautou–Lanzhou railway in the Shapotou sandy area. J. Desert Res., 1987, 7 (4): 1-11.
76. Maki T. Pictures of Food, Environmental, and Agricultural Issues in China. Tsukuba Press, Tsukuba, Japan, 174, 1999.
77. Yizhaq H, Ashkenazy Y, Tsoar H. Sand dune dynamics and climate change: A modeling approach. A modeling approach. J. Geophys. Res., 2009, 114, F01023, doi:10.1029/2008JF001138.
78. Liu X. Anti-desertification strategy and ecological model of water saving plantation of rice on the sandy land in the interlacing agro-pastoral region. J. Desert Res., 1995,15:1–6.
79. Xinmin L, Xyue-yong Z. Transformation of desertified land in the Grazing-farming interlaced belt of Northern China. Ala Report No. 200, 2002. http://www.smhric.org/SMW_content12.htm.