RESEARCH PAPER

Monitoring Forest Habitats Based on Sustainable Development Goals in the Protection of Northern Iran

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ABSTRACT

The Hyrcanian forests of northern Iran are ecologically rich ecosystems that support biodiversity and local livelihoods. This study explores the sustainable utilization of Non-Timber Forest Products (NWFPs), focusing on hazelnut (*Corylus avellana*) in the Fandoglu Forest of Namin, Ardabil Province. Physiographic factors such as elevation, slope, and aspect, along with soil characteristics including texture, pH, electrical conductivity, organic carbon, and total neutralizing value, were analyzed across two vegetation zones using systematic random sampling. Vegetation distribution was assessed through linear transects and circular plots. The findings revealed that hazelnut thrives in lower elevations (1400–1500 meters), gentle slopes (0–12%), and northern/eastern aspects with loamy soils and high humidity. In contrast, steeper and rockier terrains favored more resilient species like *Carpinus betulus* and *Parrotia persica.* The study highlights the critical role of physiographic and edaphic conditions in species distribution and identifies optimal habitats for hazelnut growth. Despite the promising potential for sustainable harvesting, signs of degradation due to human activities particularly uncontrolled tourism underscore the need for integrated management, community involvement, and ecological capacity assessment. Sustainable exploitation of NWFPs can strengthen local economies while preserving the biodiversity of these valuable forest ecosystems.

Keywords: Non-Timber Forest Products (NWFPs), Corylus avellana, Fandoglu Forest of Nimrin, Hyrcanian Forests, Physiographic Factors, Edaphic Factors, Sustainable Exploitation.

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INTRODUCTION

Forests represent the most intricate terrestrial ecosystems, playing a pivotal role in maintaining ecological equilibrium, regulating climate patterns, and sustaining human livelihoods (WATSON, 2018). According to the latest data from the Food and Agriculture Organization (FAO, 2020a), global forest coverage is estimated at approximately 4.06 billion hectares, encompassing nearly 31% of the Earth's land surface. However, the accelerating pace of forest degradation and deforestation is alarming, with an estimated 10 million hectares of forest lost annually (FAO, 2020b). In this context, Iran's predominantly arid and semi-arid climate has elevated the conservation of its remaining forested areas to a national priority. FAO (2015) indicates that Iran possesses around 1.11 million hectares of forest, accounting for 6.8% of the country's total land area. Among these, the Hyrcanian forests in northern Iran dating back approximately 40 million years are regarded as a living museum and a natural legacy from ancient geological epochs (SAGHEB-TALEBI et al., 2018). This phytogeographic zone, stretching from Ardabil Province in the west to North Khorasan Province in the east, is recognized as one of the most valuable temperate broadleaf forest ecosystems globally (MARVIE-MOHADJER, 2005). Regrettably, in recent decades, these forests have faced mounting pressures from land-use changes, unsustainable resource extraction, overgrazing, pest infestations, and disease outbreaks (JAHANBAZI-GOUJANI et al., 2020). Under such circumstances, emphasizing the non-timber functions of forests and promoting the sustainable utilization of forest by-products can simultaneously support conservation efforts and enhance the livelihoods of local communities. Non-Wood Forest Products (NWFPs), as integral and highly valuable components of forest ecosystems, encompass a diverse array of resources including medicinal plants, edible goods, gums, resins, and fibers (EMADI, 2019). Their significance is underscored by FAO estimates suggesting that approximately 80 million individuals across Europe and Central Asia rely directly on NWFPs for their subsistence (FAO, 2019). In Iran, the exploitation of these products has deep historical roots and plays a crucial role in the economic fabric of forested regions (ZOBEIRI, 2018). Among the forests of northern Iran, the Fandoglu Forest in the Namin region of Ardabil Province holds a distinctive ecological and geographical status. Situated at the convergence of two contrasting climatic zones the cold, arid climate of Ardabil and the humid, rainy climate of Gilan this forest benefits from unique conditions conducive to the growth of diverse plant species (ALIZADEH, 2022). Floristic surveys have identified 19 tree species within the forest, spanning 8 families and 17 genera (ALIZADEH, 2022). Corylus avellana emerges as a dominant species within this ecosystem. Taxonomically, DEYSSON (1964) classified it under the order Amentales and family Corylaceae, while GERMAIN (1987) placed it within the order Fagales and family Betulaceae. Contemporary taxonomic frameworks recognize it as part of the Betulaceae family (EGHTESADI, 2018). The ecological and economic importance of hazelnut in this region is so pronounced that the forest itself bears its

name. As a multipurpose species, hazelnut is valued both for its nutritional yield and its ecological contributions to soil stabilization and biodiversity preservation (GHANBARI, 2019). Research indicates that this species exhibits high adaptability to varying environmental conditions, making it suitable for forest development initiatives and the rehabilitation of degraded landscapes (MOHAMMADI-LIMAEI, 2020). Given the relevance of this subject, the present study aims to evaluate the productive capacity of forest habitats and investigate the potential for harvesting NWFPs in the Fandoglu Forest of northern Iran. Key objectives include a comprehensive assessment of ecological conditions, quantitative and qualitative analysis of dominant species such as hazelnut, and the determination of sustainable exploitation potential. The findings are expected to inform forest managers and natural resource planners in formulating effective strategies for the sustainable management of these invaluable ecosystems.

Materials and Methods

Study Area

Gilan Province, located in northern Iran, spans approximately 14,044 square kilometers and encompasses nearly 800,000 hectares of forested and vegetative cover. Geographically, it is bounded by the Caspian Sea and the Republic of Azerbaijan to the north, Ardabil Province to the west, Zanjan and Qazvin Provinces to the south, and Mazandaran Province to the east. The province lies between 45°53′ to 50°34′ E longitude and 36°36′ to 38°27′ N latitude.

As the most precipitation-rich region in northern Iran, Gilan exhibits a sub-Mediterranean climate regime, with annual rainfall exceeding 1,000 mm. This climatic profile supports the cultivation of a wide spectrum of economically significant crops, including cereals, pulses, oilseed species, tea (*Camellia sinensis*), olives (Olea europaea), citrus fruits, kiwifruit (*Actinidia deliciosa*), hazelnuts (*Corylus avellana*), medicinal plants, and other high-value botanical resources. The Hyrcanian Forests, a relict temperate rainforest ecosystem, extend over approximately 1.8 million hectares along an 850-kilometer arc from Astara to Gol-e-Daghi in Gorgan. These forests occupy the northern slopes of the Alborz Mountains, with altitudinal gradients ranging from sea level to 2,800 meters. The forest belt varies in width from 20 to 70 kilometers. Annual precipitation ranges from approximately 600 mm in the eastern sectors to up to 2,000 mm in the western zones. Maximum rainfall occurs during spring, autumn, and winter. The region experiences a mean annual temperature between 15°C and 18°C, with monthly temperature extremes ranging from 28°C to 35°C in summer and +1°C to −4°C in winter (Marvie-Mohadjer, 2006). Situated in the eastern part of Ardabil Province and adjacent to the northern forest belt, the Fandoglu Forest covers an area of approximately 4,423 hectares. Of this, 913 hectares are classified as forested land, while the remainder comprises rangelands and agricultural plots (Keivan Behjou & Pourgholi, 2019). The Fandoglu Forest Park, georeferenced at specific coordinates, is located 25 kilometers southeast of Ardabil city and 10 kilometers south of Nimrin (Figure 3-1). The region's microclimatic conditions are characterized by seasonal precipitation and frequent fog events, which contribute to adequate soil moisture and vegetative growth. Based on synoptic meteorological data, the area is classified as temperate and semi-humid under the Köppen–Geiger climate classification. The average annual precipitation is 290.4 mm, with a mean relative humidity of 70% and an average annual temperature of 9.8°C. Elevation within the Fandoglu Forest ranges from 1,500 to 1,800 meters above sea level (Keivan Behjou & Pourgholi, 2019). During the summer season and peak holiday periods, the Fandoglu Forest experiences substantial recreational and ecotourism activity, attracting both domestic and international visitors. The anthropogenic impacts of tourism particularly along access roads and within the forest park are evident in the form of soil compaction, surface degradation, and edge habitat disturbance, highlighting the need for integrated conservation and visitor management strategies.

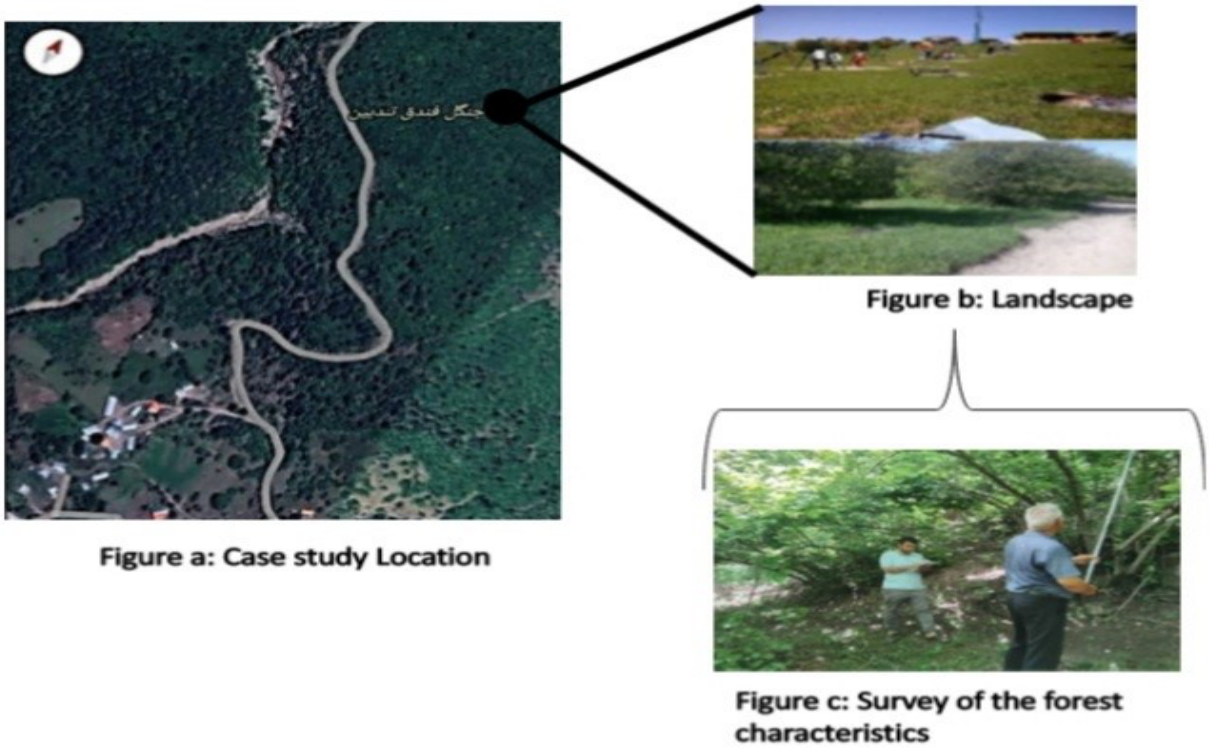

Figure 1: The study Area of the forest stands

Physiographic Characteristics of the Study Site

This study was conducted using hypsometric analysis in this research was carried out according to the standards of the Iranian Forests, Rangelands, and Watershed Management Organization (2021) using ArcGIS 10.8 software. Slope and aspect maps were extracted from the DEM model and classified based on the method presented by Marvie-Mohadjer (2005). To assess the relationship between physiographic factors and the distribution of plant species, linear transects and circular plots were employed. In each plot, the site characteristics including elevation, slope percentage, aspect, as well as species composition, density, and frequency were recorded. Species identification was based on the standard Iranian flora and recognized identification keys.

Elevation Distribution and Species Composition

The results of the hypsometric analysis revealed that the study area lies within the elevation range of 1400 to 1700 meters above sea level. As shown in Table 1, the largest portion of the area (57.87%) falls within the 1400–1500-meter elevation class.

Forest Habitat Soil mesurment

This study employed a completely randomized design with seven treatments (soil samples) and three replicates. Soil sampling was conducted in two Corylus avellana L. habitats: one in Agh Olar Talsh (longitude 48°48′ to 48°52′E, latitude 37°37′ to 37°41′N) and the other in Namin, Ardabil (longitude 48°48′ to 48°52′E, latitude 38°38′ to 38°42′N). Sampling was performed using a systematic random method based on the ISO 18400-104:2018 standard. Soil samples were taken from the four main compass directions (north, south, east, west) at three soil depths (0-10, 10-20, and 20-30 cm) during the peak root activity period (mid-April). The samples were transferred to the laboratory at 4°C and air-dried before being sieved through a 2 mm mesh.

Soil Texture Determination

In this study, the soil texture in the north, south, east, and west directions of the Agh Olar Talsh forest habitat was determined using the hydrometer method (GEE and BAUDER, 1986), and similarly, the soil texture in the same directions was analyzed for the Namin, Ardabil habitat following the USDA classification system.

Soil pH Measurement

Soil acidity (pH) was measured for both the Agh Olar Talsh and Namin, Ardabil habitats in all four cardinal directions (north, south, east, west) using a digital pH meter (Metrohm 744 model).

Electrical Conductivity (EC) Measurement

Electrical conductivity (EC) was determined in the saturated soil extract using a conductivity meter (Jenway 4510 model). EC measurements were conducted for both habitats in the four cardinal directions.

Soil Organic Carbon (OC) Measurement

Soil organic carbon (OC) was measured in the Agh Olar Talsh and Namin, Ardabil habitats in all four directions using the Walkley-Black method.

Calcium Carbonate (TNV) Determination

Following the approach of LOEPPERT and SUAREZ (1996), calcium carbonate equivalent (TNV) was determined using the titration method with 0.5 N sulfuric acid in the four directions of the study sites. Total nitrogen was measured using the Kjeldahl method as described by Bremner (1996), and the inorganic nitrogen fraction was

determined using the Olsen method (Olsen et al., 1954).

Results

The results from the hypsometric analysis revealed that the study area is located within the elevation range of 1400 to 1700 meters above sea level. As shown in Table 1, the largest portion of the area (57.87%) falls within the 1400-1500-meter elevation class.

Table 1: Distribution of Plant Species in Different Elevation Classes of Fandoglu Forest

Eco physiological characteristics	Species in highest layers (trees and shrubs)	Surface (hectare)	The height Classification level (m)
The habitat with high relative humidity, deep lumic soils, suitable drainage	*Corylus avellana*	4.62	1400-1500
Spicy slopes, stone soils with moderate depth, good drainage	*Carpinus betulus*	2.41	1500-1600
Seedlings, shallow soils conditions	*Parrotia persica*	54.51	1600-1700

Topographic analysis of the study area indicated that the mean slope gradient is approximately 0.1%. The most prevalent slope category is the 0–5% class, which comprises 42.07% of the total terrain. As illustrated in Table 2, the spatial distribution of plant species across varying slope classes exhibits a discernible ecological pattern, suggesting slope-dependent habitat preferences and microtopographic influences on species composition.

Table 2 – Floristic distribution across slope gradients in the Fandoglu Forest

The vegetation characteristics	species (tree and shrubs)	Surface (hectare)	Tilt class (percentage)
Downstream areas, deep alluvial soils, humidity	*Alnus subcordata* *Corylus avellana* *Ulmus glabra*	37.452	0-5
Mild slopes, fertile leminies, suitable drainage	*Carpinus betulus* *Diospyros lotus، Corylus avellana*	77.346	5-12
Medium slopes, Lumy-clay soils, good drainage	*Fagus orientalis Parrotia persica* *Corylus avellana*	77.234	12-30
Medium slopes, Lumy-clay soils, good drainage	*Quercus macranthera Cerasus avium*	69.40	30-60

Geographical Distribution and Species Composition

Based on the obtained results, the largest portion of the area (70.76%) is located in the southern direction. As shown in Table 3, each geographic direction hosts a specific plant community.

Table 3 - Distribution of plant species across different geographic directions of Fandoglu Forest.

Microclimia and soil characteristics	Species in highest layers (tree's and (shrubs	Surface (hectare)	Geographical Aspect
High light, relative dryness, Lavi style soils	*Quercus castaneifolia* *Celtis australis Corylus avellana*	2.71	South
High humidity, wet soil and rich humus	*Fagus orientalis* *Ilex spinigera* *Corylus avellana*	79.26	North
High humidity, wet soil and rich humus	*Quercus castaneifolia(* *Celtis australis*	82.40	East
Saturation moisture, heavy clay soils	*Alnus subcordata*	97.2	West

Discussion

The results of this study revealed that the Fandoglu Forest in Namin possesses substantial potential for the sustainable utilization of non-wood forest products (NWFPs). This potential is closely linked to the physiographic and edaphic characteristics of the habitat. The distribution of the dominant hazel species (Corylus avellana) was primarily concentrated within the elevation range of 1,400–1,500 m. This observation corresponds with the findings of ALIZADEH (2022), who identified the Fandoglu Forest as a habitat with high relative humidity and deep loamy soils, which effectively meet the ecological requirements of hazel. As elevation increases, conditions shift toward steeper slopes and rocky soils, resulting in a decline in hazel dominance and the emergence of more resilient species such as Carpinus betulus and Parrotia persica. This pattern of species composition across elevation gradients supports the conclusions of MARVIE-MOHADJER (2005), who emphasized the sensitivity of Hyrcanian forest species to microclimatic variations and soil properties. Slope analysis further indicated that economically valuable species such as hazel thrive best on gentle slopes (0–12%), where they exhibit greater density and vitality. These slopes, characterized by deep alluvial soils and optimal drainage, provide ideal conditions for root development and nutrient uptake. Geographic orientation also played a decisive role in moisture and light distribution. Moisture-loving plant communities, including *Fagus orientalis* and *Ilex spinigera*, were dominant on northern and eastern slopes, consistent with the findings of SAGHEB-TALEBI et al. (2018), who attributed higher species diversity in these directions to enhanced moisture retention and moderated light exposure.

In contrast, southern slopes hosted drought-resistant and light-demanding species such as oak, reflecting ecological adaptation to harsher environmental conditions. The concentration of high-density hazel populations on gentle slopes and northern/eastern orientations identifies zones with high potential for sustainable NWFP exploitation. However, as JAHANBAZI-GOUJANI et al. (2020) cautioned, these sensitive ecosystems face increasing threats from land-use changes, overgrazing, and unsustainable harvesting practices. Evidence of degradation caused by recreational activities along the roadsides of the Fandoglu Forest Park (see Materials and Methods) reinforces this concern and highlights the urgent need for integrated management and continuous monitoring. According to the Food and Agriculture Organization (FAO, 2019), NWFPs can play a significant role in supporting the sustainable livelihoods of local communities. The findings of this study confirm that the Fandoglu Forest, with its rich reserves of valuable non-wood species especially hazel holds considerable promise for regional sustainable economic development. Nonetheless, exploitation must be guided by comprehensive ecological assessments, determination of the forest's carrying capacity, and active involvement of local stakeholders an approach identified by EMADI (2019) as essential for successful resource management.

Conclusion

This study clearly demonstrates that the Fandoglu forest of Namin, as part of the valuable Hyrcanian ecosystems, holds significant potential for the sustainable exploitation of non-wood forest products, particularly the valuable hazel species (*Corylus avellana*). Physiographic and edaphic analyses revealed that factors such as elevation, slope, and geographic orientation play a decisive role in the distribution, density, and health of plant communities. The assessments showed that the most suitable habitat for the sustainable development and exploitation of hazel lies within the lower elevation ranges (1400–1500 meters), characterized by gentle slopes (less than 12%) and orientations to the north and east. These areas benefit from higher humidity, deeper soils, and more favorable light conditions. However, the presence of threats such as excessive recreational pressure and the potential for land-use change underscores the necessity of developing a comprehensive and scientific management plan. Such a plan should be framed within an ecosystem-based management approach, emphasizing habitat zonation, determining the true carrying capacity, and ensuring active participation from local communities. Wise exploitation of this natural resource can not only contribute to the sustainable livelihoods of local residents but also serve as an effective strategy for preserving the biodiversity of this unique natural heritage.

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