Knowing the natural patterns and site demands of species is a good guide and can reveal the ecological characteristics of species to solve many problems in managing of forest lands, such as reforestation and rehabilitation of damaged areas. In this book, we analyzed the spatial patterns of three Quercus species (Quercus brantii, Q. infectoria and Q. libani) by univariate spatial analysis of trees and finding out the relationship between environmental characteristics and distribution of these studied oak species, at the less destroyed areas in the northern Zagros region of Iran.

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978-3-659-36301-6

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Impressum / Imprint
Bibliografische Information der Deutschen Nationalbibliothek: Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

Bibliographic information published by the Deutsche Nationalbibliothek: The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet at http://dnb.d-nb.de.

Coverbild / Cover image: www.ingimage.com

Verlag / Publisher:
LAP LAMBERT Academic Publishing
ist ein Imprint der / is a trademark of
AV Akademikerverlag GmbH & Co. KG
Heinrich-Böcking-Str. 6-8, 66121 Saarbrücken, Deutschland / Germany
Email: info@lap-publishing.com

Herstellung: siehe letzte Seite /
Printed at: see last page
ISBN: 978-3-659-36301-6

Zugl. / Approved by: Yerevan, Agrarian State Armenian University, Diss.2013

PhD Thesis

Title:

Quantitive ecology and spatial pattern of three species of Oak (*Quercus brantii, Q. infectoria* and *Q. libani)* in northern Zagros in west of Iran

By:

Masoumeh Khanhasani

and

Professor Zhirair Vardanyan- Dr. Khosro Sagheb Talebi

Oct. 2012

DEDICATION

I would like to dedicate this thesis to my family, my husband Yahya and my sons Sina and Sahand. Thank you for standing by me through the years and being there for me.

Abstract

The present study is divided into two sections:

1- The **spatial patterns** investigation of trees in the natural deciduous Oak forests in west of Iran. Spatial patterns of trees are important characteristics of forests and can be used for analyzing canopy replacement, regeneration, in forest dynamics after disturbance and biological relationships between tree species such as competition and dispersion. For this purpose, 4 plots each two hectare (100 m×200 m) were selected in dominated forest of Oaks (*Quercus brantii, Q. infectoria* and *Q. libani*) stands located in northern Zagros of Iran. Diameter at breast height (dbh), crown diameter, and coordinates of all trees were recorded. Spatial point pattern was analyzed using Ripley's *K*- function. Results showed that *Q. brantii* as dominant or co-dominant species, in all pure and mixed stands showed cluster pattern at all scales. The spatial pattern of *Q. infectoria* as dominant tree in mixed stand and as co-dominant species is cluster (P<0.05) at all scales. However, its spatial pattern when mixed by *Q. brantii* is random up to 17 m and after that is cluster, except for the scale more than 45 m which falls again in random area. *Q. libani* as dominant species displays clump distribution in all scales but when mixed with *Q. infectoria* as co-dominant species, displays totally random distribution (P<0.05). Existence of *Q. brantii* had essential role in dispersal model of another species. Knowledge of the natural patterns of species is a good guide and can reveal the ecological characteristics of species to solve many problems in managing of forest lands, such as reforestation and rehabilitation of damaged areas.

2-**Site demand studies** and finding out the relationship between environmental characteristics and the distribution of the three studied oak species. After selecting the main sites of the mentioned species, vertical dispersion of the species have been determined due to their minimum and maximum altitude of presence. Also the horizontal dispersion of species, considering latitude, was determined. According to landforms and geographical coordinates, 500 m^2 circular sample plots were laid out and at least one soil profile at each geographical aspect has been dug and the physico-chemical properties of soil (P, K, Ca, total N, C%, $CaCo_3$%, pH, Ec and texture) was studied. The following quantitative and qualitative characteristics were also studied in sample plots:

All of tree species, diameter at breast height (dbh) or diameter of the thickest sprout (for sprout clumps), total height, trunk length and crown shape (straight, forked and broom shaped). The collected data were recorded in Excel and were analyzed by PC-ORD for Win.Ver.4.17 Mc software. Results show that distribution of Oak species is related to soil characteristics and habitat topographic conditions. *Q. libani* exist in acidic soils with low level of EC and $Caco_3$ and favor heavy and semi-heavy soils, and is limited in range of altitude and north direction. *Q. brantii* exist in heavy halomorphic toward alkaline soils with high level of $Caco_3$. It has the maximum range of altitude in all of directions. *Q. infectoria* isn't limited to pH and is more favorable with Light soils and steeper northern directions.

Key words:

Spatial pattern, Ripley's *K*- function, Monte Carlo simulations, Site demands, *Quercus*, Oak

Introduction

General

Forest is a living, complexly interrelated community of trees and associated plants and animals. Within that community, plants and animals grow old and die. From the soil, trees take moisture and nutrients, and with the aid of sunlight, they manufacture wood and other products used by humans. Forests are a very important part of the environment. They cover about one-third of the earth's surface. Unless seriously disturbed by people or altered by catastrophic events, they continue to live indefinitely on a given area of land. Forests contribute to the stability of nature and consequently benefit many forms of life, including human beings. A tree in a forest reflects the interaction between the inherited (genetic) growth characteristics of the tree and the environment of the tree. A small tree's growth may also be suppressed by overtopping larger trees, shallow soil, exposure harsh winds, and other environmental factors (Gary L. Rolfe et al, 2003).

Ecology is the science of the interrelationship between organisms and their total environment is also the most indistinct. In 1866 Ernst Haeckel proposed the term ecology, from the Greek Oikos meaning home or place to live, as the fourth field of biology dealing with environmental relationships of organisms and distinguished from morphology (form), physiology (internal function), and taxonomy (likeness). Thus ecology literally means "the knowledge of home", or: home wisdom". Since its introduction the term has been applied at one time or another to almost every aspect of scientific investigation involving the relationship of one organism to another, or to the relationship of an organism to its environment (Rowe, 1989).

Forest ecology is concerned with the forest as a biological community. It deals with the interrelationship between the various trees, plants, and other living organisms that make up the community and with the interrelationship between this organisms and the physical environment in which they exist. In other words, forest ecology is the study of the forest ecosystem, a concept that combines both the living and the nonliving aspects of the environment.

Natural forest ecosystems are very diverse, with many kinds of trees and plants. The various layers in a forest provide a variety of habitats for both of plants and animals, allowing many different kind of develop. This diversity results in a stable environment that is both resistant and resilient to change. Compare a diverse forest with a cornfield, which has only one plant species. In the cornfield, if you remove the one species of plant, the system can no longer function. However, in the forest, if you remove one kind of tree, there will be little impact, because other kinds of trees are available to substitute for the one remove. The trees in the forest have overlapping jobs or functions. The location and type of habitat in which a species lives, together with its functional role in the forest ecosystem, determine the niche of a species.

Forest Ecology

Forest ecology is the study of trees and their interactions with other organisms and with the physical environment. To manage forests, each component of the ecosystem and its processes affecting the trees must be examined.

Forest ecosystems are best described by their component characteristics and processes. The characteristics of stratification, zonation, diversity and stability reflect the organizational patterns of the forest ecosystem components. The processes of energy flow, decomposition, material cycling, competition, and succession are all operating within the system, influencing the organizational patterns of the vegetation communities.

It is impossible to measure all the factors and the combinations of factors that make up the total tree environment. Broad combinations of factors, however, are useful in understanding how environmental conditions are impacted by silvicultural practices.

There are two broad components of a forest ecosystem- the physical factors and the biological organisms. Soil, climate, and fire are the physical factors making up the nonliving component of the environment. Each factor plays an important role in the physiological processes and responses the trees.

Forest Type

A group of individual trees is also classified into a forest type. A stand of trees consisting principally of a single species of silvicultural or economic importance is considered a pure stand. If two or more species are present, the stand is called mixed. One commercial stand classification considers a stand pure when 80 percent or more of the overstory is of one species and is responsible for nearly all the commercial products. Conversely, if more than 20 percent of the overstory is of other species, the stand is considered mixed. Other similar classification may be used.

Forests can be classified by a variety of types, such as permanent or climax plant types, temporary or developmental plant types, physical or site productivity types, management or silvicultural types, and cover or forest composition types. Forest composition types are commonly used for surveys of forest resources. Forest composition types consider, in addition to species composition, the relative percentage of important species, their volume differences, and their relative economic importance.

Oaks are typically members of broadleaf deciduous forest communities and often are the dominant species in the central and southern regions and in mixed-Oak forests to the north and east.

Paleoecological History of Oak Forests

Pollen and charcoal preserved in undisturbed sediment in lakes and bogs can be concentrated, dated, and analyzed; the resulting data provide an invaluable source of information on the long-term dynamics of vegetational assemblages. Major spatial and temporal patterns and changes in the prevailing vegetation (inferred from pollen composition) can be used to infer climatic changes and disturbance history, including fire history (from sediment charcoal abundance), Native American activity, and insect and disease outbreaks. Eighteen thousand years ago, prior to the Holocene, the eastern United States was dominated by pine forests in the southeastern and mid-Atlantic regions, and *Picea* (spruce) and *Cyperaceae* (sedge) dominated communities in the mid-Atlantic, midwestern, and central regions; glaciers covered most of the northeastern and Great Lakes regions (Webb 1988). During this time, _"OAKS

FOREST ECOSYSTEMS" Oak occurred in the South and Southeast, but it represented only 1–5% of the pollen percentages, compared with 20–40% for pine. By the beginning of the Holocene, Oak abundances started to increase dramatically and this genus apparently dominated most forests in the eastern United States, excluding the northern tier which was primarily pine, spruce, and birch (*Betula*) (Webb 1988).

A number of paleoecological studies from the eastern United States provide long-term data on Oak forest distribution and dynamics in pecific regions. For example, at Mirror Lake, New Hampshire, in the northern hardwood-conifer forest region, peak domination of white pine and Oak occurred in the early Holocene (9,000–7,000 years B.P.) when the climate was warmer and drier than at present; charcoal was most abundant 8,000–7,000 years B.P. (Davis 1985). When the climate cooled thereafter, hemlock (*Tsuga*), beech (*Fagus*), and birch (*Betula*) increased and charcoal abundances decreased.

The occurrence of fire and Oak during the Holocene was not independent of other biotic and abiotic factors. Clearly, the historic fire frequency in Oak forests was linked to climatic changes that resulted in intermediate levels of temperature and moisture. During the Holocene, Oak forest replaced the white pine, northern hardwood, or mixed-mesophytic forests associated with warmer and drier climate and, apparently, with increased fire. Conversely, when climate became cooler and moister and fire frequency or intensity was reduced, closed Oak forests replaced Oak savanna, prairie or some pine forests. Oak species were themselves replaced by other vegetation types when a change in the climatic and fire environment dictated.

The inability of Oak reproduction to compete with either large shade tolerant advance reproduction or aggressive pioneer species is the fundamental cause of problems in Oak regeneration and sustainability (Lorimer 1993). Oak regeneration problems and reductions in Oak stocking are most likely on higher-quality mesic sites (site index > 60 feet, base age 50). Oaks appear to be successionally most stable on xeric sites, under current disturbance regimes, which are typified by frequent small-scale disturbances that cause isolated mortality to overstory trees and the absence of fire (Johnson 1993a). However, increased competition from shade-tolerant trees and shrubs threatens Oak regeneration potential even on these drier sites. Oaks are adapted to environments characterized by disturbance and stress.

Light Relations

Inadequate light often limits Oak regeneration and recruitment into the overstory (Lorimer 1993). Oak is much less shade tolerant than many of its competitors. Acorn germination and initial seedling development are not limited by light levels, because the seed is relatively large and supplies the bulk of the carbohydrates for growth until seed reserves are exhausted. Although survival of Oak seedlings at low light levels may be possible, sufficient carbohydrate to support the production of new tissue requires greater light.

Moisture Relations

The Oaks as a group are quite tolerant of drought, primarily because they have large root systems, leaf morphological characteristics that reduce transpiration, and the ability to maintain gas exchange and net photosynthesis to comparatively low levels of leaf water (Abrams 1990, Pallardy and Rhoads 1993). The development of a strong taproot system in Oaks provides them access to moisture from deep soil layers, a source less available to their more shallow-rooted competitors. The Oaks are better adapted to xeric environments than many of their common mesophytic competitors.

Despite their adaptations to drought, Oaks are still subject to injury from water stress. Drought can cause declines in leaf gas exchange, dysfunction of their xylem water transport system, decreases in shoot and root growth of seedlings, and increases in the risk of mortality (Kozlowski et al. 1991, Tyree and Cochard 1996). Under water stress, Oak seedlings exhibit lower leaf area and new root production, delayed bud break, reduced shoot elongation, and increased shoot dieback, and they produce less xylem tissue and fewer and smaller vessels.

Reproduction by seed

Most Oak seedling establishment occurs in years of good acorn production (Lorimer 1993). Seed production is highly variable among Oak species, between individual trees, over the years, and from one location to the next. For all Oak species, some trees are consistently good producers and others are consistently poor producers. Ability to produce acorns is most often attributed to the genetic capability of the tree. However, other factors, such as weather, insects, soil fertility, stand density, diseases, and wildlife, are also important in determining the size and frequency of acorn crops. In the long term, tree characteristics such as size, crown area, crown class and age, and genetics are probably more important than environmental factors in determining acorn production (Beck 1993). In general, Oaks have large seed crops at 2- to 10-year intervals.

Reproduction by seedlings

Shoot growth of Oak seedlings is relatively slow, because Oak seedlings possess moderate leaf photosynthetic capacity, relatively thick leaves, and preferential carbon allocation to the roots (Kolb and Steiner 1990, Walters et al,. 1993). Suboptimal environmental conditions also slow shoot activity and trigger an allocation of current photosynthate to the roots. This carbohydrate both supports continued root growth and is stored in the taproot for future use in shoot growth.

For most Oak species, slow height growth relative to that of competing vegetation is the most often cited cause of Oak regeneration failure, especially on high-quality sites (Lorimer 1993). In the open, young Oak seedlings are at a competitive disadvantage when growing with large advance reproduction of shade-tolerant species (e.g., maples) and shade intolerant reproduction such as yellow-poplar. In mesic and hydric ecosystems, Oak species such as northern red Oak and water Oak can be regenerated successfully from seed if there is an abundant acorn crop and a low to moderate level of competition at the time of overstory removal (Johnson and Jacobs 1981, Loewenstein and Golden 1995). More frequently, intense competition and a lack of acorns or advance reproduction result in Oak regeneration failures on these sites.

The preferential maintenance of root growth over shoot growth is an important ecological adaptation that enables Oaks to dominate on xeric sites and to persist in high-disturbance environments. A competitive rate of growth for Oak reproduction depends on the development of seedlings with a large, physiologically vigorous root system and high root-to-shoot ratio (Johnson 1993a).

Oaks are better adapted than many of their competitors to disturbances or environmental stresses that cause shoot dieback; they can repeatedly produce new sprouts from their large supply of dormant buds located at the root collar, which is often beneath the soil surface, where buds are protected from fire and herbivores.

A well-developed root system results in a high shoot-growth potential in Oak seedling sprouts, which makes them more competitive than true Oak seedlings (i.e., seedlings that have not experienced shoot dieback and sprouting). Greater net photosynthesis in seedling sprouts results from a higher root area-to-leaf area ratio (Kruger and Reich 1993a,b) and, for Oak seedling sprouts developing after a fire, improved leaf nitrogen content (Reich *et al*,. 1990). Therefore, successful Oak regeneration is dependent upon there being an adequate number of large advance reproductions (primarily seedling sprouts that are present before over story removal). Oaks are more tolerant of drought and better adapted to surviving repeated fires than many of their competitors.

Iran has a total surface area of 1.6×10^{6} km 2 . Except for the interior deserts and the lowlands along the Caspian Sea, Persian Gulf and Gulf of Oman, ca. half of Iran is composed of high mountains. The main mountain chains are Alborz, Zagros, Kopet Dagh and Khorassan and Makran (Noroozi, *et al*., 2008).

Forests of Iran

Forests of Iran are divided into five regions and genus *Quercus* as a common species does exist in three of them including humid Caspian, sub-humid Arasbaran (Yazdian, 2000) and semi-arid Zagros forests (Fattahi, 1994).

Forests of Iran with an area about 12.4 million hectares comprise 7.4% of the whole country area. While the forest cover of Iran is considered poor as compared with other countries, it is a unique country regarding plant diversity and genetic reserves. The phytogeographical regions that concern the flora of Iran are the following: the Irano- Turanian, the Sahara- Sindian Regions and the Euxino-

Hyrcanian Province of the Euro- Siberian Region (Sagheb- Talebi *et al.,* 2003) (Fig. 1).

Fig. 1. phytogeographical regions of Iran

Forests cover about 12 million ha in Iran (Forest and Rangeland Organization 2002), including 5.05 million ha. in the mountainous Zagros region, occurring in the north-western part of the country at an elevation of 650 to 2200 m a.s.l. Annual precipitation in this region varies between 350 mm and approximately 1000 mm. The main species in this region are *Quercus* spp. (Oaks), *Pistacia atlantica* (wild pistachio), *Craategus* spp. and *Pyrus* spp. (Ghazanfari *et al.,* 2004)

From a botanical and ecological perspective, Iran's forest vegetation is not uniform. On the contrary, in line with the country's ecological differentiation, Hans Bobek (1951) defines four different types of natural forests and forest-like brushwood: 1) humid forests, 2) semi- humid/ semi- arid forests, 3) steppes and deserts with loose stands and brushwood, and 4) riparian forests/coastal forests (Djazirei, 1964).

In line with Bobek's classification, the steppe and desert regions of Iran are the domain of very specific forest-types. Characterized by extremely patchy distribution and incoherent species composition (due to variations in the availability and the quality of water), Bobek's "loose stands and brushwood" seem to correspond to Djazirei's "formations xeriques" or Pabot's forest elements of the Baluchi flora zone in the context of his "xerophilous forest flora" as part of the Irano–Turanian flora

Zone.

The precipitation in Oak forests of Zagros varies between 300 to 900mm, evaporation is between 1800 to 3300mm and the mean temperature is 8 to 22 ^{o}C (Yazdian, 2000).

The semi-humid/ semi-arid forests which are the second most important forest formations are located in western iran. They stretch from the present Irano-Turkish border through Kurdistan and Lorestan into the province of Fars, and their semi-humid Oak forests characterize large sections of the Zagros mountain system (Zagrosian forests). Though not smaller in their coverage than the humid forest belt of northern Iran, the semi-humid/semi-arid forests of western and southwestern Persia are characterized by much sparser tree stands and by a comparatively light tree cover with equally light undergrowth. The number of *Quercus* is impressive (*Quercus brantii*, *Q. libanii* or *Q. Boissieri*), but the trees are comparatively short and isolated, with grass and herbs as undergrowth, so that the predominant character is that of a forest-steppe. Besides Oaks, other species such as elms, maples, wild almonds, walnuts and pistachios also contribute to the overall light forest cover.

Less protected than the Caspian forests, which were hardly accessible until the late 19th century, the Zagrosian forests have always been within easy reach of farmers, nomads, traders, and armies crossing the Zagros Mountains on their way between Mesopotamia and central Iran. Archaeological evidence shows that these forests have been exploited economically for millennia. Human interference, in combination with climatic and other ecological factors (soils, topography), must therefore be considered as decisive for the distinctly different character of this forest type.

The major soil types in the region are; Brown soils, chestnut soils, lithosols, rendzinas and alluvial soils. The most abundant soil type in Zagros region is the forest brown soil which is sometimes found integrated or in some cases with other types. Lithosols and rendzinas have less depth, fertility and water holding capacity and are generally found on moderate or steep plope. Zagros forest zone with semi-arid to temperate forests is a rich collection of Oak species (Sagheb- Talebi *et al.,* 2003).

The Iranian Oak forests are totally about 5,785,000 ha. Approximately 3 million ha of forest are covered by various oak species, mainly dominated by *Quercus persica*, *Quercus infectoria* and *Quercus libani*, in the north-west of Iran (Yazdian, 2000; Fattahi, 1995).

More than 1.7 million ha of the Zagros forests has been destroyed since 1962 (Fattahi, 1994). Increasing population, low level of development and high dependence of local communities on forests for their primary livelihood needs, are the main reasons of this destruction. This has resulted in the conversion of forested land to agricultural land and increased browsing pressure on tree regeneration. The lack of regeneration in these forests is a major concern (Fattahi 1994, Ebrahimi Rastaghi, 2001).

Deforestation in Iran has hardly left any virgin forests at present day in Zagros region; deforestation as a result of the millennia-old human impact on the natural environment-population growth, appropriation of land for agriculture, exploitation of forests by nomads, and increasing demand for wood as construction material or as fuel wood and charcoal have destroyed or depleted the forest resources of the country. It is difficult to reconstruct the original distribution and composition of the Iranian forest ecosystems. It is equally difficult to identify primary and secondary causes of their destruction and to attribute these causes to specific periods of history. As already indicated, the present poor state of forestry in Iran cannot be attributed to a single cause. The deforestation of the Zagrosian forests and that of other arid sections of Central Persia are as old as human settlement there, although with differing intensity in different periods, argues that during Greek-Hellenistic times ancient records speak of densely forested areas not only in the Zagros and its forelands, but even in the more arid parts of present-day Fars. In central Iran, on the other hand, deforestation seems to have been more advanced (de Planhol 1969).

Zagros is divided into two distinct regions based on the different Oak species: Northern Zagros and Southern Zagros. Northern Zagros is the exclusive site for *Quercus infectoria* mixed with *Quercus libani* or *Quercus brantii* or both. However, Southern Zagros is the exclusive site for *Q. brantii*. Furthermore, Northern Zagros can be generally considered more humid and colder than Southern Zagros (Sagheb-Talebi *et al.,* 2003).

Rechinger identified 10 following species of oak in Iran (Flora Iranica, 1971):

Q. robur L., *Q. infectoria* Oliv., *Q. petraea* L. ex Liebel. *Q. macranthera* Fisch & C.A.Mey. ex Hohen*, Q. castaneifolia* C.A.Mey.*, Q. libani* Oliv. *, Q. brantii* Lindl. *, Q. batoot* Griff. *, Q. dilatata*Royle. *, Q. semecarpifolia* Sm. In Rees.

According to the most recent estimate there are 202 species of *Quercus* in the New World (Fagaceae, in Flora Mesoamericana).

Fagaceae - the Beech or Oak Family

Diversity:

8 genera and about 900 species of trees and shrubs

Distribution:

Worldwide, except southern Africa with maximum diversity in the North Temperate Zone - 3 genera and 45 species in Texas (Wilson, 1998).

The Fagaceae includes common and important elements of North temperate deciduous forests worldwide, including Oak (*Quercus*), Beech (*Fagus*), and Chestnut

(*Castanea*) species. Distinctive by their 'amentiferous' floral structures combined with alternate, simple leaves and a distinctive fruiting structure. The true fruit is a nut, but this is subtended by involucre of the pistillate flower which, in *Quercus* species, is connate and lignified to form the acorn cap.

Quercus

Historically, oaks have dominated large areas of the temperate deciduous biomes in North America, Europe and Asia (Braun 1950; Barnes 1991; Peterken 1996). Oak dominance in many areas, especially on mesic sites, may have been fostered in part by anthropogenic fires, grazing, and fuelwood cutting in previous centuries (Klepec 1981; Evans 1982; Masaki et al. 1992; Crow 1988; Abrams 1992).

The genus *Quercus* is one of the most important groups of woody plants in many regions of the world. Oaks dominate various temperate, subtropical, and tropical forest types, and are also a major component of several chaparral and scrub vegetations (Nixon 1993a).

The genus *Quercus* is distributed almost worldwide in more than 500 species (Smith 1993). There are three major distribution centers in the world including North America, Europe and Eastern Asia. The Eastern Asia shows the highest species diversity and almost 250 species are recognized in this region (Kyeung and joong, 2000).

Although the seedlings are usually shade-intolerant, Oaks can form old-growth stands because of their longevity, resistance to fire, and their ability to recolonize following disturbance. There is concern for their health and continued productivity (Healy *et al.,* 1997b) because of the stresses caused by the introduction of insect pests (Houston 1981, Gottschalk 1989), suppression of fire (Abrams *et al.,* 1995), and widespread Oak decline (Oak *et al.*, 1988). Conservationists are concerned with the loss of forest to agricultural and suburban development (Robinson *et al*. 1995) and the industrial conversion of deciduous forest stands into pine plantations (Palik and Engstrom 1999). For many wildlife species, the loss of deciduous forests is compounded by the loss of seed crops in the autumn.

The oaks as a group are quite tolerant of drought, primarily because they have large root systems, leaf morphological characteristics that reduce transpiration, and the ability to maintain gas exchange and net photosynthesis to comparatively low levels of leaf water (Abrams 1990, Pallardy and Rhoads 1993). The development of a strong taproot system in Oaks provides them access to moisture from deep soil layers, a source less available to their more shallow-rooted competitors. The oaks are better adapted to xeric environments than many of their common mesophytic competitors.

Oaks, with their long history of numerical dominance, their high diversity, and their widespread distribution, create a matrix within which wildlife and other species persist.

Oak trees form the main species of the mountain forests in Iraq. *Quercus brantii* (balut) has the widest range, with *Q. infectoria* commonly admixed, occurring more frequently on the more favorable sites. *Q. libani* (dindar) is found in the northern mountains above 1,500 meters elevation (Chapman, 1948).

The aims of study

The aim of this study is:

1- to determine the spatial pattern of 3 species of Oak and their relation with ecological and edaphic characteristics in northern Zagros forests, to quantify the spatial pattern of plant associations.

2- To find a relationship between vegetative composition and habitat factors.

3- To determine the site demands and illustrating of ecograms of 3 oak species in Northern Zagros forests.

Spatial pattern of trees

Forest stand structure is a key element in understanding forest ecosystems. One of the major components of forest stand structure is the spatial arrangement of tree positions (Ludwig and Reynolds 1988; Legendre and Legendre 1998; Kint et al. 2004; Wolf 2005). Studying the pattern of trees, can be used to better understand processes of forest structure (Nelson et al. 2002).

Spatial patterns of trees are important characteristics of forests (Vacek and Lepš 1996) and can be used for analyzing canopy replacement (Horn 1975; Woods 1979;

Busing 1996), regeneration (Condit et al. 1992; Norton 1991), changes in forest dynamics after disturbance (Alekseev and Zherebtsov 1995; Vacek and Lepš 1996) and biological relationships between tree species such as competition (Hatton 1989; Duncan 1991), dispersion (Collins and Klahr 1991), or adultjuvenile relationship (He et al. 1997). Also, the spatial distribution of trees can be important for the management of natural areas (Moeur 1993).

Spatial information is important in ecosystem analysis and resource management (Chen and Bradshow, 1999). Quantitative examination of spatially explicit data in ecology is broadly categorized as ‘‘spatial analysis’’ (e.g., Legendre and Fortin 1989).

The analysis of spatial structures of forest stands has often been the subject of scientific investigations (e.g. Prodan 1958; Weidmann 1961; Bonnicksen and Stone 1981; Legendre and Fortin 1989; Stohlgren 1993; Frohlich and Quednau 1995).

The spatial pattern of recruitment is an important factor influencing the dynamics of plant communities (Callaway 1992; Tilman et al., 1997; Nathan and Muller-Landau 2000). In other words the organization of the trees in space plays a key role in its dynamics. Indeed, initial spatial patterns of seeds and seedlings set the local biotic and abiotic conditions for recruitment and subsequent stages (Lookingbill and Zavala 2000). To understand many problems in woodland ecology and management, detailed spatial tree data are a necessary prerequisite. For example, computer-based habitat and landscape models need such information (Letcher et al. 1998; Merrill et al. 1999) and are becoming important tools in environmental and conservation planning (Seppelt and Voinov 2002; Niklitschek and Secor 2005; Carroll and Miquelle 2006).

Spatially explicit tree growth models, sampling simulators, and landscape visualization tools also require detailed data including tree characteristics and tree positions (Pommerening 2000; Moravie and Robert 2003; Bauer et al. 2004; Hasenauer 2006; Pommerening 2006). Also, the spatial distribution of trees can be important for the management of natural areas (Moeur 1993).

During the preliminary phase of observation and description of the ecosystem, the analysis of the spatial structure can help us to understand the natural processes involved, and to formulate the model; while writing the model, spatial structure can be used as a response variable to fit the model. It can also be used afterward as a validation variable to test the model; once the growth model is fitted, various initial configuration of spatial structure can be simulated through "virtual stands", in order to compare the behavior of the model in various situations and test its sensitivity to each assumption.

There are three main spatial patterns as following: clumped, random and dispersed (Ludwig and Reynolds 1988; Wong and Lee 2005; Wolf 2005; Cressie 1993). Random distribution of trees is related to random events (such as mortality and seed dispersal) or the simultaneous action of competition and small-scale environmental heterogeneity (Wolf 2005).

Most of the previous studies of spatial patterns in tree stands have been on even-aged stands, monocultures or coniferous forests (Yang and Lee 2007; Salas et al. 2006; Shimatani and Kubota 2004; Nelson et al. 2002).

In many biological and ecological studies, Ripley's *K* function is used (e.g., Penttinen et al. 1992; Moeur 1993). This second-order characteristic is normally estimated from fully mapped tree point patterns in large observation windows.

Most of the previous studies of spatial patterns in tree stands have been on even-aged stands, monocultures or coniferous forests (Yang and Lee 2007; Salas et al. 2006; Shimatani and Kubota 2004; Nelson et al. 2002). The present study aims to investigate spatial pattern of trees in a natural deciduous oak forest.

Regarding to the importance of spatial pattern of trees, especially in degraded Persian oak forests in Zagros Mts., the objective of is Persian oak that has a good power of shooting. Also a long-time system of utilization in these forests to produce fuel wood, non-woody products (such as gum, gall, fruits, manna and etc.) and livestock overgrazing makes it difficult for different species to regenerate naturally by seed and causes the existing coppice structure in these forests (Jazirehi and Rostaghi 2003; Ghazanfari et al. 2004).

Site demands of trees:

The plant species dispersion in world and its variety in regions depend on close relationship between plants and environment conditions that is result of physical and biological interaction. There is certain relationship between plant societies and soil condition and this relationship isn't unidirectional, in other words, though soil condition has condign effect on species compound, in contrast, without interference of vegetation, pedogenesis will not occur. On the other hand scientists are always attempt to recognize relationship between physical and chemical features of soil (Shoenholtz *et al,*. 2000).

In a natural ecosystem, vegetation elements of similar ecological needs constitute ecological groups. In fact, through distinguishing different ecological groups, the differences among environmental variables in various sites can be realized (Mataji *et al.,* 2006).

Based on Clark's idea (1990), topographic conditions, by influence on humidity of soil and microclima, have notable effect on ecosystem characteristics and spatial pattern of vegetation.

One of the aims of this research is to explore ecological groups and their relationship with soil characteristics.

Literature review:

- Erfani Fard et al., (2008) have studied the spatial pattern of trees in Zagros forests. A 30-ha plot was surveyed by full callipering method. Using Nearest Neighbor Index, the spatial pattern was determined as "dispersed". According to the total spatial pattern, 1,500 m^2 circular sample plot was chosen as the most suitable plot to study spatial pattern of the study area.

- Safari et al., (2010) have studied the spatial pattern of Manna Oak trees (*Q. brantii*) in Bayangan forests of Kermanshah. Their results showed clumped pattern for this species.

- Pourhashemi (2004) has reported the relationship between the oak sprout clump with the physiographical factors, altitude, direction and slope gradient. He found out that oak sprout clump is more in low altitudes and northern slops.

- Alavi *et al*., (2006) had an investigation on spatial pattern in Wych Elm (*Ulmus glabra*) in Hyrcanian Forest. The results indicated that Wych elm exhibits intermediate pattern between random and clumped.

- Akhavan *et al.,* (2006) have studied spatial structure and estimation of forest growing stock in the Caspian region of Iran. Results indicated that all the estimations are biased because of the large Nugget effect in the experimental variogram. Therefore, Kriging couldn't make a precise estimation due to large variability in short distances and the weak spatial structure of forest growing stock in this heterogeneous and uneven-aged forest.

- Akhavan *et al*., (2010) have studied spatial pattern in untouched beech (*Fagus orientalis* Lipsky) stands over forest development stages in Kelardasht region of Iran. Results showed that, while the number of stems decreases from initial stage toward decay stage, the spatial pattern of trees in initial, optimal and decay stages are highly aggregated, random and slightly aggregated, respectively.

- Mataji *et al*., (2007) have studied spatial pattern of regeneration gaps in managed and unmanaged stands in natural oriental Beech (*Fagus orientalis*) forests. The results showed that frequency of gaps in managed area is more than unmanaged area. Spatial pattern of gaps were regular for both area in 60m and 80m radius, respectively.

- Talebi *et al*., (2010) have studied site demands of the Persian Oak. They indicated that that the Oak manna is a light demanding species with highest distribution on south-western slopes at 1800 to 2000 m. a.s.l. Soil pH varied from 7.7 at soil surface to 7.85 at deep layers. Total nitrogen and organic matter of soil was good and its salinity was not significant. Most of the Oak trees had a coppice regeneration form (84, 2-78-6 %). Each tree produced four to five sprouts in average. This indicates a severe impact of human on Oak forests. Diameter and height of Oak trees varied between 13.8-19 cm and 4.3-5.2 m, respectively due to variation in land form.

- Mehdifar (2005) studied site demands of *Q. infectoria* and find out that habitat of this species is located between 1200 and 2400m.a.s.l. The soil of the studied sites were usually light (loam) to heavy (clay) with a pH between 7.4 and 8.0. Organic matter is relatively good and the soil EC is insignificant in the studied sites. In general, slopes and vallies with north aspect in altitude between 1200 and 1600 m.a.s.l. are suitable sites for this oak species.

- Pourbabaei *et al.*, (2006), in a research about relationship between ecologic vegetation groups and topographic conditions in oriental beech (*Fagus orientalis*) forests, found that there is significant relation between direction and dispersion of ecologic groups.

- Salarian *et al.,* (2008), investigated on site demand of Almond (*Amygdalus scoparia* Spach.) in Zagros forests. Results showed that one of the most important affecting factors in distribution of Almond is geographical aspect; hence this species is appeared in southern aspects.

- Maroofi (2000) has studied site demands of *Q. libani* in Kordestan province. Results showed that vertical dispersion of this species of oak is; in Marivan, Zarivar lake, from 1350 to 2000m.a.s.l. and in Seyranband of Bane, up to 2050m.a.s.l.. In Marivan and Bane, mean of slop is the best situation for this species, and in valley land forms, have the maximum of canopy.

- Through a research, *Q. infectoria* society was investigated in Marivan. This society mostly was placed between 1320 to 1500 m.a.sl. on the north and north- west slopes (down of the forest heights) and areas with max and min of 15- 65%. Desired soils of this society are brown calcic soils with normal depth to deep and loam to clay-loam texture which has changed to clay in depth. Its prportion is suitable and varies between 70 to 80% but its crown canopy is between 40 to 45% and mostly oscillates with existing condition (Fattahi, 1995).

- Kunstler *et al.,* (2004) have studied spatial pattern of beech and oak seedling in natural pine woodlands. Results have shown that beech and oak seedlings have a clumped distribution in the understory of pine.

- Aakala *et al*., (2007) have studied spatial pattern in standing dead trees. The spatial pattern of standing dead trees in *Picea marina* stands was predominantly clustered. The spatial pattern of large dead trees (>19 cm diameter at breast height) in mixed and *Abies balsamea*- dominated stands were mainly random. Small dead trees (9-19 cm DBH) in these stands were generally more clustered than larger trees.

- Hanewinkel (2004) has studied spatial pattern in mixed coniferous even-aged, uneven-aged and conversion stands, and results have indicated that the even-aged stands showed a regular distribution of the standing volume, while the conversion and uneven-aged stands were more clustered.

- Pomerening and Stoyan (2008) presented an efficient method of synthesizing spatial tree point patterns from nearest neighbour summary statistics (NNSS) sampled in small circular subwindows, which uses a stochastic optimization technique based on simulated annealing and conditional simulation. Analysis and validation show that complex spatial woodlands structure, including long-range tree interactions, can be successfully reconstructed from NNSS despite the limited range of the subwindows and statistics. The results offer new opportunities for adding value to woodland surveys by making raw data available for further work such as growth projections, visualization and modeling.

- Grundy (1994) has studied the spatial pattern of *Brachystegia spiciformis* and *Julbernardia globiflora.* Results showed that the regular dispersion pattern is uncommon; that there are few significant positive correlations between size of individual and distance to nearest neighbor.

- In Rumania a research was carried out on several kinds of forest ecosystems and its results showed that there is a significant correlation between soil type, slope gradient and forest covering (Danita & Ivanchi, 1994).

- In Nepal, studied seven 1200 square meter forest accumulation in congenial growth place and a slope about 2400 to 2900 meter high. Measured high from sea level, direction, slope, diameter and height of all trees in each plot, and counted small saplings which measured accidental in ten micro plot. After that analyzed their correlation with environmental variables by DCA method. In this study cleared that *Quercus oxyodon* in lower high and more wet habitat was dominate. (Metz, 1997).

- Amorim & Batalha (2007), studied in Brazil and found that there is high correlation between plant species and environmental conditions, and soil purities had more important role.

- Chen and Bradshow (1999) studied spatial characteristics of a 2 ha spruce-fir forest located inside Changbaishan Natural Reserve (CNR), PR China. They suggest that joint field and simulation studies are conducted which relate changes in forest stand dynamics to changes in stand heterogeneity.

Some studies on oak stands in Spain showed that some ecological parameters including altitude, soil depth, mean annual temperature, and some quantitative characteristics including mean diameter and mean height of trees are suitable for correctly defining the characteristics of oak stand in Galicia (Timbal and Aussenac, 1996; Rubio *et al*., 1997; Blanco *et al*., 2000).

Díaz-Maroto *et al*. (2005, 2006) concluded that the distribution of the oaks (*Q. robur* and *Q. pyrenaica*) stands are more closely related to the physiographic and climatic characteristics than to edaphic factors in north-west Spain. Their PCA studies showed that the first vector is about stand structure, formed by diametric and height components and the second vector can be defined by distance from sea and altitude

The bivariate analysis showed that diameter and height of oaks in the studied stands in Galicia are very little related to the biotope characteristics. The statistical relationship between oak stands and ecological parameters revealed by multivariate regression analysis and showed that the physiographic parameters, particularly slope and depth of soil are the best parameters to define the present status of oak forest (Díaz-Maroto *et a*l. (2007).

Chapter 1

Materials and methods

Materials

***Quercus libani* Olivier**

Quercus libani, the Lebanon Oak, is a species of Oak native to Western Asia, including Lebanon, Turkey, Iran, Iraq. (Fig. 2).

Fig. 2. *Quercus libani* Olivier

The Lebanon Oak leave is slender, elongated and often asymmetrical, it's base is round and its tip is slightly pointed. In the adult state the leave's upper side is dark green and the underside is pale green. (Seigue, 1985). The flowers are monoecious but flowers from both sexes can be found on the same tree and are pollinated by wind. Seed's length is half covered by the cupules (Seigue, 1985).

Physical Characteristics

A deciduous tree, growing to 8 m. The flowers are monoecious (individual flowers are either male or female, but both sexes can be found on the same plant) and are pollinated by Wind. The seed is about 2.5cm in diameter (Huxley, 1992), it can be dried, ground into a powder and used as a thickening in stews or mixed with cereals for making bread. The seed contains bitter tannins; these can be leached out by thoroughly washing the seed in running water though many minerals will also be lost. It can take several days or even weeks to properly leach whole seeds, one method was to wrap them in a cloth bag and place them in a stream. Leaching the powder is quicker. A simple taste test can tell when the tannin has been leached. The traditional method of preparing the seed was to bury it in boggy ground over winter. The germinating seed was dug up in the spring when it would have lost most of its astringency.

The plant prefers a good fertile medium (loamy) and heavy (clay) soils and can grow in heavy clay soil (Chittendon, 1956 & Bean, 1981). The plant prefers acid, neutral and basic (alkaline) soils. It can grow in semi-shade (light woodland) or no shade. It requires dry or moist soil. The plant can tolerate strong winds but not maritime exposure. Reference?

Q. libani grows at above1000 meters altitude and the best conditions for growing this species, is 1200 to 1600 meters from sea level. In west of Anatoli mountains, it even can be seen above 2000 m Altitude (Browicz, 1994). It has been noted in the Flora of Iraq that *Q. libani* is located on the igneous and metamorphic rocks (Townsend, 1980).Young plants tolerate reasonable levels of side shade (Huxley, 1992).

The seed quickly loses viability if it is allowed to dry out. It can be stored moist and cool over winter but is best sown as soon as it is ripe in an out door seed bed, though it must be protected from mice, squirrels etc. Small quantities of seed can be sown in deep pots in a cold frame. Plants produce a deep taproot and need to be planted out into their permanent positions as soon as possible, in fact seed sown in situ will produce the best trees (Bean, 1981). Trees should not be left in a nursery bed for more than 2 growing seasons without being moved or they will transplant very badly

Any galls produced on the tree are strongly astringent and can be used in the treatment of hemorrhages, chronic diarrhea, dysentery etc (Grieve, 1984). A mulch of the leaves repels slugs, grubs etc, though fresh leaves should not be used as these can inhibit plant growth (Riotte, 1978).

Oak galls are excrescences that are sometimes produced in great numbers on the tree and are caused by the activity of the larvae of different insects. The insects live inside these galls, obtaining their nutrient therein. When the insect pupates and leaves, the gall can be used as a rich source of tannin that can also be used as a dyestuff. Habitats and Possible Locations: Woodland, Canopy**.**

Quercus infectoria **Olivier**

Fig. 3. ***Quercus infectoria*** **Olivier**

Quercus infectoria, is a small tree or shrub with glabrescent leaves and spiny teeth with a crooked stem, seldom exceeding six feet in height. The leaves are petiolate, obtusely toothed, smooth and of a bright-green color on both sides (Fig. 3). The acorn is elongated, smooth, two or three times longer than the cup, which is sessile, somewhat downy, and scaly. This oak tree prefers partial shade or partial sun to full sun, and requires moist soil. This species of *Quercus* grows, according to Olivier, throughout Asia Minor, from the Archipelago to the confines of Iran. M. Kinnier found it also in Armenia and Kurdistan; Hardwick observed it growing in the neighborhood of Adwanie, and it probably pervades the middle latitudes of Asia. Mainly is located on the northern slopes and domain soils (Fattahi, 1994).

It's altitude dispersion in northern Zagros is 2050 to 2300 m a.s.l., but the best habitat for this species is 1400 to 1600 m a.s.l.

***Quercus brantii* Lindl.**

Natural Distribution

West Asia**:** W & S Iran, N Iraq, Lebanon, Syria, Turkey: (E & SE Anatolia).

It is easily distinguished from other oak trees due to the spiny shape of the lightly lobed leaves. The immature leaves are lighter green (Fig. 4).

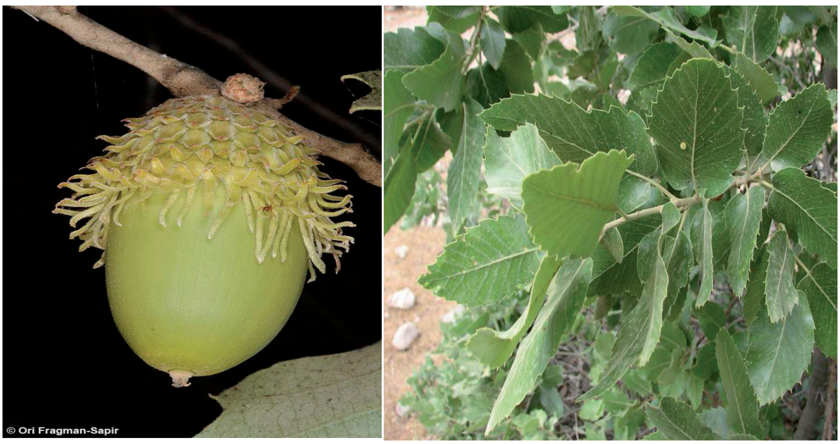


Fig. 4. *Quercus brantii* Lindl.

Physical Characteristics

Q. brantii Lindley in Bot. Reg. 26, Suppl. 41 (1840). Syn: *Q. persica* Jaub. & Spach, I11. Pl. Or. 1:109, t. 55 (1843); Deciduous shrub or small tree to 6(-10) m with greyish, rather smooth bark and rounded crown; young shoots densely yellowish-brown tomentose. Buds ovoid, ca. 4 mm, tomentose. Leaves distributed over shoots, ± regularly ovate-oblong, 6-10(-13) x 3-6 cm, cordate, ± regularly serrate with 8-14 pairs of acuminate scarcely aristate (1-2 mm) teeth; intercalary veins absent; upper surface dull green with numerous small dendroid-stellate hairs, lower pale yellowish-brown, densely stellate-tomentose; petiole 0.5-2 cm. Peduncle nearly absent, to 5 mm, sturdy. Fruit maturing in second year. Cupule hemispherical, ca. 25-30(-35) mm diam., densely pubescent; scales broadly rhomboid, uppermost much elongated, often filiform, spreading-recurved; acorn ± included to c. 1/3 exserted, apically ± convex. Fr. 8-9. Forming pure communities, with other *Quercus* species (*Q. infectoria* subsp. *boissieri*, *Q. libani, Q. cerris, Q. coccifera*), with *Pinus brutia*, *Styrax*, *Paliurus*, often on limestone slopes, 350-1700 m a.s.l.

Q. brantii varies greatly in the size of the cupule and the size and posture of the cupular scales; several varieties have been recognized based on this, apparently completely intergrading, variation. It hybridises, inter alia, with *Q. libani*, and some forms certainly appear to be what was described as *Q. oophora* Kotschy (Die Eichen t. 26, 1862), others as *Q. vesca* Kotschy (op. cit. t. 36). Additional synonyms of *Q. brantii* based on Iranian material are given by Menitsky in Fl. Iranica (1971).

Q. brantii such a native species of Iran, exist in different slops, and mainly on the calcareous and alkaloid soils.

Paleological studies in Zagros forests

The Zagros mountains, which extend from NW to SE Iran. Present a unique potential for palaeo environmental studies for the reconstruction of the vegetation and climate history of the Near East during the late Pleistocene and Holocene. During the 1960_s and 1970_s palynological investigations undertaken by H.E. wright, W. van Zeist and S. Bottema unraveled the history on vegetation and climate change near Lake

Zeribar (35°32′ N, 46°07′ E) and Lake Mirabad (33°05′ N, 47°42′ E) in the north-western and central part of the Zagros mountains (van Zeist and Wright 1963; van Zeist 1967; van Zeist and Bottema 1977). Those studies showed that during the last glacial period a cold and dry *Artemisia* steppe dominated the north-western part of the Zagros mountains. During the late-glacial-early Holocene, the Pistachio- oak forest steppe gradually expanded and was then replaced by the Zagros oak forest much later at ca. 6500 cal B.P. The spread of this forest towards the south- east probably occurred still later in the mid Holocene (Miller and Kimiaie 2006).

The study area

Zagros forests cover a vast area of Zagros mountain ranges stretching from Piranshahr (West Azerbaijan Province) in the northwest of the country to the vicinity of Firoozabad (Fars Province) having an average length and width of 1,300 and 200 km, respectively (Fig. 5). Classified as semi-arid, Zagros forests with an area of 5 million ha account for almost 40% of the Iran forests. Zagros is divided into two distinct regions based on the different Oak species, northern Zagros and southern Zagros. Northern Zagros is exclusive site of *Quercus infectoria* mixed with *Q. libani* or *Q. brantii* or both. Northern Zagros can be considered more humid and colder than southern Zagros. Southern Zagros is mostly dominated by *Q. brantii* (Sagheb- Talebi *et al.,* 2003).

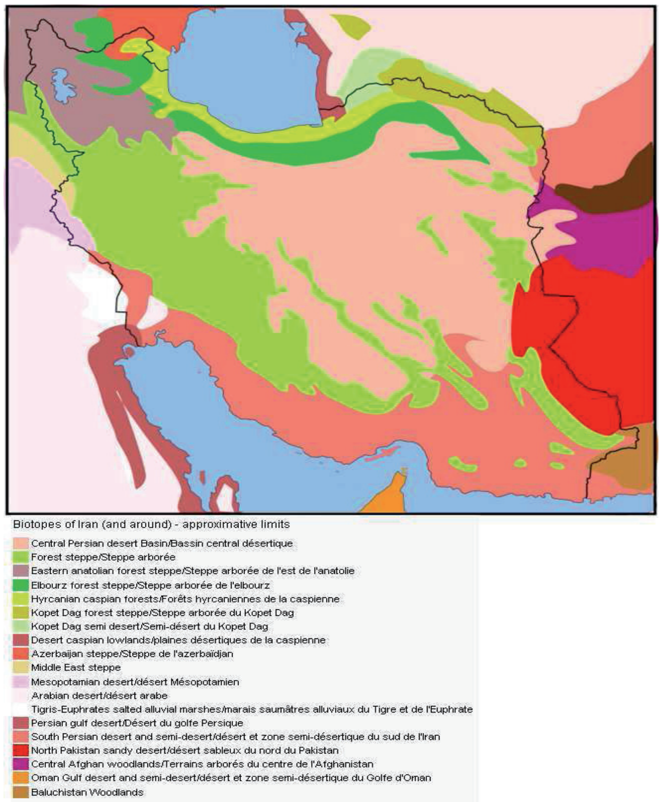


Fig. 5. Vegetation map of Iran

Soil studies

Soil study is important for landuse planning, agriculture and natural resource. Studing development of soil characteristics is one of the most important duties of soil researchers.

Soil not only support for vegetation, but also it is the zone beneath our feet (the pedosphere) with numerous interactions between climate (water, air, temperature), soil life (micro-organisms, plants, animals) and its residues, the mineral material of original and bed rock, and its position in the landscape. During its formation and genesis, the soil profile slowly deepens and develops soil layers characteristic, called 'horizons', while a steady state balance is been approached.

Soil is an active collection that will be formed between atmosphere, water and earth, and the common effects of water, atmosphere, plants and animals on the stones cause its creation and after its evolution reaches to equilibrium (Habibi Kaseb, 1992).

The relationship and interactions between soil and trees in the stands is so closed together that the study of one of them is not feasible without considering another one (Zarrinkafsh, 2001).

This study is a detailed soil survey which has been caried out in order to listing soil resources in different oak species forests in Kermanshah and Kurdistan provinces.

The obtained results will be used in reforesting in these areas and other similar forests which have common soil characteristics. The first aim of this study is classification of soil and scond is identification of soil potential and limitations for forest stands, and studing the relations between spatial patterns of different oak species with physical and chemical soil characteristics. Another aim is preparation of database includes physical and chemical soil characteristics in study sites.

General characteristics of studied sites

Two pilots are located in Bane (Kurdestan province) and two others are in Kermansah province. Geographical coordinates of first pilot (Sabadlou) in east of Bane is 36° 2′ 7″ northern latitude and 45° 57′ 21.1″ eastern longitude.

Second pilot (Armarde) is located in west of Bane as: 35° 55′ 26″ northern latitude and 45° 49′ 6.4″ eastern longitude.

The first pilot in Kermanshah province is located in Sar_Firooz_Abad region as: 33° 58′ 24″ northern latitude and 47° 0′ .6″ eastern longitude.

The second pilot of Kermanshah province is located in Heydariyeh region as: 45° 57′ 21.1″ northern latitude and 46° 12′ 13.4″ eastern longitude.

Climate

Bane meterological station is the nearest to the both pilots of Bane. Altitude of the station is 1600m. from the sea level. Based on its 8 years climate data the mean annual temperature is 13.6°c, December and January (mean .5 °) and July (mean 27.3°) are the coldest and warmest months in the year respectively. Mean annual precipitation is 714 mm. the maximum precipitation is in January (mean 153.1 mm.) and the minimum of that is in agust (mean 1.2 mm.) (Table 1).

The precipitation pattern is mediteranian so the highest rainfalls occur in cold seasons. Table 25 shows the 8 years climate datas of Bane meterological station. Amberothermic curve (Figure 30) and climate diagrams are plotted based on this meterological station datas (Figures 6 and 7).

Table 1. Climatic datas of Bane meterological station (2000-2007)

Latitude: 36◦ 0 ′ Longitude: 45◦ 54 ′ Altitude: 1600m.

Month	April	May	June	July	August	September	October	November	December	January	February	March	Sum
Mean Temperature (^{o}c)	10	14.8	21.2	26.3	27.3	23.7	18.7	10.6	4.2	.5	.5	5.7	13.6
Total Precipitation (mm.)	100.6	61.6	9.4	.4	1.2	1.4	15.2	76.3	104.6	97.1	153.1	92.1	714

Embrothermic Curve: The curve is based on the theory of coupons. The average monthly and changes in a coordinate system vertical axis are plotted. Month in which the horizontal axis, vertical axis of the monthly temperature and the right vertical axis to the monthly precipitation is allocated. The vertical axis is graded so that the number of divisions related to rainfall (mm) double the number relates to the temperature is considered (Figure 8).

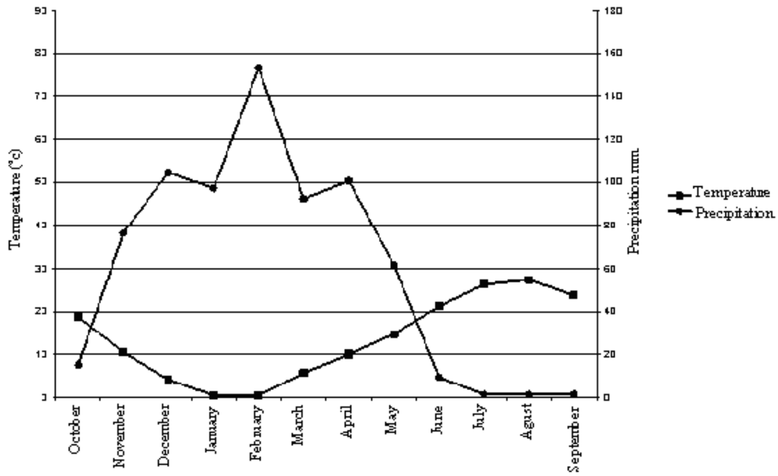


Fig. 6. Bane Embrothermic curve (Montly precipitation and temperature at the Bane synoptic station)

Bane has cold winters and relatively mild summers. Precioitation datas show that rainfall occurs in a regular wet- dry cycle. All significant precipitation falls from October to June, while the rest of year is very dry (Fig. 6).

Figures 7 and 8 show the annually distribution and average precipitation per month in Bane.

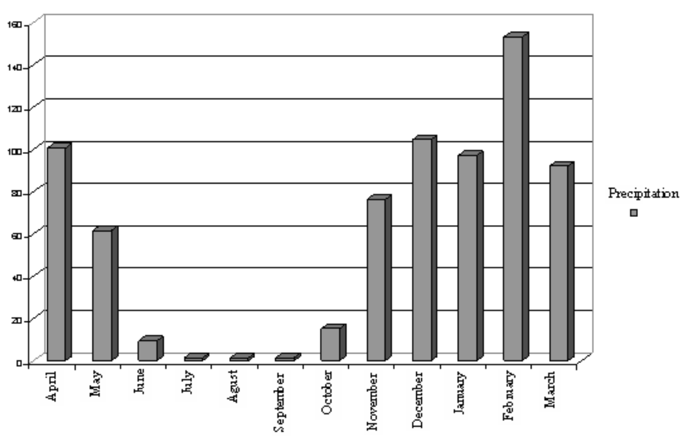


Fig. 7. Bane annually distribution and average monthly precipitation

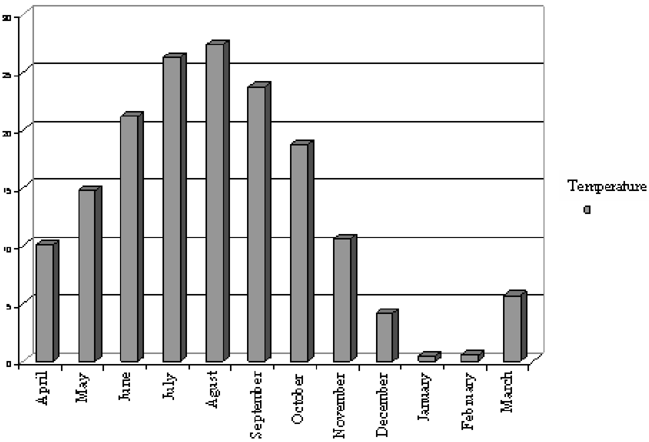


Fig. 8. Bane annually distribution and average monthly temperature

Islam Abad-e-gharb meterological station is the nearest to Heydariyeh pilot. Its altitude is 1346 m. Based on 21 years climate datas of this station, mean annual temperature is 6.1°c. January (mean 2.1°c) and July (mean 26.1°c) are the coldest and warmest months in the year respectively. Mean annual precipitation is 491.8 mm. The maximum rainfall is in March and the minimum occurs in July and Agust. The precipitation has mediteranian pattern and the highest rainfall occurs in cold seasons. According to Emberger method, this region is located in cold semi-aried climate. Table 2 shows the 11 years climate datas of this station. Amberothermic curve (Figure 9) and climate diagrams are plotted based on this meterological station datas (Figures 10 and 11).

Table 2. Climatic data of Islam Abade-Gharb meterological station (1975-1995)

Latitude: 34◦ 8′ Longitude: 46◦ 26′ Altitude: 1446m.

Month		April	May	June	July	Agust	September	October	November	December	January	February	March	Sum
Temperature (^{o}c)	Mean	12.5	16.5	21.9	26.1	25	20.9	14.9	8.9	3.8	2.1	3.4	7	13.6
	Max	20.1	25	32.2	36.4	35.8	31.9	24.2	16.3	9.1	7.7	9.7	13.4	21.8
	Min	4.8	8.8	11.5	15.7	14.2	9.9	5.5	1.4	-1.5	-3.5	-3	.6	5.3
Total Precipitation (mm)		41.7	29.3	1.2	٠	٠	٠	38.1	64.5	84.9	61.7	73.8	96.6	491.8
Potential evapotranspiration (mm)		106.4	143.4	182.9	206.5	192.2	149.3	100.3	58.3	37.1	37.5	45.3	71.1	1330.4

The mean monthly temperature ranges from 3.4 ^{o}c in February to 26.1 ^{o}c in July. The mean maximum temperature is 36.4 ^{o}c, and the mean minimum is -3.5 ^{o}c. The total annual potential evapotranspiration is 1330.4 mm (Table 2).

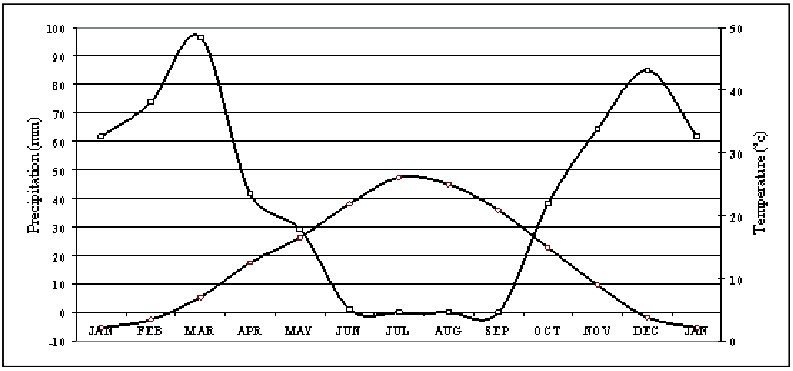


Fig. 9. Heydariyeh Embrothermic curve (Montly precipitation and temperature at the Heydariyeh synoptic station)

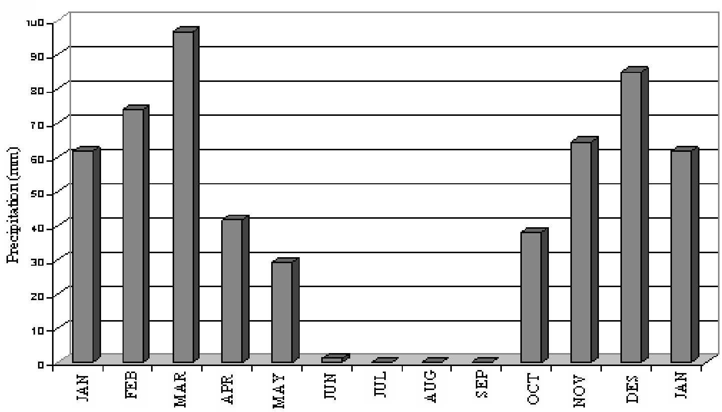


Fig. 10. Heydariyeh annually distribution and average monthly precipitation

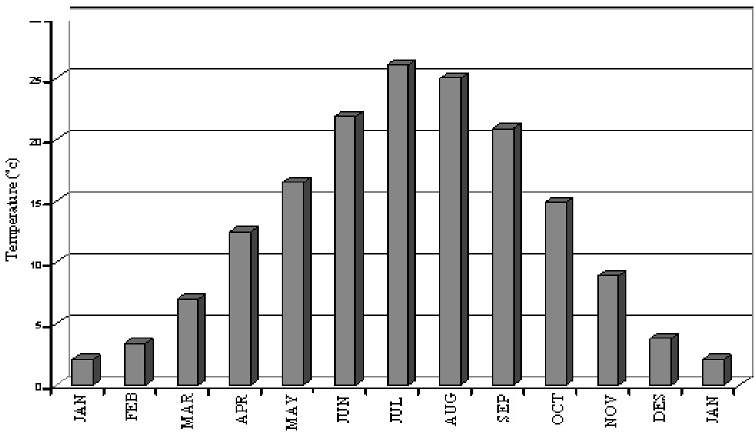


Fig. 11. Heydariyeh annually distribution and average monthly temperature

The climatic of Sar- Firooz- Abad is comparable to that of Kermanshah, so that the climatic data of Kermanshah will be used (Sar- Firooz- Abad has no meterological station) (Table 3). Its altitude is 1322 m. based on climate datas of this station; mean annual temperature is 14.1°c. January (mean 1.4°c) and July (mean 27.2°c) are the coldest and warmest months in the year respectively. Mean annual precipitation is 458 mm. The maximum rainfall is in March and the minimum of it occurs in Agust. Figure 12 shows the amberothermic curve and annually distribution of temperature and precipitation diagrams are plotted based on this meterological station datas (Figures 13 and 14 and).

Table 3. Climatic data of Kermanshah meterological station (1983-1993)

Latitude: 47◦ 7 ′ Longitude: 34◦ 32 ′ Altitude: 1322m.

Month		April	May	June	July	Agust	September	October	November	December	January	February	March	Sum
Temperature (°c)	Mean	12.8	17.2	22.7	27.2	26.5	21.9	15.7	9.4	4.5	1.4	3	7.5	14.1
	Max	20.2	25.6	33.2	37.7	37	32.6	24.5	16.4	9.8	6.5	8.7	13.7	22.2
	Min	5.3	8.8	12.2	15.7	16	11.2	6.8	2.3	-.9	-2.8	-2.7	1.2	6.1
Total Precipitation (mm)		48.4	29.8	.8	.5	.1	.7	32	57.9	81.4	59.8	62.8	83.8	458
Relative humidity (%)		53	۴۶	27	21	21	22	40	58	71	74	68	61	46.8

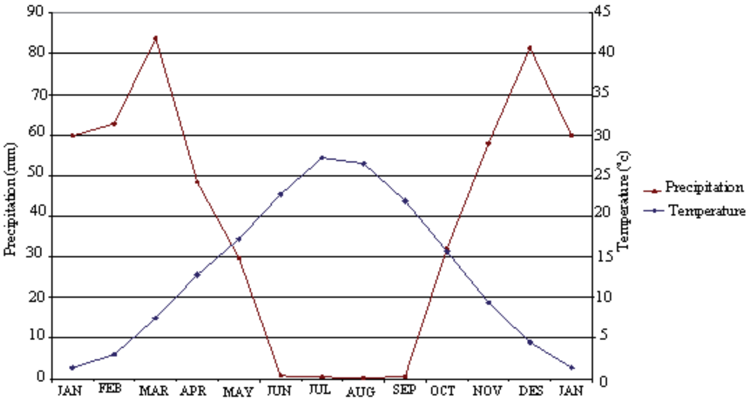


Fig.12. SarFiroozAbad Embrothermic curve (Montly precipitation and temperature at the Kermanshah synoptic station)

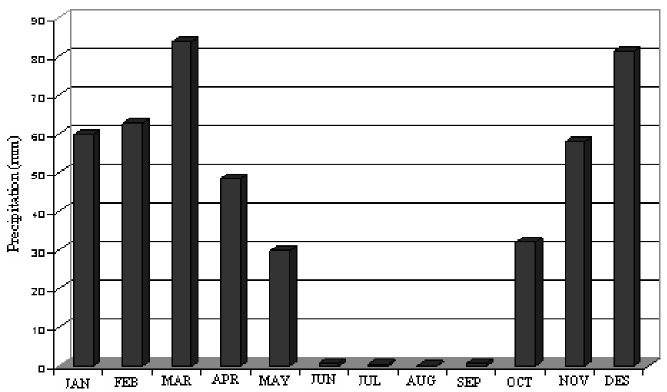


Fig. 13. Sar-Firooz-Abad annually distribution and average monthly precipitation

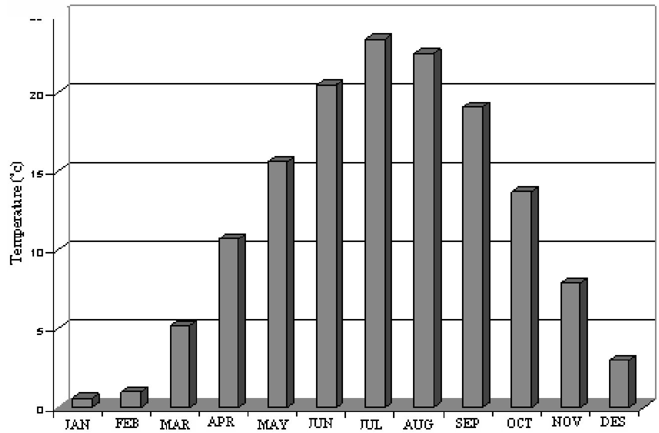


Fig. 14. Sar-Firooz-Abad annually distribution and average monthly temperature

- Soil Temperature and humidity Regimes

- Soil humidity Regime

Soil humidity regime is a major factor for the differentation of soils at the order level and related to changes of soil humidity within the year. Soils have divided into different humidity regime classes based on ground water table and having water or not in lower than 15 Bar presure.

- Soil Temperature Regime

The soil temperature regime is a distinctive criterion for the differentation of soil families and is rlated to mean annually soil temperature in main zone of root growth, namely 5- 100 cm deep and the mean of seasonal oscillation of trmperature and mean of temperature variation of warm and cold seasons in root zone growth (Van Vambeke, 1985). Based on humidity and temperature regime maps of Iran (Banaee, 1998), Heydariyeh and Sar-Firooz-Abad regions have Xeric humidity and Themic temperature regime. Sabadlou and Armarde regions have Xeric humidity and Mesic temperature regime.

- Geology

According to geology and mineral exploration organization datas (2005), Armarde and Sabadlou regions from geo- structure division viewpoint are located in Sanandaj- Sirjan zone.

Sabadlou region has located on Cretaceous lime stone that includes slighty metamorphic crystalian gray lime stones. And has placed on Fylyt Cretaceous unit**.**

Armarde region is located on Fylyt Cretaceous that generally in terms of lithology has Mica (especially Srysyt, Mskvyt and Chlorite) Quartz, Apak and Carbonaceous materials.

Sar_Firooz_Abad and Heydariyeh regions are located on Asmari**-** Shahbazan formation of Eocene – Oligocene based on geology maps of Kerend (1:100000) and Ilam- Kouhdasht (1: 250000) that includes a Carbonate row of lime stone and dolomitic limestone.

1- Spatial pattern studies:

The spatial distributions of all tree species were studied in four 100×200m (2ha) surface area plot using Ripley's univariate K function.

The study is focused in Kurdistan and Kermanshah provinces which are located in west of Iran close to the Iraq border (fig. 15) that are affected by precipitations from northern Europe, Atlantic Ocean and Mediteranian Sea. Precipitation usually decreases from north to south, and east to west (Jazirehi and Rostaghi, 2003) direct relationship between environments humidity and forest communities has created, specific pattern of eruption, thus only the western highlands, in Bane and Marivan cities (in Kurdistan), and north western to south eastern highlands of Kermanshah province, covered with Oak forest.

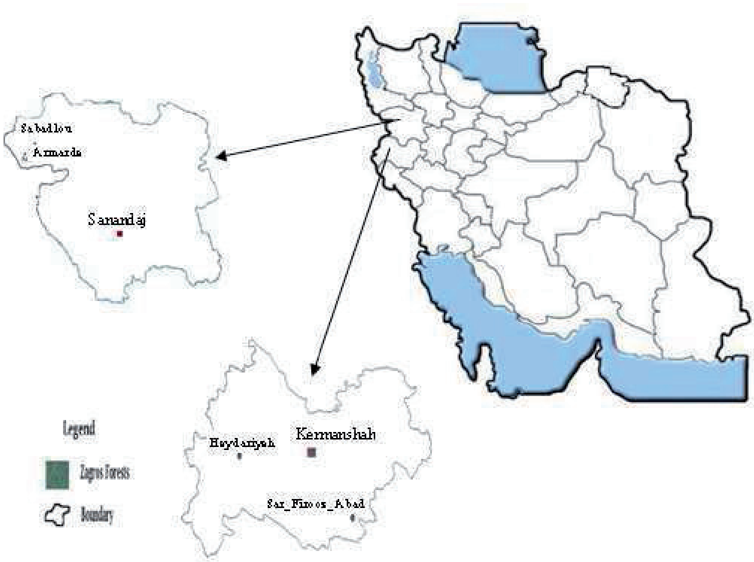


Fig. 15. Location of study area in the northern Zagros, Iran

This study considers four broad regions (fig. 6) of major oak associations in:

1. Sar_Firooz_Abad forest, in Kermanshah province with two species of Oak: *Quercus brantii* and *Quercus infectoria.* Sanandaj

2. Heydariyeh forest in Kermanshah province with *Q. brantii* as dominated species.

3. Sabadlou forest, in Kurdistan province with tree species of oak: *Q. brantii, Q. infectoria* and *Q. libani.* In this forest, *Q. infectoria* is dominated species.

4. Armarde forest, in Kurdistan province with tree species of oak: *Q. brantii, Q. infectoria* and *Q libani.*

The studied sites are located in the less destroyed areas of Zagros forest. Table 4 shows the habitat characteristics of the sites.

Tab. 4. Characteristics of study sites

Site name	Dominated Species	Soil	Mean annual rain fall (mm)	Mean annual temperature °C	Altitude (m)	Slope gradient (%)	Center coordinates (UTM)
Sar_Firooz_Abad	*Q. brantii*	Loam-Clay to Clay	458	14.2	1520	27	686277; 3760318
Heydariyeh	*Q. brantii*	Loam-Clay to Clay	491.8	13.6	1250	10	611095; 3773626
Armardeh	***Q. libani***	Loam-Clay to Loam	714	13.6	1670	30	573861; 3975874
Sabadlou	*Q. infectoria*	Loam-Clay to Loam	714	13.6	1758	30	586052; 3988248

Methods

1- Spatial pattern studies:

Various methods have been devised for eliminating or avoiding the effects of spatial dependence in measuring biotic responses. For example, sampling of ecological data has been typically carried out by stratifying across space and averaging to infer underlying processes and mechanisms. However, over the last 20 years, ecologists have begun to realize that there is a lot of important biology in the spatial dependence of biotic responses, and have become increasingly interested in examining spatial relationships directly. Where previous research ignored or sought to remove the effects of space, new research has sought to explicitly understand, measure and model spatial patterns in biotic responses as a critical aspect of the ecology of many organisms and systems.

An ideal statistical summary of a forest would be a complete description of the spatial distribution of its trees. The spatial arrangement of trees can be investigated by the map of tree locations in the area that is presented by points. So it is necessary to use Spatial Point Pattern Analysis (SPPA) to study the pattern of mapped trees (Scheuder et al. 1993; Dale 1999; Kint et al. 2004).

Perhaps equally important to conceptual advances, the availability of modern computer hardware and software (e.g., geographical information systems, increased computer speed and memory) has expanded our abilities to address many of the most interesting and critical problems in spatial ecology. Motivations for spatial analysis are diverse but the common thread is the quantification of spatial patterns. Not surprisingly, there is considerable variety in the types of statistical methods that have been selected to analyze and model spatial variation in ecological data.

Some of these methods have a long history in ecology, such as the early variance-mean analyses of Bliss (1941), Greig-Smith (1952), Taylor (1961), and Iwao (1972), the distribution work of Patil (e.g., Patil and Stiteler 1974), and ‘‘spatial pattern analysis’’ of grid and transect data (e.g., Hill 1973, Greig-Smith 1979, and recently summarized by Dale 1999). In some cases, specific models were built (e.g., the ‘‘functional response’’ of predators to host densities, Holling 1959) that in effect attempted to capture spatially-dependent processes without explicit reference to spatial location. The development of certain new, specialized statistical metrics has been motivated by the emerging field of landscape ecology, which focuses on spatial processes operating over various spatial extents (Turner 1989, Wiens 1989). However, many methods currently being applied for spatial analysis in ecology were originally developed in other scientific disciplines such as geography and mining geology. The analysis of spatial pattern is one way to distinguish between the different factors acting on forest ecosystems (Wolf, 2005).

Several different major schools of spatial analysis from other disciplines have been adopted by ecologists. The first of these comes from geography, and its methods include the use of statistics (e.g., Moran’s I, Geary’s C) to measure spatial autocorrelation (Moran 1950, Sokal and Oden 1978, Cliff and Ord 1981), as well as the employment of Mantel tests (e.g., Fortin and Gurevitch 1993, Legendre 2000). This school of analysis generally incorporates hypothesis testing as an important part of the analysis. These methods have also been adapted for correcting for spatial autocorrelation in data when testing hypotheses about relationships between two or more variables, particularly by using Mantel tests (e.g., Smouse et al. 1986, Legendre

1993, Manly 1997, Me´ot et al. 1998). A different tradition for the statistical analysis of spatial data adopted by ecologists, known as geostatistics, was originally developed for applied geological problems. These methods use various statistical methods (e.g., construction of variograms and determination of spatial covariance) to quantify spatial utocorrelation (or ‘‘spatial dependence’’; e.g., Isaaks and Srivastava 1989, Rossi et al. 1992, Liebhold et al. 1993).

While equivalencies exist for many of the statistics employed in this tradition and those used in geography, these schools of spatial statistical analysis developed independently, have different terminology, and have different perspectives. For example, geostatistics emphasizes spatial estimation, rather than hypothesis testing (e.g., Liebhold et al. 1991). Methods (including kriging and spatial simulation) have been developed in geostatistics to estimate values at unsampled locations via interpolation from nearby locations, and to provide confidence intervals for interpolated values. These methods are used for estimating entire surfaces or mapping spatial data. Kriging and related spatial estimation procedures increasingly are being used in both basic and applied ecology (Robertson 1987, Liebhold et al. 1993).

One of the most famous methods to analyze the spatial pattern of points that show the position of trees in an area is the nearest neighbor index introduced by nearest neighbor distances (Ludwig and Reynolds 1988). The nearest neighbor technique is widely used for spatial pattern recognition, due to their simplicity and ease of implementation (Dale 1999; Kint et al. 2004; Yang and Lee 2007).

Other approaches to spatial analysis, such as dispersion indices, were developed specifically for ecological applications (see review in Dale 1999). In the late 1960s and 1970s) a variety of methods were developed to infer spatial pattern from the frequency distribution of sam- ple counts (e.g., Taylor 1961, Iwao 1972). Although these methods can be used to differentiate among some types of spatial patterns, they do not use information about the spatial location of samples and fall short in their abilities to differentiate between types of patterns. Other methods developed for ecological applications were designed for specific types of data. Nearest neighbor and related statistics, for example, were developed for analysis of data consisting of exhaustive maps depicting the locations of all individuals (e.g., trees in a forest; Ripley 1979, 1981). Another group of methods were developed for applications in landscape ecology for analysis of polygonal data (e.g., polygons representing isolated forest stands in a largely agricultural land use; McGarigal and Marks 1995). In addition to the methods broadly described above, other approaches, such as spectral analysis (Ford and Renshaw 1984), wavelet analysis (e.g. Bradshaw and Spies 1992, Dale and Mah 1998), and fractal analysis (Milne 1992) have been applied to the analysis of spatial data in ecology.

In ecological studies of spatial patterns, Ripley method very has been used recently (liebhold and Gurevitch, 2002). That is used in this study too.

At first glance, these ecological methods appear to be fundamentally different from methods derived from geological or geographical applications, but as Ripley (1981) showed, for example, point locations can be aggregated into counts in quadrats which can then be analyzed for spatial autocorrelation. Similar transformations could be applied to polygonal data as well. Thus, relationships may exist among these methods, but these relationships generally remain obscure to most ecologists.

Sampling and analysis:

The spatial distributions of all tree species were studied in four randomly established 100x200m (2ha) surface area plot using Ripley's univariate K function.

After recording geographical coordinate of plots, position of trees in each plot was recorded using distance-Azimuth method. In the square plot, each stem had an *x* and a *y* value, depending on its distance to the reference point (one of the corners of the plot). Distance and Azimuth of each tree were determined regarding to the previous tree of them and then transformed to UTM. Furthermore diameters of trees bigger than 7.5 cm have been recorded and classified in 1 cm classes. Ripley index was used to determine spatial pattern of trees based on the geographical position.

A point process is the equivalent of a random variable whose result is a point, defined by its coordinates (x, y) in a pre-defined area.

The «point process» formulation was used to describe and analyze point patterns, especially by determining some global properties (laws) in the random locations of trees in the stand. A point process P is a stochastic process which « generates » random point patterns that share the same spatial structure (the law of the process), such as Poisson (completely random), regular, or clustered patterns. A stand can be considered as a realization of an underlying point process, whose properties are a good description of the spatial structure of the stand (Goreaud *et al*., 1997).

Mathematical method: Point processes and Ripley's K(r) function.

Stand spatial structure is quite a complicated concept, including both horizontal and vertical use of space by trees. To simplify this approach, we focus here on the horizontal location of stems in the stand: the study area is represented by a part of the horizontal plane bounded by stand borders, and each tree is represented by a point, defined by its coordinates (x,y). The stand is then reduced to a finite set of points, called a point pattern.(Fig. 16)

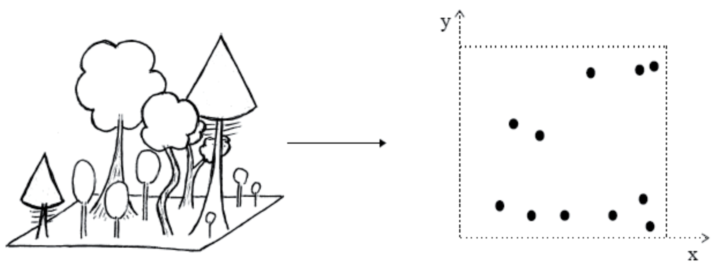


Fig. 16: From the real stand to the point pattern (after Goreaud et al., 1997)

A point process is the equivalent of a random variable whose result is a point, defined by its coordinates (x, y) in a pre-defined area.

The «point process» formulation can be used to describe and analyses point patterns, especially by determining some global properties (laws) in the random locations of trees in the stand. A point process P is a stochastic process which « generates » random point patterns that share the same spatial structure (the law of the process), such as Poisson (completely random), regular, or clustered patterns (Fig. 17). A stand can then be considered as a realisation of an underlying point process, whose properties are a good description of the spatial structure of the stand.

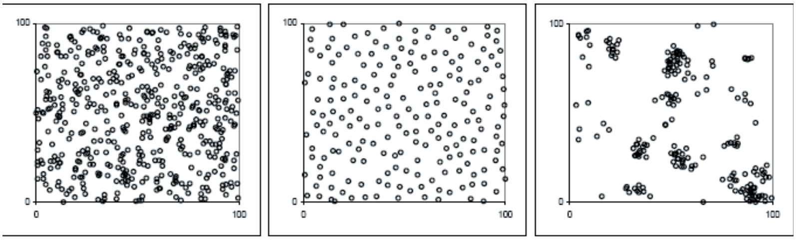


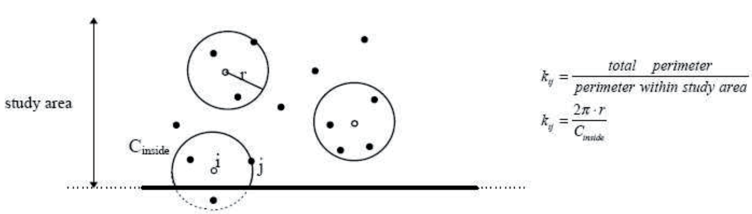
Fig. 17: Examples of Poisson, regular and clustered point patterns (after Goreaud et al., 1997)

Under the assumptions of stationary (the process must be invariant under translation) and isotropy (invariance under rotation), the main characteristics of a point process can be summarized by its intensity λ (the expected number of points per unit area) and Ripley's K(r) function, defined so that λ*K(r) is the expected number of neighbors in a circle of radius r centered on an arbitrary point of the process (Ripley, 1977). We can calculate estimators of λ and K(r):

$\hat{\lambda} = \frac{N}{S}$; Where N is the number of points in the pattern and S is the area of the study region;

$\hat{K}(r) = \frac{1}{\hat{\lambda}} * \frac{1}{N} * \sum_{i=1}^{N} \sum_{j \neq i} k_{ij}$; Where kij=1 if the distance between i and j is less than r, and 0 otherwise.

However, for the points located near the border, this underestimates the real number of neighbors (some neighboring trees could be outside the study area, see Fig. 9). Therefore, we use the edge-correction factor proposed by Ripley: for those points kij is the inverse of the proportion of the perimeter of the circle (centered on i and passing through j) which is within the study area.



For a Poisson process, the expected number of points in a region S is known to be $\lambda \times S$, where λ is the intensity of the process.

Therefore the number of neighbours in a circle of radius r will be $n = \lambda \times \pi \times r^2$, and then: $K(r) = \pi \times r^2$

For a regular process, each point tends to have fewer neighbours than in a Poisson process, so that $K(r) < \pi \times r^2$

In a clustered process, trees have more neighbours than in a Poisson process, so $K(r) > \pi \times r^2$

To simplify the interpretation, we use a linearized function L (r) proposed by Besag (1977): $\hat{L}(r) = \sqrt{\hat{K}(r)/\pi} - r$.

Then for a Poisson pattern, $L(r) = 0$ at every distance r; for clustered patterns at distance r, $L(r) > 0$; and in the case of regularity at distance r, $L(r) < 0$.

In real bounded areas, stochastic variations can lead to small positive or negative values of L_(r) even for the Poisson process. In order to test this « complete spatial randomness » (csr) hypothesis, we build confidence intervals using the Monte Carlo method. Therefore, a great number (1000 or 10000) of Poisson patterns are simulated. The L(r) values of those patterns are then ordered, and the confidence interval is defined for each r so that only the 5% highest and the 5% lowest values of L(r) are outside the interval.

The *K* function, defined by Ripley (1976); Ripley (1977) is a good indicator for spatial structures (Besag, 1977, Diggle, 1983, Cressie, 1993).

Ripley's K function for the data is compared with the expected line y=x under Poisson distribution of the points.

2- Site demand study:

After selecting the main sites of the mentioned species, following steps were done:

Vertical distribution of the species was determined by studying the minimum and maximum altitude of presence of the species. Horizontal distributions of the species were determined by considering the latitude and longitude. Various landforms including crest line, valley and slope, and various geographical aspects (north, east, south and west) were determined as well.

Regarding the above mentioned criteria, 45 500m^2 circular plots were laid out, where the studied species were dominant. In each plot, the following quantitative and qualitative characteristics of trees were studied:

All of tree species, diameter at breast height (dbh) or diameter of the thickest sprout (for sprout clumps), total height, trunk length and crown shape (straight, forked and broom shaped).

In order to study life restoration, in center of any plot, a sample of circular plot was taken into consideration and counted restoration to life of considered species to calculate sapling numbers in unit of level. Also plant specimens determined in species rank.

3- Soil study

For soil study, in each different position of sample plot, a soil profile has been prepared and the physico-chemical properties (P, K, Ca, total N, C%, CaCo3%, pH, Ec and texture) of soil were studied.

The main activities:

- Bibliography as below sections:

1- Aerial photographs with the scale 1:50000

2- Topographic maps with the scale 1:50000

3- Geology maps with the scale 1:250000

4- Satallite photographs in algorithm

-Field work

After initial field observations and determinating sampling areas, 5 points were selected and pedons were excaveted to a depth of about 150 cm and soil morphological properties were studied by using field book for describing and sampling soils (Shourenberger et al., 1998). All horizons of the soil profiles were sampled for labratoary analysis in Soil and Water Research Department of

Kermanshah Research Center of Natural Resource. Geographic position of study regions were recorded by Global Poisoning System (G.P.S.) too.

- Experimental analysis

Soil samples for Physical and chemical analysis were transferred to the laboratory. In labratoary the required chemical and physical analysis based on the conventional methods in journals No. 893 and 1024 of Soil and Water Research Institue, was performed. The primary analysis contain: electrical conductivity of soil solution (EC) by soil electrical conductivity meter, soil reaction by soil Potentiometric method (measuring the activity of hydrogen ions), soil texture by hydrometric method and conductivity with inter material reacting with the acid titration method was done. According to initial results and field observations, the control profiles were determined and the analysis completed as follow: determination of soil texture, organic carbon, and Cations exchange capacity, Gyps content, total nitrogen by Kjeldahl method, phosphorus absorption measurement by Olsen method, soil potassium measuring through film photometric and Calcium and magnesium measurement by complexiometery method was carried out.

Statistical analysis

Study of the relationship between the presence of the species and the environmental factors was used by PC-Ord for Win. Ver. 4.17 Mc (Cune and Mefford, 1999).

Principal component analysis (PCA):

PCA is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components. The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has as high a variance as possible (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it orthogonal to (uncorrelated with) the preceding components. Principal components are guaranteed to be independent only if the data set is jointly normally distributed. PCA is sensitive to the relative scaling of the original variables.

Canonical Correspondence Analysis (CCA):

CCA is derived from correspondence analysis, but has been modified to allow environmental data to be incorporated into the analysis. It is calculated using the reciprocal averaging algorithm of correspondence analysis. However, at each cycle of the averaging process, a multiple regression is performed of the sample scores on the environmental variables. New site scores are calculated based on this regression, and then the process is repeated, continuing until the scores stabilize. The result is that the axes of the final ordination, rather than simply reflecting the dimensions of the greatest variability in the species data, are a linear combination of the environmental variables and the species data. In this way these two sets of data are then directly related. CCA is a 'constrained' analysis technique because the ordination is constrained by the environmental variables.

Chapter 3

Results

General information of the studied sites is given in table 5. Stem number per ha varied between 168.5 in Heydariyeh and 289.5 at Sar_Firooz_Abad. The least mean dbh was calculated in Sar_Firooz_Abad (6.2 cm) while the maximum mean dbh was found in Armardeh (30.9 cm). Sar_Firooz_Abad showed the minimum mean crown cover (5.9%), whereas Haydariyeh showed the maximum crown cover (14.9%).

Tab. 5. Summary of stand characteristics

Mean crown cover (m^2ha^{-1})	dbh coefficient of variation	Max dbh (cm)	Mean dbh (cm)	Density (trees ha^{-1})	Site name
5.9	161.9%	57	6.2	289.5	Sar_Firooz_Abad
14.9	46.7%	70	18.6	182.0	Heydariyeh
7.4	30.1%	64	30.9	222.5	Armardeh
13.2	30.4%	52	24.2	168.5	Sabadlou

As shown in table 6, *Q. brantii* had the maximum frequency (148 N/ha) and *Q. libani* the minimum frequency (65.5 N/ha) in the studied sites. In contrast to density, the crown canopy of *Q. libani* was the highest (16.3 m^2/ha) among the studied species. Mean height of the trees was more or less equal and varied between 6.5 m by *Q. brantii* and 6.9 m in the both other oak species. Mean dbh was also almost the same among the species and varied between 23.8 cm by *Q. libani* and 24.5 cm by *Q. brantii*.

Tab..6. Species parameters estimated using descriptive statistic in deferent regions. Standard errors of parameters estimates are given in parenthesis.

	Density (N ha^{-1})	Canopy area (m^2 ha^{-1})	Maen height (m)	Mean dbh. (cm)
Q. brantii	148.0	14.1 (1.29)	6.5 (0.16)	24.5 (0.8)
Q. libani	65.5	16.3 (1.1)	6.9 (0.17)	23.8 (1.2)
Q. infectoria	92.2	12.6 (0.3)	6.9 (0.07)	24.2 (0.4)

Soil studies

Habitat characteristics and soil properties of the studied sites are presented in table 7.

Tab. 7. Habitat characteristics and soil properties of the studied sites.

Species	Aspect	Slope gradient (%)	Altitude m.	Soil properties						
				Clay (%)	Silt (%)	Sand (%)	C (%)	$CaCo_3$ (%)	pH	EC ds/m
Q. infectoria	N NW	17-70	1200-1710	1.6-40.6	25-63	26-43	1.05-4	2.5-41	6.9-7.7	.2-.88
Q. libani	N NE	5-55	1450-1710	16-60	6-30	26-56	.36-3.8	.5-1.87	6.4-7	.1-.89
Q. brantii	All	5-60	1200-1940	13.4-58	17-49	5-47	.84-4	2-41	6.7-7.7	.4-2.7

Soil acidity of the habitats of the three oak species is very different. *Q. libani* is present in acid soils, the minimum and maximum of soil pH are between 6.4- 7, interquartile range is really low so it can be said that pH is one of the restricted factors for *Q. libani* (fig. 18).

The variation range of pH in *Q. brantii* habitats is too low (7.0 – 7.75), and its interquartile range is less than *Q. libani*. Obviously, *Q. brantii* prefers neutral to alkaline soils.

Q. infectoria has the wider range of pH than two other species. Although such species as like as *Q. brantii* prefers neutral to alkaline soils, but has a wider range of variations, and its interquartile range is larger too, so it seems that *Q. infectoria* distribution isn't restricted to pH (Fig.18).

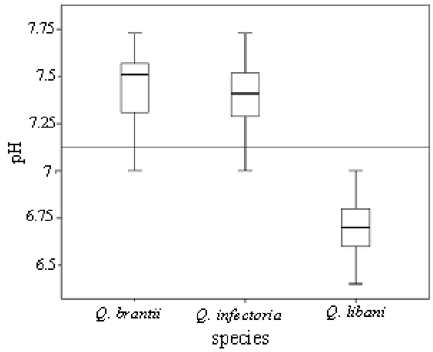


Fig.18. The range of pH in habitats of the three oak species

Although oak habitats overall have low EC (Lower than average), Figure 19 shows that the EC variation range in *Q. libani* habitats is much less than two other species. The minimum and maximum of EC are 0.1 and 0.9 ds/m, respectively and its interquartile range is more limited, the median has more tendencies to maximum of observations.

Q. infectoria has an EC variation range between 0.2- 0.9 ds/m which is more than *Q. libani* but its median has more tendency to minimums and such ranges among *Q. brantii* habitats is 0.4 – 2.7 ds/m and its median has more tendency to minimums, in other words the minimum frequency is around the mean (Fig. 19).

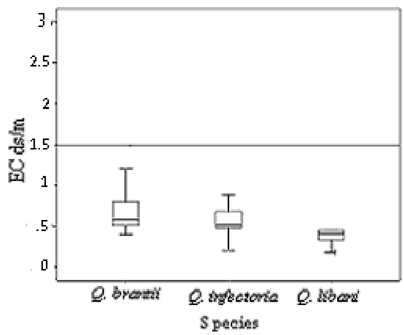


Fig.19. The range of EC in habitats of the three oak species

Q. libani exists in the soils with low $CaCo_3$ and the least variation range; therefore $CaCo_3$ content is a restricted factor for the presence of *Q. libani*. The maximum $CaCo_3$ variation range in *Q. infectoria* habitats is between 2.5% and 41%, whereas in *Q. brantii* habitats $CaCo_3$ varies between 2% and 41% Hence, *Q. brantii* is consistent to soils with high $CaCo_3$ content (Fig.20).

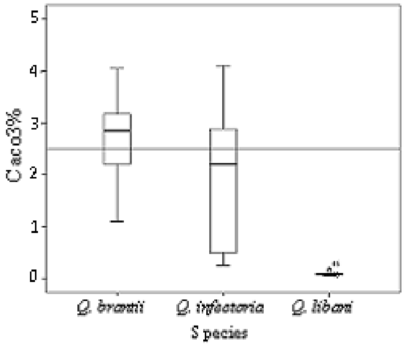


Fig.20. The range of $CaCo_3$ in habitats of three species of oak

Figure 21 shows the Carbon content in all three species habitats with a wide range of this factor. The maximum variation range of carbon is between 0.36% and 3.9% for *Q. libani*. Carbon content varies between 0.84% and 4% for *Q. brantii* and between 1.05% and 4% for *Q. infectoria*. Interquartile range for all three species has a large variety and it seems that carbon content of soil does not play any limitation role on the presence of all three studied oak species.

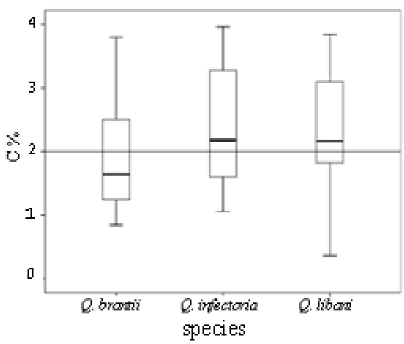


Fig.21. The range of C% in habitats of three species of oak

It seems clay is one of the limiting factors for *Quercus* spp. presence (Fig. 22). *Q. libani* favor heavy and semi-heavy soils. The clay variation range in these species habitats is 16% to 60%. In other words, it has adaptation with heavy and semi heavy soils. *Q. infectoria* occurs in soils with 1.6% to 40.6% of clay content, therefore is more favorable with Light soils. The clay variation range in *Q. brantii* habitats is more than in the two other species (13.4% - 57.8%). Although it seems that distribution of *Q. brantii* is toward to heavy soils but its box plot shows that the range of distribution in low sand soils is more.

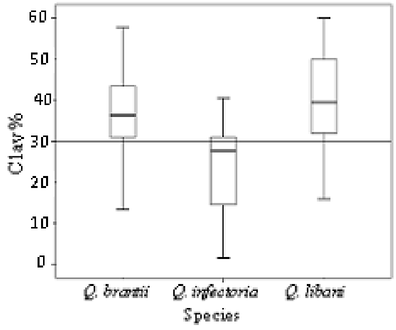


Fig.22. The range of clay in habitats of three species of oak

Q. libani and *Q. infectoria* prefers high sand content in soil. Sand content varies between 26% and 56% in *Q. libani* sites, and in *Q. infectoria* habitats is 26% to 42.6% while the range of *Q. brantii* distribution in low sand soils is more. (Fig. 23).

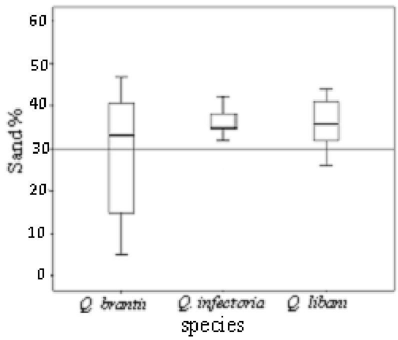


Fig.23. The range of sand in habitats of three species of oak

Fig.24. shows that the variation range of silt content is larger in *Q. infectoria*'s sites than in the other two oak species.

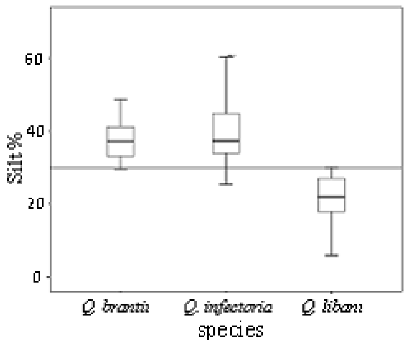


Fig.24. The range of silt in habitats of three species of oak

Fig.25. shows that *Q. brantii* has a wide altitude range (1200-1900) m.a.s.l. which is larger than the other two species. Moreover, the minimum altitude range of *Q. libani* is 1500 m.a.s.l., while *Q. brantii* and *Q. infectoria* can occur in lower altitudes at almost 1200 m.a.s.l.

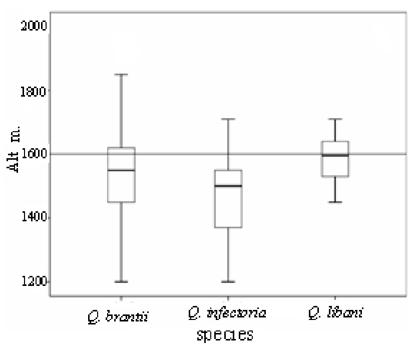


Fig.25. the range of Altitude in habitats of three species of oak

There is difference between slope gradient tolerances in habitats of these three species (Fig. 26). *Q. brantii* and *Q. infectoria* trees are distributed in steeper slopes with gradient between 15% and 70%, most observations are in higher than average (more than 30%). Maybe the most important reason is the native's activities and replacing to farms and consequently this species has located in higher slops areas where there is no cultivation possibility. While *Q. libani* occurs in less steep sites with a gradient between 5% and 55%. The first and second quartiles of its observations are lower and the third and fourth are higher than average. As a result such species presents in high slops because of local residents damages.

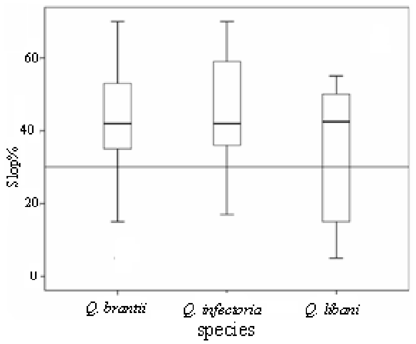


Fig.26. the range of slope gradient in habitats of three species of oak

The direction variation range for presenting different oak species shows that such species have great difference from geographical diverse directions point of view. *Q. brantii* nearly finds in all different directions but two other species mostly are in northern directions and seldom find in other directions. Consequently direction is one of the most effective factors in distributing of different oak species (Fig. 27 and 28).

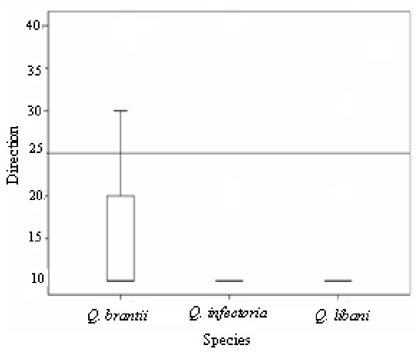


Fig.27. The range of direction in habitats of three species of oak

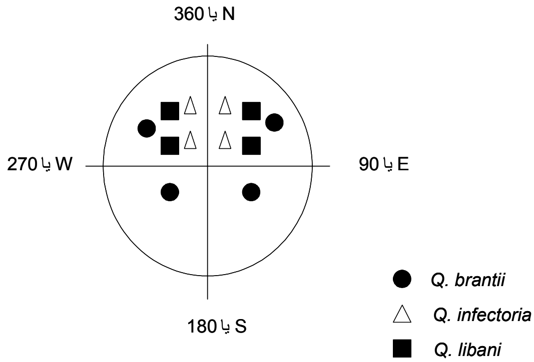


Fig. 28. Presenting different oak species in different directions

Table 8 shows the results of T-student analysis for comparison of means for environmental characteristics and soil properties in habitats of the three oak species. There are significant differences between pH, CaCo3, clay, and sand content ($p<0.01$) as well as altitude ($p<0.05$) at the *Q. libani* and *Q. infectoria* sites. The mean of ph, CaCo3, clay and sand content showed significant differences ($p<0.01$) at *Q. brantii* and *Q. libani* sites. None of the environmental characteristics had significant difference in *Q. brantii* and *Q. infectoria* sites.

Tab.8. Comparison of mean (T- student) for environmental characteristics in habitats of three oak species

Criteria	t (*Q. brantii* & *Q. infectoria*)	Sig.	t (*Q. brantii* & *Q. Libani*)	Sig.	t (*Q. Libani* & *Q. infectoria*)	Sig.	df
pH	0.94	0.34ns	9.9	0.000**	8.84	.000 **	61
EC	0.96	0.33ns	1.83	٠.07 ns	1.96	0.059ns	61
Caco3	٠.69	0.49ns	5.3	.000 **	4.78	0.000 **	61
%C	٠.99	0.32ns	٠.42	٠.66 ns	٠.29	٠.77ns	61
Clay	٠.76	0.45ns	4.3	0.000**	4.18	0.000 **	61
Sand	٠.64	0.52ns	3.03	٠.004**	3.3	0.002 **	61
Silt	٠.15	0.88ns	٠.39	٠.69 ns	٠.51	٠.61ns	61
Altitude	1.75	0.08ns	٠.91	٠.36 ns	2.67	٠.012 *	61
Slop gradiant	٠.94	0.34ns	1.3	٠.18 ns	1.807	0.081ns	61

*= ($P<0.01$) **= ($P<0.05$) ns= not significant

Tab. 9. Characteristics of trees in Armarde region

location	Species		Canopy area (m^2)	Trunk length (m)	Crown length (m)	Total height (m)	Diameter at breast height (cm)
1	*Q. brantii*	**Mean**	7.72	1.94	4.56	6.50	30.3
		Std. Deviation	3.04	0.23	0.92	0.81	8.3
		Minimum	2.98	2	3	5.6	22.0
		Maximum	12.56	2	6	7.7	43.0
	Q. infectoria	**Mean**	10.34	2.23	5.60	7.813	31.30
		Std. Deviation	45.02	.414	4.25	4.31	9.83
		Minimum	0.63	2	2	3.5	16
		Maximum	644.34	4	61	64.0	58
	Q. libani	**Mean**	7.64	1.91	5.60	7.51	30.74
		Std. Deviation	4.67	0.24	1.80	1.87	8.93
		Minimum	1.22	2	1	3.0	16
		Maximum	30.66	3	10	12.0	64

Tab. 10. Characteristics of trees in Sabadlou region

location	Species		Canopy area (m^2)	Trunk length (m)	Crown length (m)	Total height (m)	Diameter at breast height (cm)
2	*Q. brantii*	**Mean**	14.16	1.81	4.66	6.47	24.59
		Std. Deviation	8.87	0.23	1.07	1.12	5.66
		Minimum	3.97	1	2	3.9	15
		Maximum	42.40	2	7	9.0	37
	Q. infectoria	**Mean**	12.63	1.81	5.14	6.94	24.20
		Std. Deviation	5.06	0.23	1.20	1.24	7.73
		Minimum	0.00	1	2	3.2	1
		Maximum	28.26	3	9	11.0	52
	Q. libani	**Mean**	16.35	1.92	5.02	6.94	23.82
		Std. Deviation	6.40	0.29	0.95	0.93	6.72
		Minimum	5.30	1	3	5.4	14
		Maximum	36.8	3	7	9.0	36

Tab. 11. Characteristics of trees in Heydariyeh region

location	Species		Canopy area (m^2)	Trunk length (m)	Crown length (m)	Total height (m)	Diameter at breast height (cm)
3	*Q. brantii*	Mean	13.41	1.78	4.71	6.49	18.83
		Std. Deviation	11.05	0.831	1.78	1.73	8.66
		Minimum	0.78	1	-11	1.6	2
		Maximum	55.38	16	9	10.7	70
	Crataegus pontica	Mean	9.59	0.94	4.07	5.00	14.9
		Std. Deviation	6.17	0.653	1.48	2.10	9.75
		Minimum	.567	0	2	1.9	1
		Maximum	23.74	3	7	9.6	30

Tab. 12. Characteristics of trees in Sar_Firooz_Abad region

location	Species		Canopy area (m^2)	Trunk length (m)	Crown length (m)	Total height (m)	Diameter at breast height (cm)
4	*Q. brantii*	Mean	5.09	0.94	1.89	2.829	3.10
		Std. Deviation	7.85	0.381	0.61	0.80	2.09
		Minimum	0.19	0	0	1.1	0
		Maximum	153.86	3	4	5.1	10
	Q. infectoria	Mean	16.52	2.01	4.37	6.37	35.01
		Std. Deviation	5.89	0.35	1.23	1.28	7.73
		Minimum	1.76	1	1	2.8	4
		Maximum	30.66	3	7	9.2	57

All characteristics as canopy area, trunk length, crown length, total height and diameter at breast height (dbh), between *Q. brantii* and *Q. infectoria* in Sar_Firooz_Abad forest showed significance differences ($p<0.01$), in which the data for and *Q. infectoria* was superior than *Q. brantii* (Table 13).

Tab. 13. Comparison of *Q. infectoria* and *Q. brantii* characteristics by T- student in Sar_Firooz_Abad forest

	t- student for Equality of Means	
	t	Sig. (2-tailed)
Canopy area m^2	-13.143	.000 **
	-15.972	.000 **
Trunk length m	-24.587	.000 **
	-25.764	.000 **
Crown length m	-29.207	.000 **
	-18.738	.000 **
Total height m	-34.702	.000 **
	-25.334	.000 **
Diameter at breast height cm	-77.451	.000 **
	-38.889	.000 **

** = ($p<0.01$)

Table 14 shows the comparison of *Q. infectoria* and *Q. brantii* characteristics by t- student in Sabadlou forest.

Tab. 14. The comparison of *Q. infectoria* and *Q. brantii* characteristics by t- student in Sabadlou forest

	t- student for Equality of Means	
	t	Sig. (2-tailed)
Canopy area (m^2)	1.662	0.098 ns
	1.147	0.257 m^2
Trunk length (m)	-.100	0.921 ns
	-.101	0.920 ns
Crown length (m)	-2.529	0.012 *
	-2.749	0.008 **
Total height (m)	-2.468	0.014 *
	-2.648	0.010 **
Diameter at breast height (cm)	.337	0.737 ns
	.417	0.678 ns

*= $p<0.05$, ** = $p<0.01$, ns = not significant

Tab. 15. The comparison of *Q. libani* and *Q. brantii* characteristics by T. test in Sabadlou region

	t- student for Equality of Means	
	t	Sig. (2-tailed)
Canopy area	-1.152	0.253 ns
m^2	-1.243	0 .218 ns
Trunk length m	-1.793	0.077 ns
	-1.701	0.095 ns
Crown length m	-1.494	0.139 ns
	-1.536	0.129 ns
Total height m	-1.891	0.063 ns
	-1.976	0.052 ns
Diameter at breast height cm	.538	0.592 ns
	.517	0.608 ns

ns = not significant

Table 16 shows the comparison of quantitative characteristics for *Q. infectoria* and *Q. libani* by t- student analysis in Sabadlou region. Only canopy area ($p<0.01$) and trunk length ($p<0.05$) showed significant differences between *Q. libani* and *Q. infectoria*. The canopy area of *Q. libani* was higher than in *Q. infectoria*, whereas the trunk length of *Q. infectoria* is higher than in *Q. libani*.

Tab. 16. The comparison of *Q. infectoria* and *Q. libani* characteristics by t- student in Sabadlou forests

	t- student for Equality of Means	
	t	Sig. (2-tailed)
Canopy area	-3.637	0.000**
m^2	-3.017	0.005**
Trunk length m	-2.196	0.029*
	-1.870	0.071*
Crown length m	.488	0.626 ns
	.588	0.560 ns
Total height m	.034	0.973 ns
	.042	0.966 ns
Diameter at breast height cm	.251	0.802 ns
	.281	0.781 ns

*= p<0.05, ** = p<0.01, ns = not significant

The comparison of quantitative characteristics of *Q. brantii* between Armerde and Sabadlou forests is presented in Table 17. Only canopy area of *Q. brantii* showed significant difference ($p<0.05$) between Armarde and Sabadlu.

Tab. 17. The comparison of *Q. brantii* characteristics in Armerde and Sabadlou forests by t-student analysis

	t- student for Equality of Means	
	t	**Sig. (2-tailed)**
Canopy area m^2	-1.890	0.030*
	-3.720	
Trunk length m	1.426	0 .896 ns
	1.440	
Crown length m	-.245	0.656 ns
	-.275	
Total height m	.067	0.357 ns
	.086	
Diameter at breast height cm	2.350	0.152 ns
	1.768	

*= $p<0.05$, ns = not significant

Results of t- student analysis for quantitative characteristics of *Q. brantii* between Armerde and Heydariyeh forests are presented in table 18. Canopy area and total height of Q. brantii trees showed a significant difference ($p<0.05$) in these two sites.

Tab. 18 . The comparison of *Q. brantii* characteristics in Armerde and Heydariyeh forests by t-student analysis

	t- student for Equality of Means	
	t	Sig. (2-tailed)
Canopy area m^2	-1.358	0.014 *
	-4.401	
Trunk length m	.510	0.711 ns
	1.643	
Crown length m	-.203	0.245 ns
	-.385	
Total height m	.011	0.069 *
	.022	
Diameter at breast height cm	3.488	0.915 ns
	3.637	

*= $p<0.05$, ns = not significant

The quantitative characteristics of *Q. brantii* were also compaired Between Armerde and Sar_Firooz_Abad forests by t- student analysis. Crown length and dbh of the trees showed significant differences ($p<0.01$) between Armarde and Sar_Firooz_Abad sites (Tab. 19).

Tab. 19. The comparison of *Q. brantii* characteristics in Armerde and Sar_Firooz_Abad forests by t- student analysis.

	t- student for Equality of Means	
	t	**Sig. (2-tailed)**
Canopy area m^2	.885	0.729 ns
	2.186	
Trunk length m	6.930	.161 ns
	11.313	
Crown length m	11.368	.080 **
	7.668	
Total height m	12.055	.991 ns
	11.964	
Diameter at breast height cm	31.505	.000 **
	8.677	

**= $p<0.01$, ns = not significant

The comparison of the quantitative characteristics of *Q. brantii* in Sabadlou and Heydariyeh forests showed that only d.b.h. of trees had a significant difference ($p<0.01$) between these two sites (Table 20).

Tab. 20. The comparison of *Q. brantii* characteristics in Sabadlou and Heydariyeh forests by t- student analysis.

	t- student for Equality of Means	
	t	**Sig. (2-tailed)**
Canopy area m^2	.446	0.096 ns
	.527	
Trunk length m	.213	.306 ns
	.464	
Crown length m	-.127	.018 ns
	-.186	
Total height m	-.087	.002 ns
	-.120	
Diameter at breast height cm	4.457	.005 **
	6.127	

**= p<0.01, ns = not significant

Comparison of the quantitative characteristics of *Q. brantii* showed that all of the characteristics had significant differences (p<0.01) between Sabadlu and Sar_Firooz_Abad (Tab. 21).

Tab. 21 . The comparison of *Q. brantii* characteristics in Sabadlou and Sar_Firooz_Abad forests by t- student analysis.

	t- student for Equality of Means	
	t	**Sig. (2-tailed)**
Canopy area m^2	7.476	.001 **
	6.759	
Trunk length m	15.320	.000 **
	22.779	
Crown length m	27.353	.000 **
	17.501	
Total height m	28.639	.001 **
	21.712	
Diameter at breast height cm	54.175	.000 **
	25.869	

** = p<0.01

As given in table 22, all quantitative characteristics of *Q. brantii* trees, except trunk length, had significant differences (p<0.01) between Sar_Firooz_Abad and Hedariyeh forests.

Tab 22 . The comparison of *Q. brantii* characteristics in Sar_Firooz_Abad and Heydariyeh forests by t- student analysis.

	t- student for Equality of Means	
	t	**Sig. (2-tailed)**
Canopy area m^2	12.752	.000 **
	12.068	
Trunk length m	19.719	.805 ns
	17.680	
Crown length m	32.078	.000 **
	28.115	
Total height m	40.995	.000 **
	36.764	
Diameter at breast height cm	38.553	.000 **
	33.237	

**= p<0.01, ns = not significant

The multivariate test for the quantitative chararcteristics of Q. infectoria in Sabadlou, Armarde and Sar_Firooz_Abad forests showed that except canopy area, all other chararcteristics have significant differences (p<0.01) in the three mentioned forests (tab. 23).

Tab. 23. Multivariate test for quantitative chararcteristics of *Q. infectoria* in three different forests

Multivariate Tests[c]

	Effect	Value	F	Hypothesis df	Error df	Sig.
Location	Pillai's Trace	.422	36.611	8.000	1094.000	.000
	Wilks' Lambda	.608	38.578[a]	8.000	1092.000	.000
	Hotelling's Trace	.595	40.563	8.000	1090.000	.000
	Roy's Largest Root	.495	67.688[b]	4.000	547.000	.000

Tab. 23.

Tests of Between-Subjects Effects

Source		Dependent Variable	Type III Sum of Squares	df	Mean Square
Corrected Model		Canopy area	2425.769[a]	2	1212.885
		Trunk length	19.859[b]	2	9.929
	dimension1	Total High	149.860[c]	2	74.930
		Diameter at breast height	10603.923[d]	2	5301.962
Location		Canopy area	2425.769	2	1212.885
		Trunk length	19.859	2	9.929
	dimension1	Total High	149.860	2	74.930
		Diameter at breast height	10603.923	2	5301.962
Error		Canopy area	417196.917	549	759.922
		Trunk length	60.515	549	.110
	dimension1	Total High	4288.295	549	7.811
		Diameter at breast height	39353.579	549	71.682

Tab. 23.Tests of Between-Subjects Effects

Source		Dependent Variable	F	Sig.
Corrected Model		Canopy area	1.596	.204
		Trunk length	90.080	.000
	dimension1	Total High	9.593	.000
		Diameter at breast height	73.965	.000

Location	Canopy area	1.596	.204
	Trunk length	90.080	.000
dimension1	Total High	9.593	.000
	Diameter at breast height	73.965	.000
Error	Canopy area		
	Trunk length		
dimension1	Total Height and		
	Diameter at breast height		

Comparison of means by Duncan

Comparison of means by Duncan test for quantitative chararteristics of *Q. infectoria* in different the studied forests (Table 24) showed that the mean canopy area had no significant difference, whereas trunk length, crown length, total height, anf dbh of trees showed significant differences among the sites.

Tab. 24. Comparison of mean of *Q. infectoria* characteristics in three different forests

Group	Mean	Location	Character
a	10.38	Armarde	Canopy area m^2
a	12.63	Sabadlou	
a	16.58	Sar_Firooz_Abad	
a	2.23	Armarde	Trunk length m
b	2.01	Sar_Firooz_Abad	
c	1.81	Sabadlou	
a	5.60	Armarde	Crown length m
a	5.14	Sabadlou	
b	4.38	Sar_Firooz_Abad	
a	7.824	Armarde	Total height m
b	6.949	Sabadlou	
b	6.393	Sar_Firooz_Abad	
a	35.36	Sar_Firooz_Abad	Diameter at breast height cm
b	31.21	Armarde	
c	24.2	Sabadlou	

Consequently, we can say that the maximums of trunk length, crown length and total height of *Q. infectoria* are observed in Armarde forest, while the maximums of dbh and canopy area have occurred in Sar_Firooz_Abad forest (Table. 24).

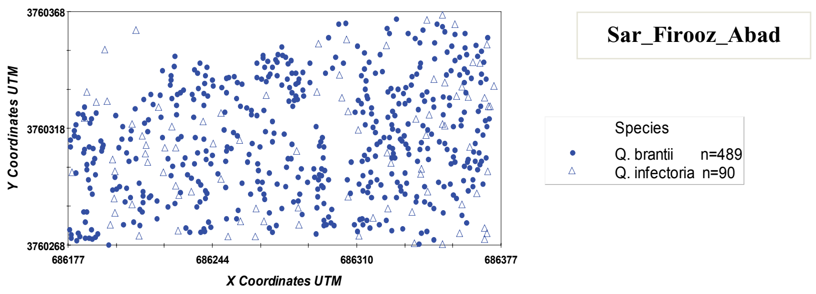
The comparison of quantitative characteristics of *Q. brantii* in four different studied forests is given in table 25. All characteristics showed significant differences among the sites and trees are grouped into two groups, except for dbh that is divided into four groups.

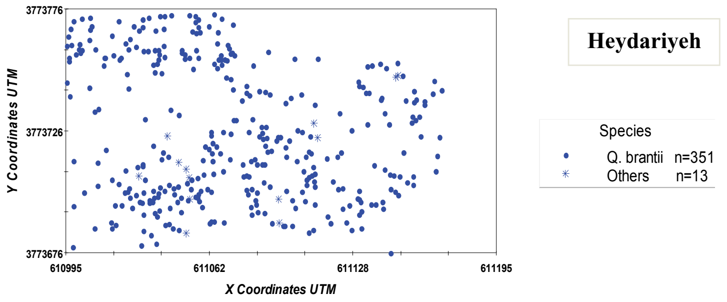
Tab. 25. The comparison of mean of *Q. brantii* characteristics in different forests

Group	Mean	Location	Character
a	14.16	Sabadlou	Canopy area m^2
a	13.45	Heydariyeh	
b	7.72	Armarde	
b	5.10	Sar_Firooz_Abad	
a	1.94	Armarde	Trunk length m
a	1.81	Sabadlou	
a	1.78	Heydariyeh	
b	.94	Sar_Firooz_Abad	
a	4.72	Armarde	Crown length m
a	4.66	Sabadlou	
a	4.55	Heydariyeh	
b	1.88	Sar_Firooz_Abad	
a	6.47	Sabadlou	Total height m
a	6.5	Armarde	
a	6.51	Heydariyeh	
b	2.83	Sar_Firooz_Abad	
a	30.33	Armarde	Diameter at breast height cm
b	24.59	Sabadlou	
c	18.82	Heydariyeh	
d	3.1	Sar_Firooz_Abad	

Spatial pattern

Figure 29 shows the spatial pattern of the 3 studied oak and some other accompanied species in the four studied plots. As illustrated in this figure, *Q. brantii* is dominant species in Sar_Firooz_Abad and Heydarieh, while *Q. libani* in Armardeh and *Q. infectoria* in Sabadlu.





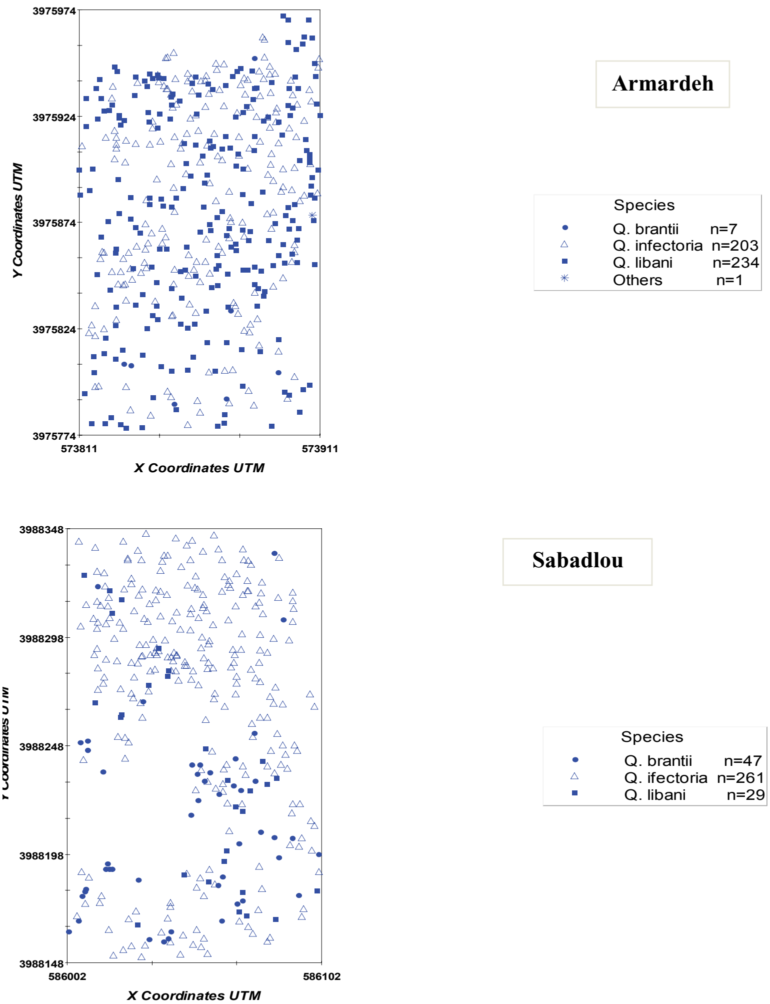


Fig. 29. Stem map of different trees species in the four study sites. n: number of trees for each species; Other species including of *Pyrus* sp. and *Crataegus* sp.

As seen in Figure 30, the spatial distribution in all study sites is cluster (aggregated).

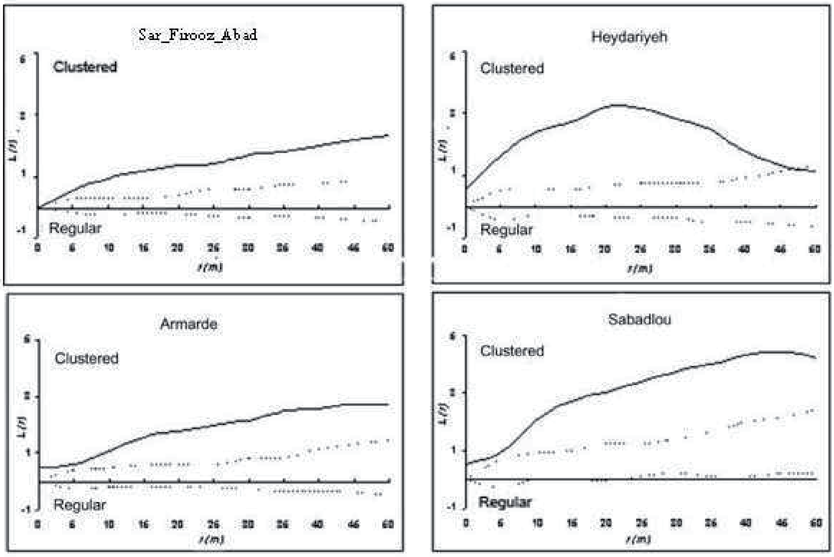


Fig. 30. Univariate results for the *L*-function for all tree species in the four study sites. Solid lines represent the *L*-function, dotted line correspond to the 95% Monte Carlo intervals of the null hypothesis of complete spatial randomness. *L*-functions that fall above, below and within confidence intervals indicate a cluster, regular and random spatial patterns, respectively.

Q. brantii as dominant or co-dominant species, in all pure (Fig. 31, A), and mixed stands (Fig. 31, B and C) showed cluster pattern at all scales. The spatial pattern of *Q. infectoria* as dominant tree in mixed stand (Fig. 31, D) and as co-dominant species in Armardeh (Fig. 31, E), is cluster ($P<0.05$) at all scales. However, its spatial pattern when mixed by *Q. brantii* in Sar_Firooz_Abad is random up to 17 m and after that is cluster except for the scale more than 45 m which has again fall in random area (Fig. 31, F). *Q. libani* as dominant species displays clump distribution in all scales (Fig. 31, G), but when mixed with *Q. infectoria* as co-dominant species in Sabadlu, displays totally random distribution ($P<0.05$) (Fig. 31, H).

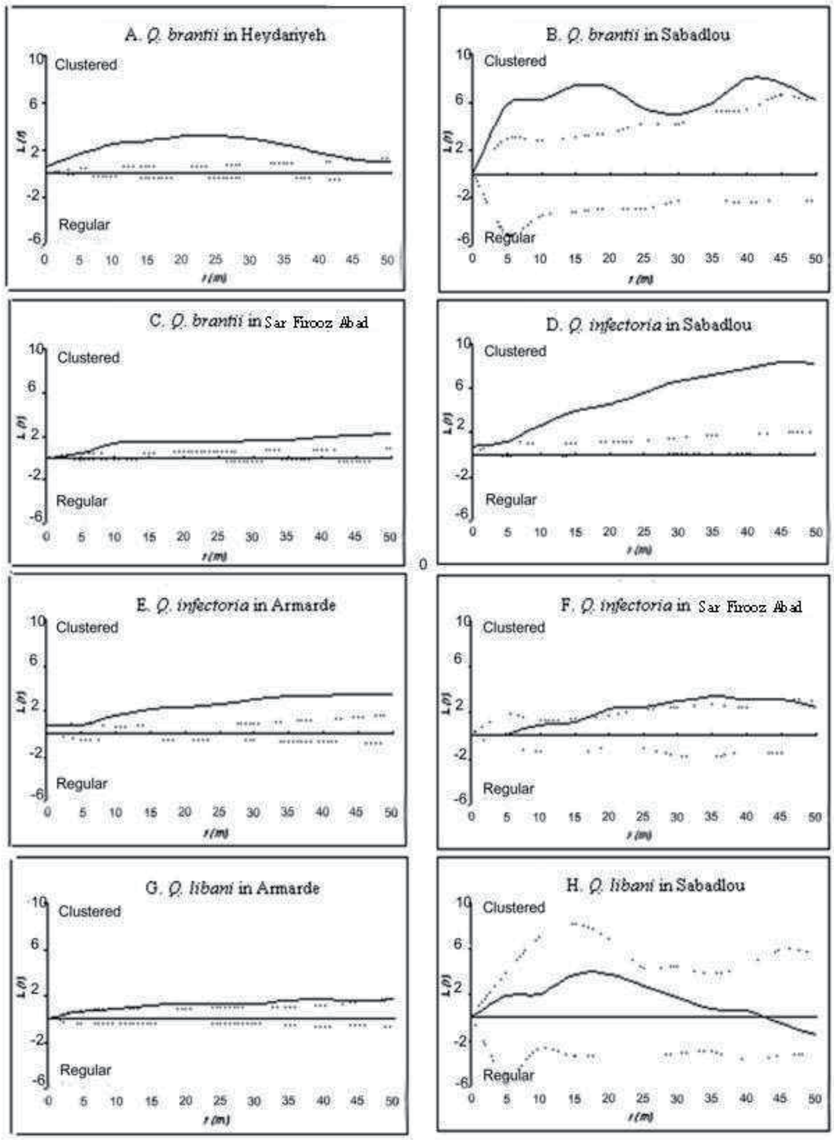


Fig. 31. Univariate results for the *L*-function based on oak species in the every study sites. Solid lines represent the *L*-function, dotted line correspond to the 95% Monte Carlo intervals of the null hypothesis of complete spatial randomness. *L*-functions that fall above, below and within confidence intervals indicate a cluster, regular and random spatial patterns, respectively.

Canonical Correspondence Analysis (C.C.A.)

Because the maximum special value, Axes 1 and 2 were selected (Axis 1= .623 and Axis 2= .145)

As shown in figure 32, *Q. libani* is located in the right side of the first axis (in the first quarter) and is more related to altitude as well as sand and silt content of soil. *Q. infectoria* is located in the third quarter (negative sides of both axis 1 and 2) and is related to CaCo3, pH, clay and slope gradient. *Q. brantii* is located in the second quarter (left side of axis 1 and the positive side of axis 2) and is more related to EC.

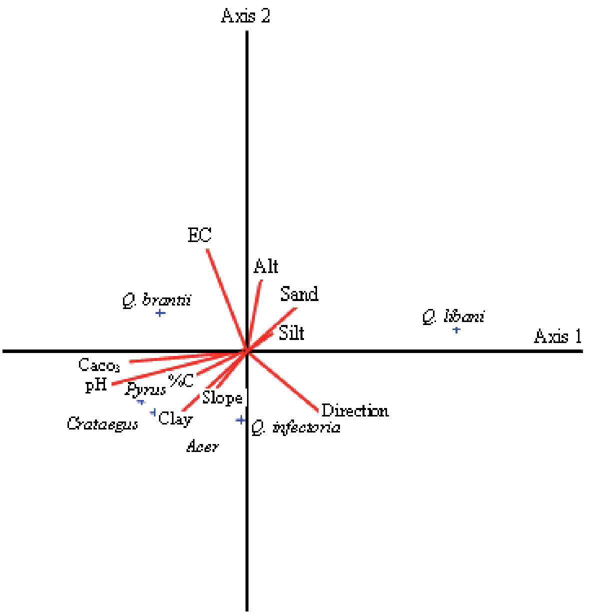


Fig. 32. Output of CCA for the position of species, environmental factors and soil properties

Categorizing of all sample plots and their position besides position of the environmental factors for the three oak species is shown in figure 33. Most of the sample plots for *Q. libani* (pv) are located around the right side of the axis 1, which shows their relation to altitude and direction. Most of the plots for *Q. infectoria* (pm) and other species (*Acer monspessulanum, Pyrus syriaca* and *Crataegus pontica*) are located around the left side of the axis 1, which showes their relation to CaCo3, pH and clay. Sample plots of *Q. brantii* are mostly located in the second quarter which is more related to EC.

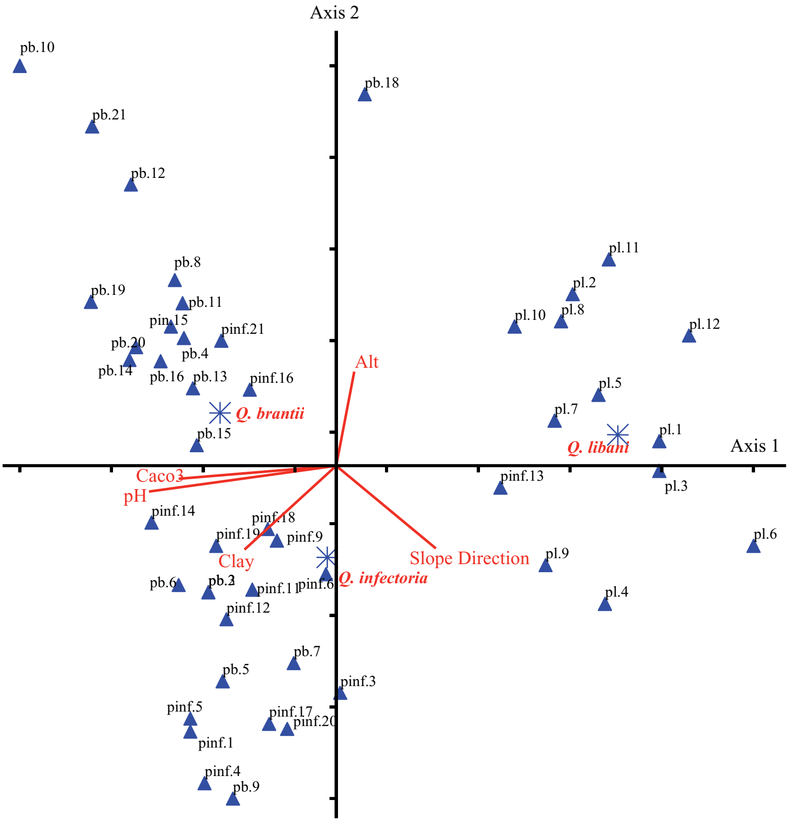


Fig. 33. C.C.A. Categorizing of sample plots (Axises 1 and 3)
, pl= *Q. libani*, Pinf= *Q. infectoria* Pb= *Q. brantii*

The results of Principle Corresponding Analysis (P.C.A.) for *Q. libani*

Figure 34. P.C.A was carried out for soil chemical and physical characteristics in *Q. libani* habitats as follow:

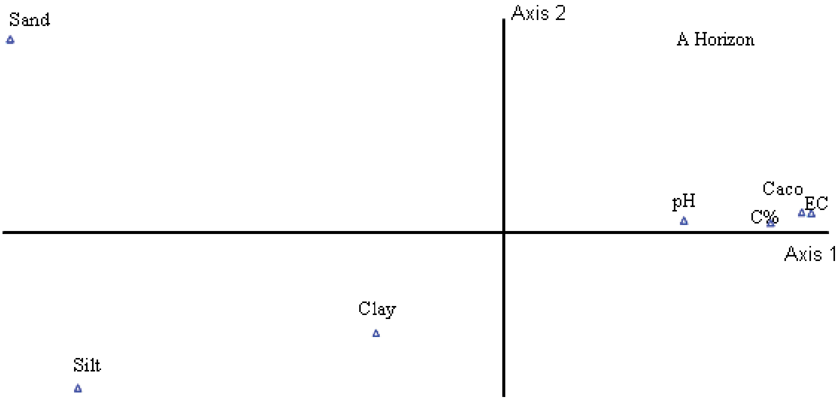


Fig. 34. P.C.A. Categorizing for *Q. libani*

Based on the first component of P.C.A. analysis (Fig.34) in soil's horizon A of *Q. libani* habitats, the factors pH, Caco$_3$, EC and C% are in positive side and silt and sand are in negative side. As clay has the minimum changes so it can be considered as a determinant habitat factor for *Q. libani*.

Figure 35. P.C.A was carried out for soil chemical and physical characteristics in *Q. infectoria* habitats as follow:

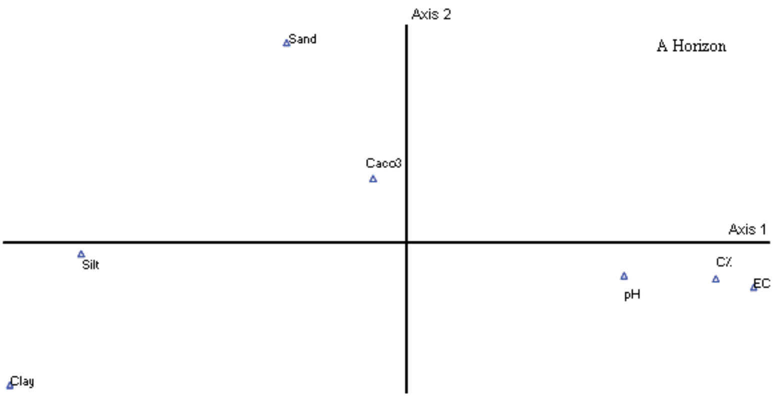


Fig. 35. P.C.A. Categorizing for *Q. infectoria*

Bi plots of P.C.A. analysis (Fig. 35) in soil's horizon A of *Q. infectoria* habitats, based on the first component shows that %C, $Caco_3$ and pH, have the most positive and silt and clay have the most negative changes. Based on the second component $Caco_3$ and sand have the minimum changes, so it can be said $Caco_3$ and sand are determinant factors for *Q. infectoria* habitats.

Figure 36. P.C.A was carried out for soil chemical and physical characteristics in *Q. brantii* habitats as follow:

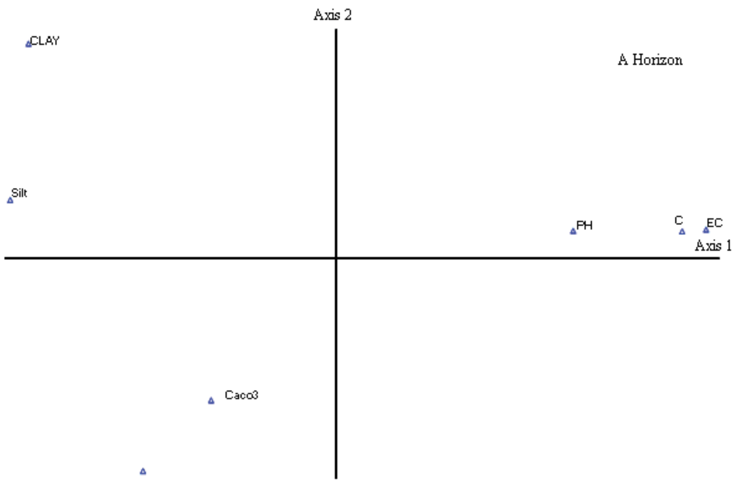


Fig.36. P.C.A. Categorizing for *Q. brantii*

Bi plots of P.C.A. analysis (Fig. 36) in soil's horizon A *Q. brantii* habitats, based on the first and second component shows that none of the factors have essential role in presence or absence of this species. Although second component shows that %C, EC، silt and pH have little determinant role.

Table 26. Shows correlation between the tree species and C.C.A. axises and table 27 indicates the correlation between environmental factors and C.C.A. axises.

Tab.26. Pearson correlation between tree and shrub species with C.C.A. 1 and 2 Axises

Tree species	First axis	Correlation	Second axis	Correlation
Q. brantii	-0/58	❉❉	0/331	❉❉
Q. infectoria	0/59	ns	-0/0436	❉❉
Q. libani	0/821	❉❉	0/087	ns
Acer monspessulanum	-0/141	ns	0/0222	ns
Crataegus pontica.	-0/281	ns	-0/234	ns
Pyrus syriaca.	-0/225	ns	-0/132	ns

❉❉= Significant (*P*<0.05), ns= not significant

Tab.27. Pearson correlation between Environmental factors and C.C.A. 1 and 2 Axises

Environmental factors	First axis	Correlation	Second axis	Correlation
EC	−۰/۲۹	❉	۰/۱۵۱	ns
pH	−۰/۹۳۷	❉❉	−۰/۱۸۶	ns
$CaCo_3$	−۰/۷۶۹	❉❉	−۰/۱۲۳	ns
%C	−۰/۳۱۸	❉❉	−۰/۰۸۴	ns
%Sand	−۰/۳۷۸	❉❉	۰/۳۱۶	❉❉
%Silt	−۰/۰۳۴	❉	۰/۱۴۷	ns
%Clay	−۰/۴۲۵	❉❉	−۰/۴۵۱	❉❉
Altitude	۰/۰۱	ns	۰/۶۲۱	❉❉
slope gradient	−۰/۲۱۶	ns	−۰/۳۶۷	❉
Direction	۰/۴۸۷	❉❉	−۰/۴۷	❉❉

❉❉= Significant (*P*<0.01), ns= not significant

Results of soil studies

Table ۲۸ shows the soil classificated of under study areas. The profiles characteristics and results of labratoary analysis are presented later.

In the studied areas the soils have generally been evoluted on calcareous parent material so climate and parent material are the main controller factores of soils evolution.

Tab. 28. Geomorphology and classification of studied areas soil

Landscape	Relief/Molding	Lithology/Facies	Landform	POLYPEDON
Mountain	backslope	Limestone	Slope facet complex	fine-loamy, mixed,active mesic Typic Haploxerepts
	footslope		Low hill	fine, carbonatic, thermic Typic Calcixerepts
	footslope		Slope facet complex	fine, carbonatic, thermic Typic Calcixerepts
Hilland	Middle hill	phylite	backslope	fine-loamy, mixed,superactive mesic Typic Haploxerepts

Description of soil profiles

Soil profiles are presented based on mean of morphological characteristics and labroatory datas of soils in per unit of map. Soil profiles descriptions are based on Field book for describing and sampling soils (Schoenberger et al. 1998) and soil classification has been done by the last keys to soil taxonomy (Soil Survey Staff 2006).

Morphological characteristics and labratoary analysis results of Sabadlou soil profile (Table 29).

- Land form: Slope facet complex
- Geographical Coordinate: northern latitude: 45° 57′ 21.1″ and and eastern longitude: 36° 2′ 7″.
- Altitude: 1732 m
- Land use: Oak forest (*Q. brantii, Q. infectoria and Q. libani*)
- Slope: 12-25%
- Surface gravel: 70%
- Mykrvrlyf: average
- Soil drainage classification: good
- Soil-forming materials: Marni and calcareous materials
- American soil classification (2006): fine-loamy, mixed, active mesic typic haploxerepts
- FAO soil classification (2006): Haplic Cambisols (calcaric, eutric)

Tab. 29. Results of labratovary analysis of Sabadlou soil profile

Texture	CEC Cmol(+)/kg	T.N.V .%	Available Potassium mg/kg	Available phosphorus mg/kg	N%	C%	Saturated mud	EC ds/m	Horizon	Depth cm
L	17	1.3	197	17.6	.25	2.48	7.49	.48	Ap	0-15
L	14.8	1.8	197	11.6	.09	.92	7.32	.33	Bw1	15-35
L	14.8	1.3	220	3.6	.05	.45	7.25	.23	Bw2	35-60
CL	20.8	1.3			.04	.38	7.09	.18	Bw3	60-120

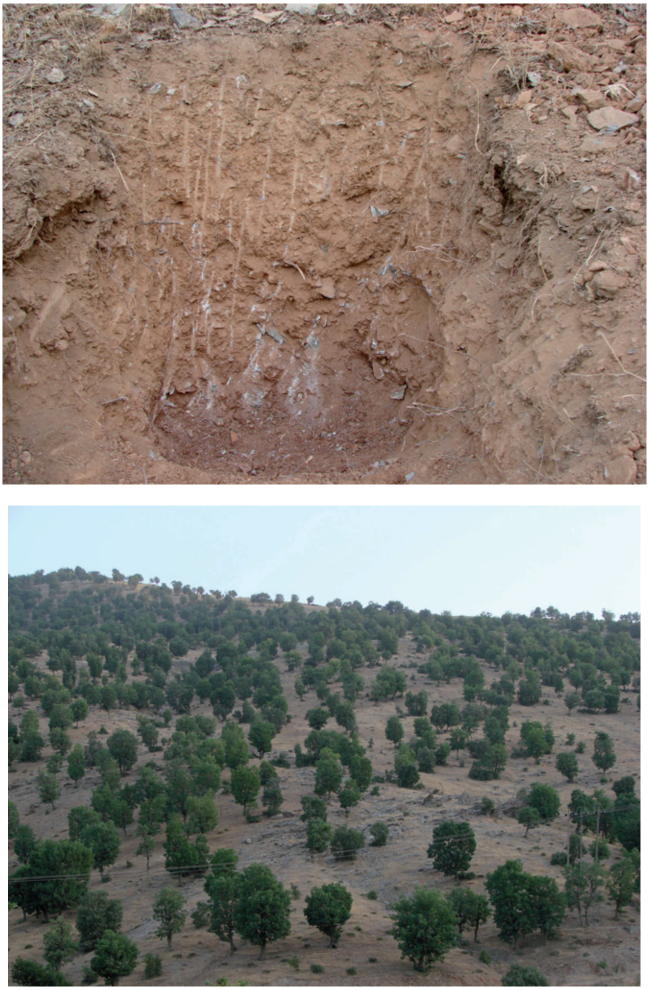


Fig. 37. Sabadlou land form and soil profile

Morphological characteristics and labratoary analysis results of Armerde soil profile (Table 30)

- Land form: backslope
- Geographical Coordinate: northern latitude: 35° 55′ 26″ and and eastern longitude: 45° 49′ 6.4″.
- Altitude: 1698 m
- Land use: Oak forest (*Q. infectoria and Q. libani*)
- Slope: 8-12%
- Surface gravel: 30%
- Mykrvrlyf: average
- Soil drainage classification: good
- Soil-forming materials: Marni materials
- American soil classification (2006): fine-loamy, mixed,superactive mesic Typic Haploxerepts
- FAO soil classification (2006): Haplic Cambisols(calcaric, eutric)

Tab. 30. Results of labratovary analysis of Armarde soil profile

Texture	CEC Cmol(+)/kg	T.N.V. %	Available Potassium mg/kg	Available phosphorus mg/kg	N٪	C٪	Saturated mud	EC ds/m	Horizon	Depth cm.
L	25.4	2	390	3.6	.32	3.2	7.28	.58	Ap	0.20
CL	23	1	210	5	.05	.53	7.09	.26	Bw	20-35
CL	23.8	2			.07	.7	6.93	.23	C	35-70
	25.2	3.2			.03				R	70-100

Fig. 38. Armarde land form and soil profile

Morphological characteristics and labratoary analysis results of Sra-Firooz_Abad soil profile (Table 31).

- Land form: Low hill
- Geographical Coordinate: northern latitude: 33° 58′ 24″ and and eastern longitude: 45° 49′ 6.4″.
- Altitude: 1448 m
- Land use: Oak forest (*Q. infectoria and Q. brantii*)
- Slope: 8-12%
- Surface gravel: 30%
- Mykrvrlyf: High
- Soil drainage classification: good
- Soil-forming materials: calcareous materials
- American soil classification (2006): fine, carbonatic, thermic Typic Calcixerepts
- FAO soil classification (2006): Haplic Calcisols (Clayic, Chromic)

Tab. 31. Results of labratovary analysis of Sra-Firooz_Abad soil profile

Texture	CEC Cmol(+)/kg	T.N.V .%	Available Potassium mg/kg	Available phosphorus mg/kg	**N** ٪	C ٪	Saturated mud	EC ds/m	Horizon	Depth cm.
CL	27.8	36.2	430	5.6	.17	1.67	7.37	.46	Ap	0-10
SiC-C	24.6	42	150	2.2	.09	.88	7.84	.23	Bw	10-35
SiC-C	20.4	49.5	60	5.6	.05	.45	8.25	.25	Bk1	35-75
C	20.4	49.8			.03	.3	8.35	.22	Bk2	75-130

Fig. 39. Sra-Firooz_Abad land form and soil profile

Morphological characteristics and labratoary analysis results of Heydariyeh soil profile (Table 32).

- Land form: Slope facet complex
- Geographical Coordinate: northern latitude: 35° 5′ 53.7″ and and eastern longitude: 46° 12′ 13.4″.
- Altitude: 1448 m
- Land use: Oak forest (*Q. brantii*)
- Slope: 8-12%
- Surface gravel: 70%
- Mykrvrlyf: Average
- Soil drainage classification: good
- Soil-forming materials: calcareous materials
- American soil classification (2006): fine, mixed, carbonatic, thermic Typic Calcixerepts
- FAO soil classification (2006): Haplic Calcisols(Clayic,Chromic)

Tab. 32. Results of labratovary analysis of Heydariyeh soil profile

Texture	CEC Cmol(+)/kg	T.N.V .%	Available otassium mg/kg	Available phosphorus mg/kg	**N** ٪	C ٪	Saturated mud	EC ds/m	Horizon	Dept h cm.
C	21	9.5	380	5	.26	2.61	7.79	.43	Ap	0-20
C	18.6	45.5	100	2.2	.1	1.05	7.95	.35	Bk	20-60
									R	60-100

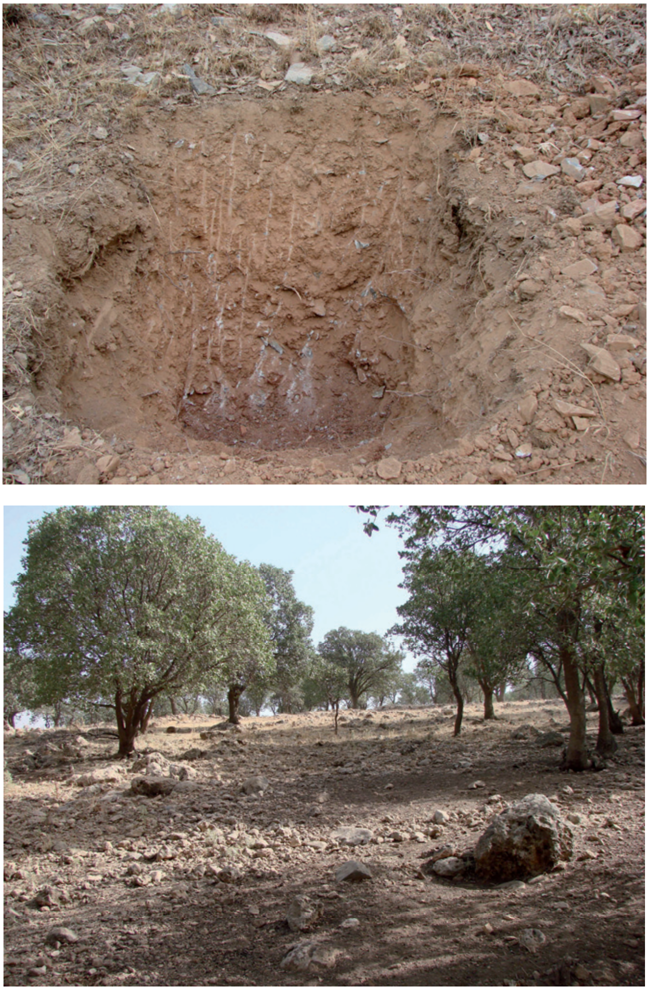


Fig. 40. Heydariyeh land form and soil profile

Soil characteristics and topographic conditions of study areas are presented per unit of map in table 33.

Tab. 33. Soil characteristics and topographic conditions of studied areas

Region	Nprofile No.	Drainage	pH	% O.C	Soil depth	%gravel	Sand %	Silt	% Clay	$CaCo_3$%	Ec×10^3	ESP
Sabadlou	1	Well drainage	7.5	2.5	120	15.3	39.7	35.8	24.5	1.5	.3	15>
Armerde	2	Well drainage	7.3	3.2	70	2.8	37.5	33.2	29.4	1.9	.36	15>
Sar-Firooz-Abad	3	Well drainage	7.4	1.7	130	.7	13.1	39.9	47	45	.27	15>
	4	Well drainage	7.7	1.9	100	5	19.4	35.5	45.1	43.8	.31	15>
Heydariyeh	5	Well drainage	7.8	2.6	60	12.4	23.8	27.8	48.5	34.6	.37	15>

Table 34 shows the number of sections and weight coefficient in different depths of soil.

Tab. 34. Number of sections and weight coefficient in different depths of soil

Depth (cm)	Number of sections	weight coefficient
125-150	6	.25-.5-.75-1.5-2
100-125	5	.25-.5-1-1.5-1.75
75-100	4	.25-.75-1.25-1.75
50-75	3	.5-1-1.
25-50	2	.75-1.25
0-25	1	1

Forest climatic classification

For climatic evaluation the weather characteristics is divided into four groups as: precipitation, temperature, humidity and radiation. Climatic class is determinate by the most limitative factor. For this purpose the mean of annually precipitation, the mean of annually temperature and of precipitation to evaportranspiration ratio are the important factors in climatic classification. The results of climatic proportion in studied areas are presented in table 35.

Tab. 35. The results of climate classification in study areas

Rregion	Climate caracteristics		
	Mean of anually precipitation (mm)	Mean of anually temperature (c°)	Climate class
Sabadlou and Armarde	714	13.6	S2
Sar-Firooz-Abad	458	14.1	S3
Heydariyeh	491.8	13.6	S3

Description of land proportion of soil map units for forest

Sabadlou region soils because of climatic limitations as: low mean of annually precipitation, really low lime and high slope, is located in S2cst class. In Armarde forests the soil is located on S2cs class because of low mean of annually precipitation, really low lime and depth soil lower than 70 cm.

Both high climatic limitations as: low annually precipitation (lower than 500 mm) and middle limitations as: low mean of annually temperature, heavy soil texture and high lime, cause Sar-Firooz-Abad and Heydariyeh regions are located in S3c class. In addition to all of these, Heydariyeh region has a high limitation by soil depth lower than 60 cm.

Chapter 4

Discussion

Knowing the natural patterns and site demands of species is a good guide and can reveal the ecological characteristics of species to solve many problems in managing of forest lands, such as reforestation and rehabilitation of damaged areas.

Competition as a main ecological factor affects dynamic, growth, and survival of species (Peet and Christensen, 1987; Keddy, 2001; Szwagrzyk and Szewczyk, 2001). Tilman (1994) believed that spatial structure is created by dynamic, competition and biodiversity of vegetation. Thus, competition and interaction between species are two important factors on spatial pattern of trees (Frelich et al., 1993). Chen and Bradshaw (1999), believed that competition is a process causing random pattern.

The analysis of spatial pattern is the prime of interest to ecologists because most ecological phenomena investigated by sampling geographic space are structured by forces that have spatial components. It is now understood that species distribution result from the combined action of several forces, some of which are external whereas others are intrinsic to the community (Legendre and Legendre, 2003). Many factors such as human activities, forest fire, physiographic conditions, and mixture of species have important impact on distribution model of trees.

Changes in the structure and composition of the forest community result from the constant demand of each individual tree for more crown and root space. Competition between the trees of the same species does not affect the composition of the forest ecosystem and therefore has no direct effect on forest succession. Competition among individuals of different species, however, results in a change of composition and structure of the stand (Barnes et al., 1998).

Niche Theory tells us that species have ecological preferences, meaning that they are found at sites where they encounter favourable conditions. This statement is rooted in the idea that species have unimodal distributions along environmental variables, more individuals being found near some environmental value which is "optimal" for the given species (Legendre and Legendre, 2003). This has been formalized by Hutchinson (1957) in his fundamental niche model. Gause's (1935) competitice exclusion principle suggests that, in their micro-evolution, species should have developed non-overlapping niches.

In this study, we analyzed the spatial patterns of three *Quercus* species at the less destroyed areas in the northern Zagros region of Iran. Spatial pattern of trees in the four study sites showed cluster distribution both in the pure and mixed stand. At the same time, the observed patterns for the individual species, especially for dominant species were aggregated (Fig. 22; A, B, C, D, E and G) except for two co- dominant species, one in the Sar_Firooz_Abad site at very low and very high scale (Fig. 22, F) and the other one in the Sabadlou site at all scales (Fig. 22, H) which showed random distribution. In general, cluster pattern indicates limitation in resources (light, water, nutrients) and harsh environmental condition in the growing area which results aggregation of plants in more favorable area. It's worth to say that growth condition in Zagros region is harsh with low precipitation (mostly in autumn and winter) and dry summer with poor and shallow soil. Furthermore, inherent limitation to seed dispersal of *Quercus* is a heavy seed species, would lead to an aggregated spatial pattern of juvenile oak trees. It seems that inter-specific competition for resources with dominant species resulted in random distribution for co- dominants species.

In total, the overall spatial aggregation in the all study sites reflects the spatial distribution of the dominant tree species in each site (Table 1). Nevertheless, the main driver of the aggregated spatial pattern of all trees in each site, as investigated through Ripley's *K*-function, was the high aggregation pattern of the dominant tree species. Therefore, the role of dominant species in the configuration of whole stand spatial pattern is extremely important, influencing the overall spatial pattern of all trees in each study site.

Although there isn't available much information about Zagros forests structure, studies in a less destroyed region of southern Zagros, showed that the *Q. brantii* seedlings have irregular dispersed pattern (Erfani Fard et al. 2008), while based on our results and Safari et al. (2010), *Q. brantii* has clustered distribution in all situations in northern Zagros.

Our results by univariate spatial analysis of trees revealed that *Q. brantii* as the dominant species in Zagros forests has essential role in distribution and establishment of another species. In every mixed stands that *Q. brantii* has high abundance, the spatial pattern of *Q. infectoria* and *Q. libani* has been influenced.

The element that is more competitive for being dominant in the inter-specific competition, affects the distribution of other species. Because of ecological wide range and high flexibility of *Q. brantii*, other species are only located randomly and in special habitats.

Q. infectoria has random pattern in stands where heavily dominated by *Q. brantii*, while in non-existence of *Q. brantii,* it has significant clumped spatial distribution. *Q. libani* just in while dominance has clustered pattern, otherwise it shows random pattern. This altering from significantly clumped to significantly random spatial distributions, explains inter-specific competition, obviously. It means in competition for resources, dominant species don't allow another species to be integrated which confirm the Chen and Bradshaw's theory (1999), however, factors other than competition (soil and topographic conditions) may affect the spatial distribution of trees.

The Zagros forests in west of Iran are influencing by forest dwelling people by animal husbandry, agriculture and fuel compensating, So this area is engaged with very socio- economical problems and considered as degraded forests; consequently, intact areas can rarely be found in this region.

Some studies on oak stands in Spain showed that some ecological parameters including altitude, soil depth, mean annual temperature, and some quantitative characteristics including mean diameter and mean height of trees are suitable for correctly defining the characteristics of oak stand in Galicia (Timbal and Aussenac, 1996; Rubio *et al*., 1997; Blanco *et al*., 2000).

Díaz-Maroto et al. (2005, 2006) concluded that the distribution of the oaks (*Q. robur* and *Q. pyrenaica*) stands are more closely related to the physiographic and climatic characteristics than to edaphic factors in north-west Spain. Results of this study show that distribution of Oak species is related to soil characteristics and habitat topographic conditions which have the same results with them.

The factors; Altitude (h.a.s.l) (mean 1602 m.), Silt (mean 35.64) and sand (mean 36.75) content have important roles on the presence of *Q. libani*, This species usually occupies less steep northern directions and higher altitudes and prefers light to moderate acid soils. As in Maroofi (2000) studies, this species occurs in moderate slopes and 1350- 2000 m altitude.

Fattahi (1997) reported that this species is in neutral soils with high $CaCo_3$ content while our results are in opposite side and show that its presence in quite acid soils with low $CaCo_3$ and so high content of it in soil seems to limit its (*Q. libani*) distribution.

As a consequence *Q. brantii* is related to EC (mean .76) and *Q. infectoria* is related to direction and both of them prefer neutral to alkaline soils and distributed in steeper slopes. *Q. libani* presents in acid soils, it seems habitats are more similar and *Q. libani* has more special habitat.

Maybe the most important reason that *Q. brantii* and *Q. infectoria* are in steeper slopes is the natives' activities and replacing to farms and consequently these species have located in higher slops areas where there is no cultivation possibility.

Overall in oak habitats pH, EC, $CaCo_3$, Clay content and direction, are some restrictive factors, and carbon content seems not to have an important role on the presence of all three studied oak species.

In soil studies section can be said that parent material, topographic conditions, climate and time are the most important factors to pedogenesis in recognized geomorphs, and biological factors are in second step. The soils on mountain and hilly slope lands are Haploxerepts soils.

In low slope regions and at the foot of mountain (Sar-Firooz-Abad and Heydariyeh) Calcixerepts soils has been seen.

In the studied areas, dissolution, lime leaching and circular, angled and cubic structure forms, suitable porosity and humification are the most important consequences of pedogenesis. Acric in top of soil layer (A horizon) and Cambic in under horizons and in some areas Calcic are the most important soil horizons.

Electrical conductivity of soil solution (EC) in different geoforms was wery low and hardly was more than 1 ds/m so the soils have not any salinity limitation.

In Sar-Firooz-Abad and Heydariyeh regions, soil texture in different depths of profiles was varied from heavy to exteremely heavy (loam- clay to clay). In Sabadlou and armarde region the soil texture were heavy to medium (loam- clay to loam). The mean of organic matter in A horizon of soils are more than 1 percent.

Results showed that increasing of soil depth causes decreasing of organic matter. Lime content is varied in different horizons and the maximum amount of that is in calcic layer.

The main food elements soil as: N, K and CEC are in good condition but P content in most of regions is low except Sabadlou.

Land proportion results for forest show that restrictive climatic factor in Sabadlou and Armarde regions is relatively low temperature and in Sar-Firooz-Abad and Heydariyeh regions are relatively low temperature and precipitation.

Other restrictive factors in Sabadlou region are: really low lime content and high slope and in Armerde region is under 70 cm soil depths. In Sar-Firooz-Abad and Heydariyeh regions another restrictive factors consist of: very heavy texture, high lime (40-50%) and under 60cm soil depth for Heydariyeh too.

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