



Effect of Environmental Factors on Natural Regeneration of Beech Stands in the Hyrcanian Forests (Case Study: Kojoor Forest, Namkhaneh District of Kheyroud Forests)

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ABSTRACT

Aims Natural regeneration will guarantee forest future and sustainability. Ecological factors (soil and physiology) may influence regeneration process and provide a variety of sites favorable for seed generation and establishment of different plant species. The present study aimed to evaluate effect of environmental factors on *Fagus orientalis* regeneration in Kojoor Forest, one of Hyrcanian inscribed sites on UNESCO's Natural World Heritage List.

Materials & Methods After determination of high valued and undisturbed stands of *F. orientalis* Lipeskey on the vegetation map, sampling was carried out with 2.5% of statistical intensity (the surface area of each plot was 0.1ha and statistical network dimension was 200×200m²). The effects of abiotic ecological factors including topography (aspect, elevation, and slope), soil type (pseudogley, brown forest soil, and brown marmorized), canopy closure (50-70% and >70%) on abundance of regeneration were studied on 60 plots.

Findings The mean density was 0.52seedlings/m², and *Fagus orientalis* Lipeskey, and *Carpinus betulus* fastigiata comprise 82% of seedlings. *F. orientalis* prefers north faced slopes (Northeast and northern) (probability of 95%; p= 0.044) and the highest seedlings abundance occurs in the elevation of 1,000 to 1,200m a.s.l., while, the altitude of 700 to 800m a.s.l. had the lowest density of seedlings (probability of 95%; p= 0.034). This species more is found on the slope of 0-40% (probability of 95%; p= 0.012) on the pseudogley and forest brown soil (probability of 99%; p= 0.001). Canopy covers between 50-70% are more suitable for this species and canopy cover >70% had the minimum number of seedlings per hectare (probability of 95%; p= 0.021).

Conclusion These set of environmental conditions are optimal conditions under which *F. orientalis* as a climax species of the Hyrcanian Forests will grow and reproduce and Kojoor Forest is a developed old growth forest with the best environmental conditions for establishment and regeneration of climax species like *F. orientalis*. This site is an undisturbed forest with less anthropogenic effects and diverse topography and soil types which make it the best site of the Hyrcanian Forests.

Keywords World Heritage List; Topography; Soil Type; Statistical Intensity

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Introduction

Forests stretch in an arc along the southern shores of the Caspian Sea are known as the Hyrcanian Forests. These forests contain Arcto-Tertiary relicts from broad-leaved forests that 25-50 million years ago covered most parts of the northern temperate zone. These huge forest areas retreated during Quaternary glaciations and later during milder climate, expanded and spread out from this refugia. It is considered as an origin for European broad-leaved forests and, due to this isolation, hosts many relict, endangered, regional and local endemic flora species giving the whole Hyrcanian Region in general, important natural features and very high ecological values [1, 2].

The floristic biodiversity of the Hyrcanian Region is on a global level remarkable with over 3,200 vascular plants documented. About 44% of known vascular plants in Iran occur in the Hyrcanian Region which covers only 7% of Iran's territory, emphasizing the exceptional importance of this region for the protection of biodiversity. Approximately 280 taxa are endemic and sub-endemic for the Hyrcanian Region and about 500 plant species are Iranian endemics. A total of 80 native tree species have been documented in the study of Tohidifar *et al.*[3].

However, the Hyrcanian Forests, in general, face many threats affecting both forest cover and forest condition, and, therefore, biodiversity [1]. For increasing protection level and global awareness about these ancient forests, nomination of the Hyrcanian Forests in the UNESCO's World Heritage List became Iranian government priorities in 2017. Finally, these forests were inscribed on the Natural World Heritage List in the 43rd session of the World Heritage Committee, Baku, Republic of Azerbaijan, 30 June-10 July 2019. Natural World Heritage sites are globally recognized as the most significant protected areas on Earth which provide life-supporting benefits to millions of people. These sites are a litmus test for the ability of persons as a conservation community to protect biodiversity and pass on nature's treasures to the next generation (IUCN website). Against this background, world natural heritage deserves special attention in terms of sustainable management and development in its global dimensions and universal concerns. The study area, Kojoor Forest, is one of the inscribed sites on the World Heritage List and *Fagus*

orientalis is the main broadleaved species and typical climax woody plant in the site [4]. Oriental beech forests (*Fagetum hyrcanum*) become dominant only as late as in the final phase, when a closed-stand microclimate has already been created, in the mountain belt in the western and central parts of the Hyrcanian Forests [2]. Although the oriental beech could be found at altitudes ranging from 500m to 2,100m a.s.l., the optimum growth can only be achieved at altitudes of 900 to 1,600m [5]. Beech forest has remarkable significance due to its productivity and following its function as carbon storage. Some beech trees grow up to 50m in height with a diameter of 2m. One third of the wood volume of Hyrcanian Forests is contributed by beech (*Fagus orientalis*) [2].

Natural regeneration will guarantee forest future and sustainability. Topography (aspect, elevation, and slope) and associated environmental characteristics (soil type and light intensity) may influence abundance, distribution and diversity of plant species in a forest community since they provide a variety of sites favorable for seed generation and establishment of different plant species [6]. The aim of the current study is evaluation of environmental factors affecting *Fagus orientalis* Lipeskey regeneration in Kojoor Forest for sustainable management of the forest.

Materials and Methods

Characteristics of the study site

Kojoor Forest is part of the central Alborz protected area in the north of Iran between Chalus and Noor cities in Mazandaran Province, around 36°32'45.7" northern latitude and 51°40'3.5" eastern longitude. It is one of the first protected areas of Iran designated in 1967. It includes the best remaining primary forests of the lower and middle mountain belts from 24 to 2,246m a.s.l.. The highest rainfall occurs in autumn (45%) and winter (23%) and the lowest rainfall is also reported in spring (12%) and summer (19%). In general, the average annual rainfall in the region is over 1,284mm per year. The highest and the lowest monthly temperature is 27.7 and 3.5°C, respectively. The maximum relative humidity in the month of March is 93% and the minimum is about 71% in June. The growing season in this area is about 270 days. The circular and deep valley consists of limestone, schist, shale, tuff, and metamorphic rocks. Land cover soil is semi-deep to deep with

heavy texture, and the amount of organic matter in the surface soil is relatively high and generally has prophylactic development. Soil types include calcic skeleton brown, calcic brown, forest brown, pseudogley brown soils, and washed soils brown (information was compiled from Hyrcanian Project database) [7].

Forest, vegetation types and flora

Forest habitats cover almost the entire surface of the site, which consist of a wide variety of forest trees and shrubs including many relic and endemic species. The slopes and valleys of the lower mountain belt are covered by Ironwood-Oak- and Ironwood-Hornbeam forests with trees such as *Parrotia persica* (DC.) C.A. Mey., *Quercus castaneifolia* C.A. Mey., *Zelkova carpinifolia* (Pall.) K. Koch, *Alnus subcordata* C.A. Mey., *Carpinus betulus* L., *Ulmus glabra* Huds., *Ulmus minor* Mill., *Celtis australis* L., *Tilia platyphyllos Scopoli*, *Diospyros lotus* L., *Albizia julibrissin* Durazz., *Sorbus torminalis* (L.) Crantz, *Juglans regia* L., etc. *Buxus hyrcana* Pojark, *Ilex spinigera* (Loes.) Loes, and *Ruscus hyrcanus* form evergreen shrub understory, and the lianas *Hedera pastuchovii* and *Smilax excels* climb until the crowns of the trees. The herb layer is very rich in species, especially of ferns like *Pteris cretica*, *Scolopendrium vulgare*, *Asplenium adiantum-nigrum*, *Polypodium vulgare*, and *Matteucia struthiopteris*. Along river banks *Pterocarya fraxinifolia* forms riverine forests. Trunks and branches of the trees are covered by epiphytic mosses, lichens and ferns (information related to herbal and woody plant was compiled from Hyrcanian Project database, Forest Rangeland and Watershed Management Organization (FRWO) and Department of Environment Organization (DOE) database) [8].

Above 700m a.s.l. the forest composition is changing to beech dominated forests of the middle mountain belt. The diverse beech forest types include also Ironwood-beech forests as rare relic forest type, as well as mixed beech forests with *Alnus subcordata*, *Quercus castaneifolia*, *Carpinus betulus*, *Acer velutinum*, and *Tilia platyphyllos*. Because of the high humidity, the trunks and branches of trees are covered by epiphytes also in this belt. Giant trees of *Fagus orientalis*, *Quercus castaneifolia*, *Zelkova carpinifolia* reach heights of over 40 meters and develop mighty crowns whose branches are densely covered with epiphytic mosses (information was compiled from Hyrcanian Project database).

Determine canopy cover

Canopy cover was measured as the proportion of a plot covered by tree crowns under an open and clear sky (11.30 am to 12.30 pm). First, a plot was divided in four parts (250m²), then, the canopy cover percentage was measured in each part (Figure 1) [8].

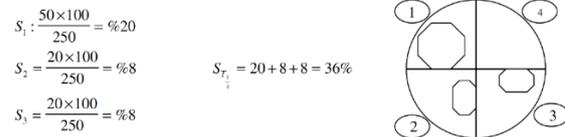


Figure 1) Determining canopy cover in the plots

Sampling

For sampling, first, high valued and undisturbed stands of *Fagus orientalis* were determined on the vegetation map in the elevation of 800 to 1,200m. a.s.l and area of 250ha (some parts of this site are inaccessible because of high and steep slopes). Then, sampling was carried out with 2.5% of statistical intensity (the surface area of each plot was 0.1ha and statistical network dimension was 200×200m²). The effects of abiotic ecological factors including topography (exposition, elevation, and slope), soil type (Pseudogley, Brown forest soil, and Brown marmorized), canopy closure (50-70% and >70%) on abundance of regeneration were studied on 60 plots. The first plot was selected randomly. The seedlings with the height of 0.5m (seedling), 0.5-2m (small sapling), and >2m were measured (sapling) [9].

All statistical analyses were done using SPSS 17.

Findings

The mean density was 0.52seedlings/m² that 31,546 seedlings of 6 tree species were found in this study (height of 0.5m= 22,251 seedlings, 0.5-2m= 4,585 seedlings, and >2m= 4,710 seedlings). In addition, two species *Fagus orientalis* Lipeskey and *Carpinus betulus* fastigiata comprise 82% of seedlings and were more common as mature individuals. Other species were *Acer velutinum* Boiss, *Ulmus glabra* Lutescens, *Tilia begonifolia* Stev., *Quercus castaneifolia* C.A. Mey, and *Acer cappadocicum* Aureum.

Variance analysis (Duncan's test) results for the number of seedlings per hectare in the Fagetum association showed that all evaluated factors had a significant effect on seedlings abundance.

Fagus orientalis prefers north faced slopes (Northeast and northern; probability of 95%; $p=0.044$) and the highest seedlings abundance occurs in the elevation of 1,000 to 1,200m a.s.l., while, the altitude of 700 to 800m a.s.l. had the lowest density of seedlings (probability of 95%; $p=0.034$). This species more is found on the slope of 0-40% (probability of 95%; $p=0.012$) on the pseudogley and forest brown soil (probability of 99%; $p=0.001$). The results also showed that canopy covers between 50 to 70% are more suitable for this species and canopy cover >70% had the minimum number of seedlings per hectare (Diagram 1; probability of 95%; $p=0.021$).

Discussion

F. orientalis natural regeneration requires meeting several conditions like presence of mother trees in sufficient numbers, presence of seed crop, suitable germination substrate, favorable stand microclimate and appropriate climatic conditions over the period from seed fall to seedling establishment [8-10]. The results show that *F. orientalis* and *C. betulus* had the highest seedlings abundance in the study site and are more common as mature individuals with high diameter and height (direct observation). In the Hyrcanian Region, *F. orientalis* is an important climax species, together with species such as *Carpinus betulus*, *Quercus castaneifolia*, *Alnus subcordata*, *Acer cappadocicum*, *A. velutinum*, etc. [10]. This result emphasizes on a developed forest at the final stage of succession in the study site with related species. In a climax forest, *F.orientalis* becomes dominant only as late as in the final stage of succession, when a closed-stand microclimate has already been created [11].

The present study also showed that the highest seedlings abundance occurs in <70% canopy cover in the northeast direction with the elevation of 1,000 to 1,200m a.s.l.. This species prefers pseudogley and forest brown soil with the slope of 0-40%. Oriental beech is a shade-tolerant species that prefers mild mountainous or marine climates with high humidity and direct sunlight damage the seedlings [5].

Some physical factors such as temperature, moisture, and light also control the germination of vital seeds [11]. Soil moisture content has an important role in germination and survival [12,13], because during germination, water demands of seedlings are high. Since the canopy cover and herbs affect the soil moisture and the rate of drying out of surface soil layers, the number of germinated seedlings may equally be decreased in very dense as in very thin forest stands [14].

Canopy cover and light density show an important relation. Light density has strongly effect on germination, site condition, and soil cover (weed and litter cover) [12-14]. Under dense canopy cover, forest floor receives less light, subsequently the moisture is high. On the other hand, stands with 70-75% canopy cover may provide favorable water regimen [15]. Some studies reported soil moisture as an important factor for survival and abundance of beech regeneration [16-18]. However, soil moisture was not measured in this study but it is clear that this

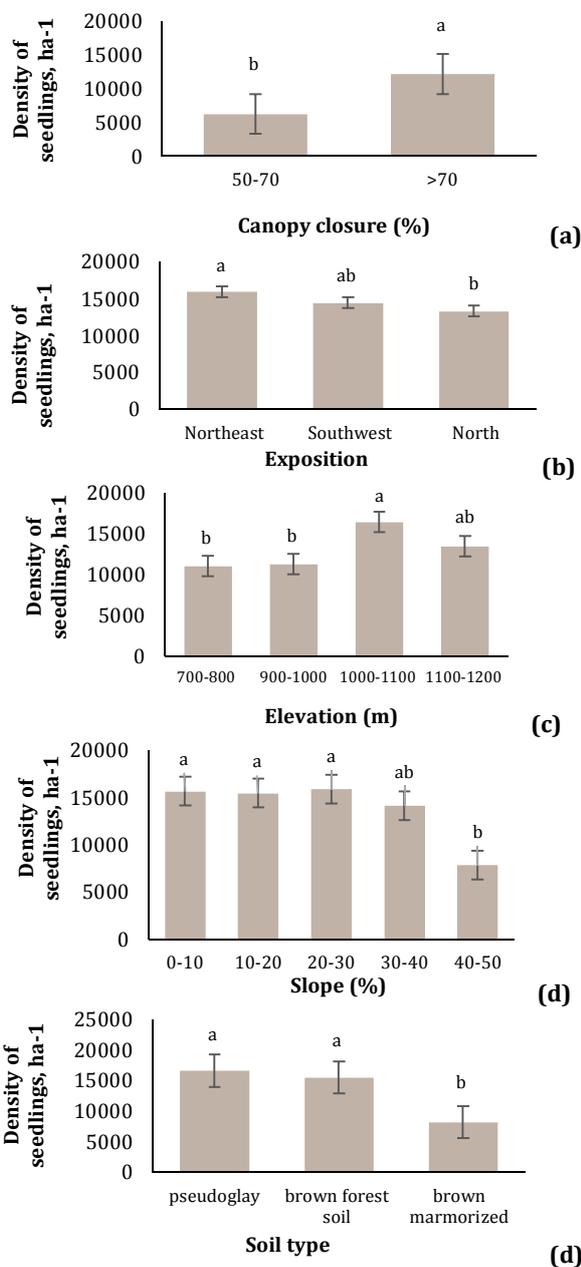


Diagram 1) The effect of ecological factors on the seedlings abundance

factor is high in higher canopy cover [19]. Furthermore, seedling survival and growth may be affected by weed competition, which also depends on canopy cover. In some studies, it was demonstrated that seedling growth of *F. sylvatica* was greater under high canopy cover which is similar to the report of the present study^[20, 21]. Taheri reported the highest seedling abundance in <70% canopy cover^[22]. Moreover, northeast slope receives more moisture and less light related to other considered exposition. These results are in line with Asadollahi, Abrari Vajari *et al.*, and Korpel who reported in his study about 2-3-times lower establishment success on south-facing slopes than on north-facing ones^[23-25].

Fagus orientalis prefers well-drained fertile soils which are characters of forest brown soils. Asadollahi and Abrari Vajari *et al.* showed similar results^[23, 24].

Conclusion

The results showed that the beech seedlings prefer <70% canopy cover in the northeast direction with the elevation of 1,000 to 1,200m a.s.l.. This species prefers pseudogley and forest brown soil with the slope of 0-40%. The present study could conclude that the management of this forest base on close to nature forest management as well as small gaps in forest canopy will help natural regeneration. In general, Kojoor Forest is a developed old growth forest with the best environmental conditions for establishment and regeneration of climax species like *F. orientalis*. Some distinct species in Europe like *Ulmus glabra* regenerates in this forest. This site is undisturbed forest with less anthropogenic effects and diverse topography and soil types which make it the best site of the Hyrcanian Forests. Natural regeneration will guarantee the future of the forest.

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connector author and delegate all the responsibility of the article to him/her regarding to follow the relation with the Ecopersia journal.

Conflicts of interests: This article is extracted for the PhD thesis entitled "The comparative analysis of selected sites of Hyrcanian forests for prioritization of inscription on UNESCO's World Heritage List" by Ali Ghomi Avili, that its supervisors were Dr. Moslem Akbarinia and Dr. Seyed Mohsen Hosseini. Ministry of Cultural Heritage, Tourism and Handicrafts contribute in study writing.

Authors' Contribution: Ali Ghomi Avil (First author), Original researcher (50%); Moslem Akbarinia (Second author), Original researcher (20%); Seyed Mohsen Hosseini (Third author), Methodologist (10%); Mohammad Hassan Talebian (Fourth author), Assistant (10%); Hannes Dieter Knapp (Fifth author), Methodologist (10%)

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