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ECOLOGICAL MANAGEMENT AND RESTORATION OF DISTURBED AREAS IN THE MEDITERRANEAN: A CASE STUDY OF SALIX DIVERSITY

ALEXANDRA D. SOLOMOU[1*], RAFAILIA GERMANI[2], PANAGIOTIS MICHOPOYLOS[1], KONSTANTINIA TSAGARI[1], GEORGE KARETSOS[1]

[1]Hellenic Agricultural Organization "DEMETER", Institute of Mediterranean and Forest Ecosystems, Terma Alkmanos, Ilisia, 11528, Athens, Greece.

*E-mail: alexansolomou@gmail.com (Corresponding author).

[2]Department of Agriculture, Crop Production and Rural Environment, University of Thessaly, Fytokou str., N. Ionia, 384 46, Volos.

ABSTRACT

This paper reviews the distribution, biodiversity and ecological significance of the *Salix* species in restoring disturbed environments in the Mediterranean basin. These plant species have important attributes such as: tolerance to heat, drought and impoverished soils. Moreover, *Salix* species are common primarily plants that are able to thrive on degraded sites, industrial spoils, mine and gravel pits, peatlands, overburdens, quarries and highly eroded soils. Conclusively, they can be employed in an array of ecotechnological projects to alleviate environmental degradation, to control cycling of nutrients and contaminants, and to provide value-added products.

Keywords: Landscape, environment, phytoremediation, reclamation, willow.

INTRODUCTION

The Mediterranean region extends along approximately 3800 km from east to west, from the coastline of Portugal to Lebanon, and about 1000 km from north to south, from Italy to Morocco and Libya [1]. The comprehension of "Mediterranean Area" can be perceived through two distinct perspectives: The geographical approach defines the area as a group of land, which surround the Mediterranean sea. On the other hand, the biogeographical approach considering so climatic and geological conditions, as the distribution of plant species, defining a region whose boundaries are different from those posed by geographical approach, however much more homogeneous (Figure 1) [2,3].

The Mediterranean climate is characterized by a sharp seasonality of temperature and precipitation. In general, summers are warm and dry, which creates an obvious pressure on species of Mediterranean ecosystems due to water scarcity, while winters are cool and wet. However, this general pattern varies as a result of different topography and distance from the sea, factors that introduce a variable degree of continentality and climate severity (Figure 2) [3,4].

The sudden torrential downpours or strong winds episodes in different seasons is a characteristic of Mediterranean ecosystems. Thanks to this, they show a high diversity of vegetation types and landscapes: high mountains, rocky shores, impenetrable scrub steppes, deciduous forests, coastal wetlands or sandy beaches, is only a sample of the great mosaic of Mediterranean landscapes [3].

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Figure 1. Mediterranean biogeographical region.

Figure 2. Scattered areas with a Mediterranean climate.

A characteristic feature of the Mediterranean ecosystems is the great biological wealth and the third richest region in plant diversity, with 25,000 plant species, more than half of which grow nowhere else in the world [5]. The adaptive responses of plant species are similar to some extent in all areas with a Mediterranean climate, and represent ecological "keys" with application to habitat restoration [3].

For thousands of years, human settlements and habitat modifications have caused distinct changes in vegetation. The most far reaching impact of human activities has been deforestation for the expansion of cultivated land and/or for exploitation of woods. Also forest fires, intensive grazing and tourism infrastructure development especially in coastal areas have greatly modified the Mediterranean environment. Severe droughts tend to exacerbate the loss of habitat plants [3,6].

Noteworthy is the fact that biodiversity conservation has a long and multifaceted importance for humanity. Biodiversity is essential to the economy, culture, ecology and recreation for people. It offers numerous products, necessary for the survival and quality of life, at the same time is the most important factor for the functioning of the biosphere. But biodiversity is not only a source of material wealth, but it also provides aesthetic and moral values. Man has always appreciated and been inspired by these as evidenced by painters, musicians, poets and writers [7,8].

Therefore, the loss of biodiversity has a major impact not only on natural ecosystems but also on human life quality. Considering that almost all economic, our cultural and leisure activities, as well as our health, depend, directly or indirectly, on biodiversity, it is understandable why its conservation is critical and of

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urgent priority. We only need to take a look at the ingredients of most medications, clothes, the tastier fruits and foods, holidays resorts, many great works of art, to realize how much we depend on other organisms, from germs, to large plants and animals [7,8].

During the last years ecological design has been applied to a wide range of technologies such as environmental protection, ecological restoration, food production, landscape design and architecture [9] offering new services that will benefit the ecological engineering.

New ecotechnologies have focused on creating more sustainable systems as the additional potential of green plants to accelerate and improve ecological and biochemical transformations of destroyed land. The proper selection of plant genotypes for particular applications at specific geographic locations, that need them, is an important step in successful ecosystem design [10]. Hence, the objectives of the present paper are to: a) mention the biological and ecological characteristics of genus *Salix* and b) identify the importance of genus *Salix* for reclamation of degraded areas.

Ecosystem Restoration

Various economic, but also social, activities can upset the ecological balance of the natural ecosystem [11]. The most important of these activities are related to mining and the storage of waste.

The term recovery refers to restore stable productivity conditions in disturbed environments [12]. Very unfavorable conditions in planting medium in these environments often exist for plant growth (extreme soil pH values, high concentrations of heavy metals, absence of organic matter and soil microorganisms, damaged soil structure and low water-holding capacity). These conditions determine the choice of species for the establishment of vegetation in these environments, limiting the types of native vegetation that can be used.

When restoring a disturbed area special significance beyond the aesthetic and ecological rehabilitation should be given to land use of the area after the restoration. It is possible that the restored area be used for agriculture, livestock, beekeeping, forestry or outdoor recreation. The choice of land use depends on environmental, social and economic parameters [13].

Biological characteristics of genus *Salix*

In the interglacial period, one of the first recorded species of flowering plants was the genus *Salix* [14]. This genus originated in subtropical aria and then dispersed to tropical and temperate area, reaching at last to Arctic zone, but currently, they are widespread mainly in temperate regions such as Europe, Asia and North America. As far as species are concerned, the largest diversity is found in China with 270 species and Russia with 170 ones. On the other hand, 65 species can be found in Europe and 160 in North America [15]. Only three species originated in Central and South America [16] and about 12 in Africa which are endemic of local occurrence [15]. Two more genera, Populus and Salix were described in 1763 by Linné. Also, another genus named Chosenia, which shares features of the preceding genera was outlined by Nakai [17].

Heterogeneity is a characteristic of genus *Salix,* and includes 400-500 species and vary in the size structure and growth forms [18]. Skvorstov's classification (1968) [19] is the most legitimated, which distinguishes three main subgenera: Representatives of the subgenus Salix - so called “real” willows are trees or high shrubs with narrow or pointed leaves. Together with leaves or after them, grow the flowers. The presence of two and/or several stamens constitutes the characteristic of male flowers. Typical representatives include crack willow (*Salix fragilis L.)* and white willow (*Salix alba L.*) [15]. On the other hand, there are shrubs or small trees with a wide variety of leaf shapes and entire or distinctly serrated margins, are included in the subgenus Vetrix. Also, inflorescences (catkins) emerge before the formation of leaves. At last, female flowers have only one nectary. The representatives of this subgenus have two stamens and buds are enveloped by a single scale such as *Salix caprea* and *Salix aurita.*

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Table 1. Botanical characteristics of *Salix* [17].

Character	genus *Salix*
Genome	2n = 38 chromosomes; diploid to dodecaploid (12x); genome has not been sequenced
Flowers	Appear before, with, or after leaves; catkins mostly erect; insect or wind pollinated. Perianth and disk usually absent but with 1 or 2 nectaries; bracts entire, pubescent, usually persistent; stamens few – 2 to 12 - usually with yellow anthers; pollen thick-walled and tricolpate; stigmas two-lobed; ovaries with 2 carpels
Fruit	2-valved capsule
Leaves	Never lobed or deltoid. Almost always elongate in shape – obovate, oval, ovate-lanceolate, lanceolate, or lanceolate-linear; venation pinnate; margins finely serrate or entire, occasionally glandular.
Stipules	Sometimes persistent and prominent
Petioles	Short, round in cross-section
Buds	Enveloped by a single scale; closely appressed to twig; mostly sympodial and lacking a true terminal bud
Shoots	Slender; green, brown, yellow,, orange, purple, or red in colour; circular in cross-section; pith circular in cross-section; homophyllous (does not form brachyblasts). Rarely develop root suckers.
Wood	Light (specific gravity 0,30-0,42), uniform, straight-grained, soft, pale, not durable, tough and shock resistant, odourless; rays heterocellular
Habit	Extremely variable; can be procumbent plants, multi-stemmed shrubs, and medium to large trees
Habitat	Mostly cold temperate regions; common in wetlands, peatlands, riparian corridors, but uncommon in uplands; abundant in tundra and alpine zones
Number of taxa	330-500

Ecological characteristics

Tolerance to drought and heat. Overwhelmingly, willows belong to the mesic–hydric type of vegetation, but there is a small number of species, such as *S. humilis* and *S. myricoides*, that exhibit xeric traits and in that way they are adjusted to drought and heat stress [20]. Moist conditions seem to play an important role, while for many other willows to wetlands and floodplains reflects a critical requirement, but after seedling establishment constant moisture is not as important to survival of some species [21, 22]. So, willows that appear to thrive in high temperatures and drought should be chosen for restoration.

Tolerance to frost. As foliation comes early in Spring alike late-season growth and leaf severance can terminate in spring frost damage and impaired winter hardening in northern climates. Selected species' annual development have to be compatible to the microclimate of the site, since phenological mismatches may cause severe losses [23].

Tolerance to inundation is crucial for soil stabilization against seasonal flooding and wave erosion along riverbanks and reservoirs. Open and wet habitats create a beneficial environment for seed germination for these main colonists of water margins. Some willow species can withstand water fluctuations and extended periods of partial deluge [24].

Tolerance to root exposure is a an obligation of the inhabitant in riparian environment where subsequent erosion events follow seasonal flooding periods [25]. A few willows such as *S. humilis, S. myricoides* are prosperous immigrants of sand dunes, able to withstand root exposure as a result of wind erosion [20].

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Tolerance to deposition, or burial, relies on the plant's capability to develop new adventitious roots on buried stems, and to flush dormant buds. This plays an important role in riverbank and sand dune stabilization projects, characterized by constant deposition of silt, gravel and sand and sediment burial [25].

Tolerance to salinity and high pH are essential concerns for plantings in coastal settings, in areas in sight of extensive use of deicing salts, where vegetative cover is installed as ahydraulic barrier; and in plantings where high-salinity, high ammonia leachate is recirculated for irrigation [22].

The Diversity of the Genus *Salix* and its Importance in Regional Floras

Mediterranean forests favor the plant diversity more than the European forests. This rich diversity is a result of historical [26] and palaeogeographical factors as well as ecological conditions [27]. The Mediterranean basin also indicates closer interrelations than any other region in the world between its flora and major landscapes and the human activities that have been configuration them for nearly 10 000 years [15,28].

The willows, genus *Salix* (Figure 3), belong to the family *Salicaceae,* and it comprises about 330-500 species worldwide distributed mostly in the Northern Hemisphere [16]. Although occurring mainly in temperate and arctic zones, willows also thrive in subtropical and tropical zones and include trees, shrubs and groundcovers. The geographical distribution of willows includes all mains except Antarctica and Australia [15]. Any native flora in temperate parts of the world includes populous *Salix* species, thus a variety of indigenous willows is appropriate for a design in most locations [15].

The representatives of the genus *Salix* are divided into the below subgenera: a) *Salix*, b) *Protitea*, c) *Longifoliae*, d) *Chamaetia* and e) *Vetrix* and each subgenus except *Longifoliae* consists of many divisions. The subgenus *Salix* is consisted of mostly tree-type species dealing many common characteristics with *Populus*, such as dendroid growth, large size, and rather loose catkins that appear with the leaves on leafy stems [15].

The most common representatives of subgenus *Salix* include *S. alba* (white willow), *S. babylonica* (weeping willow) and *S. lucida* (shining willow). Subgenus *Protitea* demonstrates a dozen species distributed in temperate as well as tropical and subtropical regions with considerate free overlapping bud scale margins. Common North American species – *S. nigra* (black willow) and *S. amygdaloides* (peachleaf willow) – belong to the subgenus *Protitea*. Subgenus *Longifoliae* constitute only a few New World species, such as widely distributed *S. interior* (sandbar willow), that have the ability to reproduce by root shoots, or root suckers, and form dense thickets [15].

Subgenus *Vetrix* includes more than two-thirds of the species in the genus and consist of mostly shrubs and small trees. Among its common representatives are *S. eriocephala* (heart-leaved willow), *S. discolor* (American pussy willow), *S. caprea* (goat willow) and *S. viminalis* (basket willow). Subgenus *Chamaetia* invokes low-growing and prostrate species, such as *S. herbacea* (snowbed willow); many of them are particularly suitable to the extreme conditions in alpine and arctic zones. The diversity census of representatives of the subgenera of New World species is as follows: *Salix* (8 species), *Protitea* (7 species), *Longifoliae* (7 species), *Chamaetia* (27 species), and *Vetrix* (56 species) [15, 28].

The total number of willow species growing throughout North America is about 106 [29]. In many northern floras the number of willow species out- numbers those of other woody genera (Figure 4). In temperate regions, a variety of native willow species is almost always available near the site of a restoration project; these can provide site-specific naturalizing materials with wide public identification and acceptance [15].

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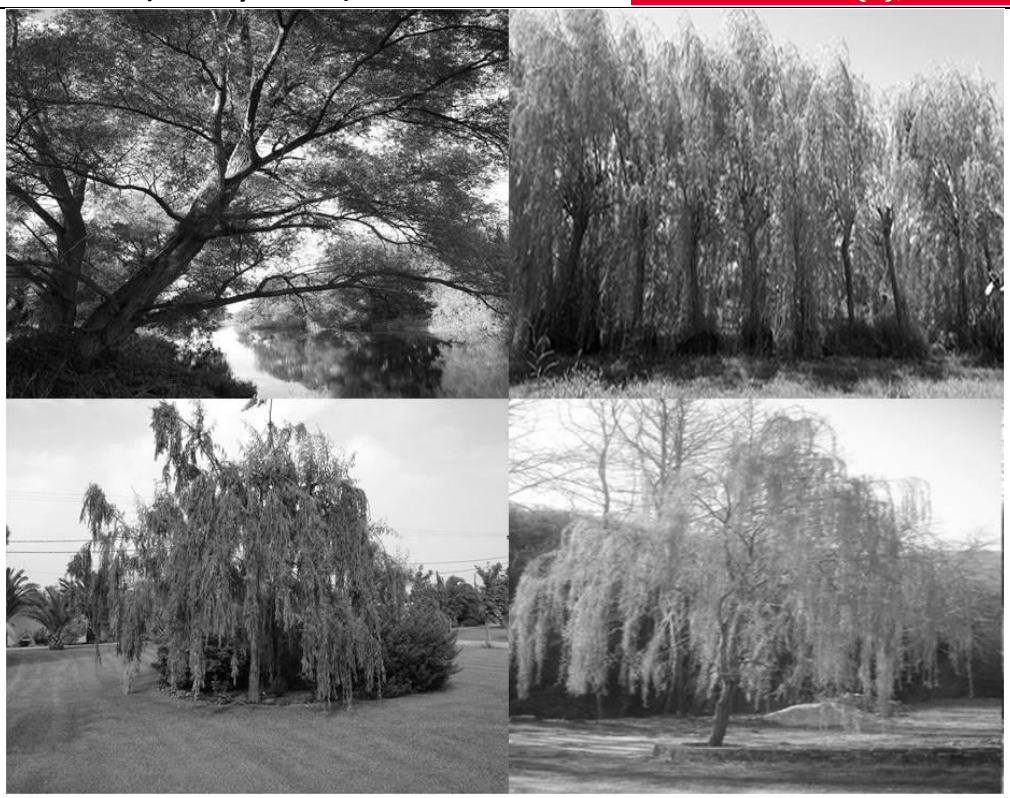

Figure 3. *Salix L.*

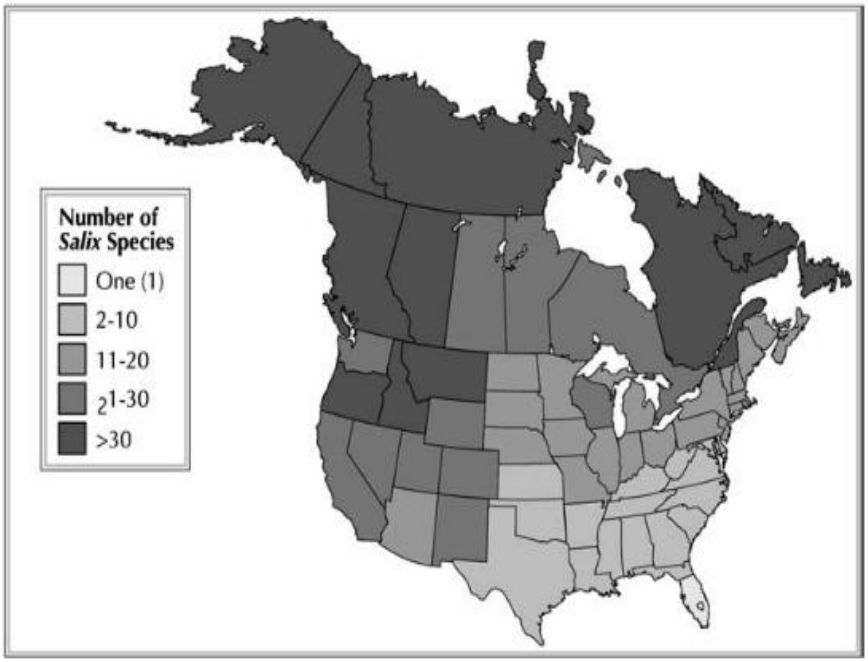

Figure 4. *Salix* species diversity in U.S.A. and Canada based on regional floras.

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Uses of *Salix L*. species for ecological restoration

The land reclamation process based on the strategic planting of early successional plants on degraded areas express the principal stage of restoration projects. *Salix* species are common primarily plants that are able to establish on degraded sites, industrial spoils, mine and gravel pits, peatlands, overburdens, quarries and highly eroded soils. If Salix species settle effectually they change the microclimate, improve soil conditions, control invasive species, and re-establish natural ecological complexity [18,30].

The major requirements for plant species selection in the areas which need restoration, include tolerance to the specific areas conditions which may present several combinations of drought, wetness, alkalinity, acidity, shallow and compacted soils, low nutrient availability, metal toxicity and toxic organics [31].

Moreover, willows have been proposed for installation in the specific areas as rhizofiltration. This process involves the removal of pollutants from aqueous solutions through direct uptake by plant roots. It is applicable to wetlands, vegetation filters, riparian nutrient buffers, vegetative caps and recirculation gardens created for nutrient and wastewater management [32].

Also, Salix species are currently under intensive investigation for their potential for phytoextraction to identify genotypes with high metal uptake and accumulation capacity [32,33]. Information on the biological transformation of organic pollutants by willow varieties and associated microorganisms is coarctate, though it has been reported that willow roots increased methane oxidation rates on the landfill and boost the degradation of mineral oil on contaminated dredged sediment [32,34].

Conclusion

The restoration of disturbed lands with proper layout, the use of materials to improve soil conditions and the selection of appropriate plant species such us *Salix sp*. for the establishment of vegetation can contribute to ecological and aesthetic regeneration, making them suitable again for a variety of uses land in the future. Conclusively, Willows are being employed in an array of ecotechnological projects aiming to alleviate environmental degradation, to control cycling of nutrients and contaminants, and to provide value-added products.

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