

[Research]

## Determination of suitable areas for reforestation and afforestation with indigenous species

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### ABSTRACT

To be successful in tree establishment, an assessment of land suitability would be necessary. The aim of this study was determining the potential habitats of three native tree species (*Quercus persica*, *Pistacia atlantica*, *Amygdalus scoparia*) in Siahkoh region of Ilam County, using Boolean method and Geographic Information Systems (GIS). For this regard, the slope, aspect and hypsometric maps of the area were produced using topographic maps. To provide soil properties maps, 40 soil samples in depth of 30 cm were randomly taken from the defined region (about 954 ha). Soil sample properties such as pH, texture, electrical conductivity, and organic material were measured. Soil maps and soil data layers were produced in GIS environment. With respect to ecological needs of the selected tree species and combining of all provided maps, about 890 ha of the total area could be reforested or afforested. The results show that from the total suitable area, 368.72 ha (41.41 %) for *Quercus persica*, 353.44 ha (36.69 %) for *Pistacia atlantica* and 176.2 ha (19.78 %) for *Amygdalus scoparia* were found to be suitable for these species. The results of comparing the extracted suitability map with the existing 30 ha afforestation in the region show that, from 10 hectares afforested by each species, *Quercus persica*, *Pistacia atlantica* and *Amygdalus scoparia* 7.65, 3.11 and 4.25 ha are located in the high suitable areas, respectively.

**Key words:** Native species, Suitable areas, GIS, Forestation.

### INTRODUCTION

The changes in species diversity, structural diversity and abundance of non-native species are also common concerns that are parts of the international criteria for assessing sustainability of forestry practices (Kerns & Ohmann 2004). As the current crisis of species extinction has become apparent (Debinski *et al.* 1999), land managers and biologists have sought to identify important habitats to the reservation of species diversity (Mahdavi & Jamshidifard 2014). Understanding the potential distribution of rare plant species is a key component in managing and regulating land-use activities (Nock 2002). Therefore, with respect to the importance of protection guarantee and continuing of this valuable heritage (rare species) for the future generation, afforestation and reforestation should be done with a cautious selection (Zeng *et al.* 2007).

The selection of suitable species for planting is one of the most important factors in afforestation or reforestation activities to development and inter-planting of forests (Eslami *et al.* 2010). The wrong choice of suitable species or appropriate area according to site conditions and ecological needs of species would not have been producing desired results or most of species would be destroyed. The potential areas for afforestation and reforestation should be determined by an evaluation of climate, soil, topographical and environmental components, ecological needs of the species and the understanding of local biophysical limitations (Ceballos-Silva & Lopez-Blanco 2003).

Nowadays, due to rapidly increasing destruction of natural resources and problem of desertification, it seems to be essential to employ new techniques for accelerating the

identification, control and management of natural resources (Sedighian 1996; Eshraghi 1996). The integration of multi - criteria evaluation within Geographic Information System (GIS) context helps users to improve the decision - making processes about these issues. There are many studies about the identifying of the potential habitat of plant or tree species. We referred to some of them here.

Gupta and Owais (2000) attempted using GIS techniques to determine the areas that have the potential for planting *Cardamom elttaria* in Ratechaha watershed in Askim at the North and East of India.

The results of the study showed that about 3.39 % and 55.21 % of the total areas have a very good and good potential for cultivation of this plant, respectively. Shahadat & Kwei (2003) used GIS for the selection of suitable areas for the afforestation of mangrove species in the coastal areas of Bangladesh.

They showed that the mangrove forest could be in both natural and artificial conditions in Bangladesh. Dilek *et al.* (2007) conducted a study about afforestation in Golbasi protected area in Turkey. They concluded that for determination of the afforestation area the hydrological landscape and erodibility of the sites should be considered. Abbasi *et al.* (2009) determined the potential suitable habitat for three industrial and Mediterranean trees species (cypress, black pine and olive) using RS and GIS techniques in forested areas of Armand in Chaharmahal-o- Bakhtiari Province.

In this study, various maps such as topography, geology, climate, soil, land use, forest cover, irrigated and dry farm lands and rangelands were prepared using TM data.

Results showed that about 1150 ha of the area for cypress species, 996 ha for black pine and 5199 ha for olive had the potential of suitable habitats. Eslami *et al.* (2010) investigated the application of GIS for the selection of suitable species for afforestation in Caspian forests of Iran.

They determined the ecological requirements of 16 species and also topographic and edaphic conditions of the area.

They used Analytical Hierarchy Process (AHP) method for weighing different map layers. Mahdavi & Jamshidifard (2014) determined the potential habitats of two rangeland species in semi-desert area of Qasre-Shirin based on soil factors using GIS. The results of their study showed that in total, two locations with surface area of 1677.3 ha and 1356 ha were suitable for growing of *Salsola rigidia* and *Agropyron trichophorum*, respectively.

The forest ecosystems of the study area (Siahkoh in Ilam County) are destroyed due to the vicinity to Ilam City as well as neighboring villages and excessive grazing which resulted in soil erosion and loss of the vegetation cover and also the species diversity in this region (Tolabi 2014). Hence, it is essential to adopt an appropriate way to conserve this forest ecosystem and to try in the reforestation, afforestation and development of forests by the native tree species. So, we should plant the native tree species resistant to drought and also be able to adapt to the area such as Oak, Pistachio and Almond.

The most important reason for choosing these three species is that they are indigenous species to the Zagros region and widely employed in the reforestation and afforestation activities in this region. Therefore, the main purpose of this study was to determine the suitable areas for the three native species, *Quercus persica*, *Pistacia atlantica* and *Amygdalous scoparia* within GIS context in Siahkoh area, Ilam County.

## MATERIALS AND METHODS

### Study area

The study area (in Siahkoh region) covers an area of 954 ha located near the county of Ilam in Ilam Province, southwest of Iran. The studied area limited between 45° 24' east longitude and 31° 58' north latitude (Fig. 1). Its maximum elevation above sea level is 1850 m and minimum elevation is 1250 m. Rainfall is started in the first half of October and ends in early June. Summer is the dry like other places in Zagros region. The annual rainfall and temperature averaged 589 mm and 23.5°C, respectively (Fig. 2).

August with the average temperature of 48.3°C is the warmest month. The average minimum

temperature in January is (9.7°C) (Ilam General Meteorological Office 2014).

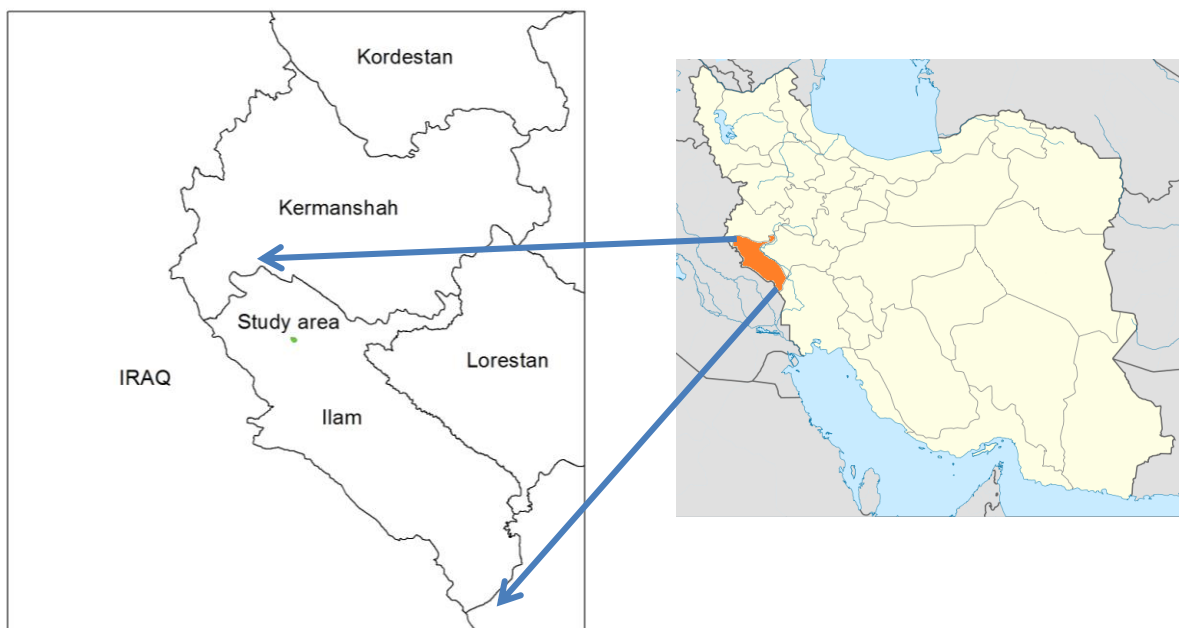


Fig. 1. Map of the location of the study area in Ilam County and Iran.

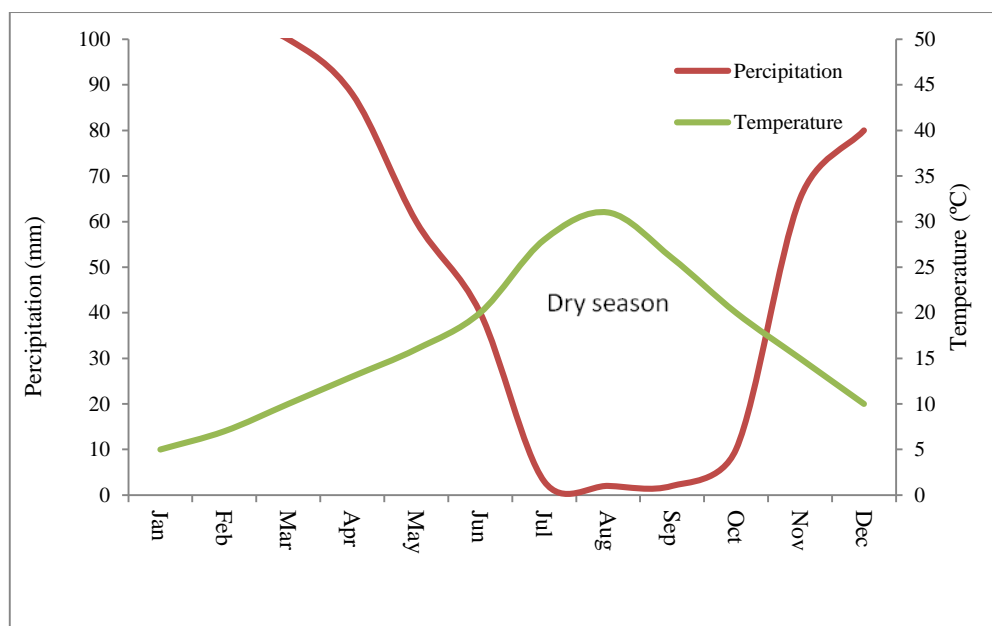


Fig. 2. Ombrothermic curve of Ilam station.

**Methodology**

This research was conducted in four phases.

**Phase 1. Identifying the study area and preparing the land use map**

After the field survey and identifying the boundaries of the study area, the land use map was provided from General Natural Resource

Office in Ilam Province.

The different land uses were delineated on map for afforestation and reforestation activities including agricultural, rangeland, rocks and other suitable areas (Fig. 3). Some basic thematic maps also were provided from related organizations.

The land use map and the other required ones were created by Arc GIS 10.2 software.

### Phase 2. Soil sampling and measuring soil characteristics

After identifying the suitable areas for afforestation and reforestation, soil sampling was carried out to determine soil characteristics of the area and also the soil requirements of some species. 40 profiles in depth of 0-30 cm

were randomly digged and soil samples were taken. Among certain characteristics of the soil, the most influential factors were measured including: soil texture (using the particle size and hydrometer methods), electrical conductivity (by extraction method and EC apparatus), soil acidity (by pH meter) and soil organic matter (%) (Walkley Black method) (Xu *et al.* 2006; Mahdavi & Jamshidifard 2014).

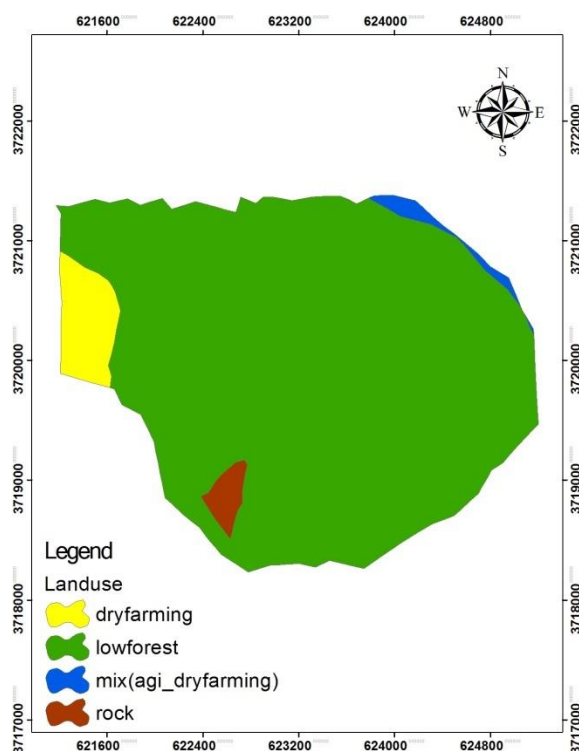


Fig. 3. The land use map of study area.

### Phase 3. Digitizing and creation of various required maps

After providing required topographic and physiographic maps, the slope, aspect and hypsometric maps were created using topographic map and Digital Elevation Model (DEM). In these maps, the elevation, aspects and slope were divided into 6, 4 and 4 classes, respectively.

The data layers of soil were also prepared based on characteristics of soil samples and Inverse Distance Weighting (IDW) interpolation in ArcGIS. The layers of soil texture, depth, EC, pH and soil organic matter were classified into 3, 4, 4, 4 and 3 classes, respectively. For all polygons of resource and land capability map, the information on various soil parameters was

performed according to the land unit components as separate fields. Each field represented one of the soil factors prepared as a separate layer according to the land capability maps. In addition, an information layer was prepared for each of the investigated soil factors. Another data layer was provided concerning the waterways and streams map in the area. Hence, at first, the waterway and stream lines were digitized, then a waterways and streams map was drawn using a distance buffer of 50 m (Figs. 4-7).

### Phase 4. Combining the provided data layers

The suitable habitats for all the three species on the map were specified by combination of the data layers and adjusting with soil and

ecological needs of each species separately. The latter were provided from literature review, books and published articles about this species from similar areas in Zagros region. Thus in each ecological and environmental data layers, the suitable areas for growth and establishment of intended species were classified as a class (with numerical value of 1) and unsuitable areas for growth and establishment as another different class (with numerical value of zero). Boolean logic method was employed to weight the data layers in GIS. Boolean algebra is based on the basics of binary logical operations. It forms a mathematical structure that is based only upon the values 1 (true) and 0 (false). In addition, Boolean algebra provides different links that can be "true" or "false" but never both

(Heywood *et al.* 2006). In this study the criterion maps were converted to 0–1 maps based on the constraints and then the Boolean operation was used to combine the maps. Finally, after combining all data layers, the suitable areas were identified for the growth and establishment of each species according to the ecological needs and ecological restrictions of each one, separately. Based on the resulted maps, we could measure the suitable areas for reforestation and afforestation of certain species. To check the adjustment of existing plantations of the three species in the region with maps of their potential suitable sites, the data layers of existing plantations boundaries were overlaid and then compared with the extracted maps.

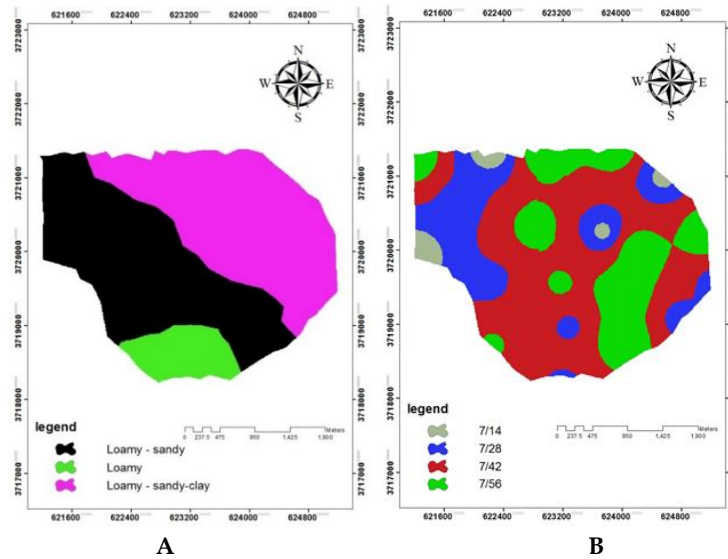


Fig. 4. The map of soil texture (A) and soil pH (B) in the study area.

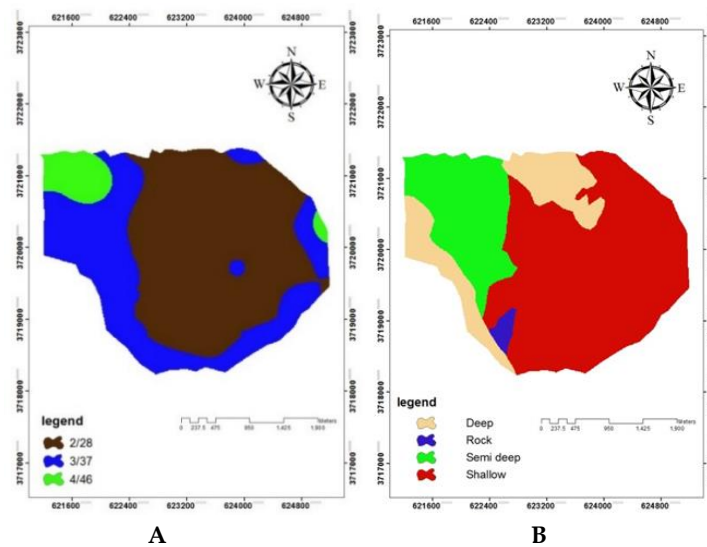


Fig. 5. The map of amount of organic matters (%) (A) and the depth (B).



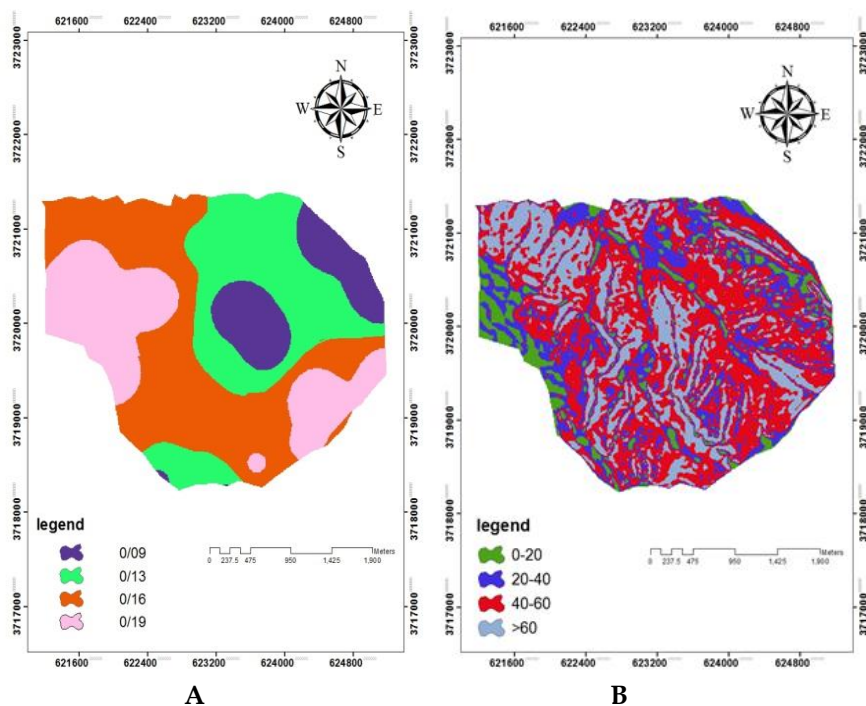


Fig. 6. The map of soil EC (A) and slope (%) (B) in the study area.

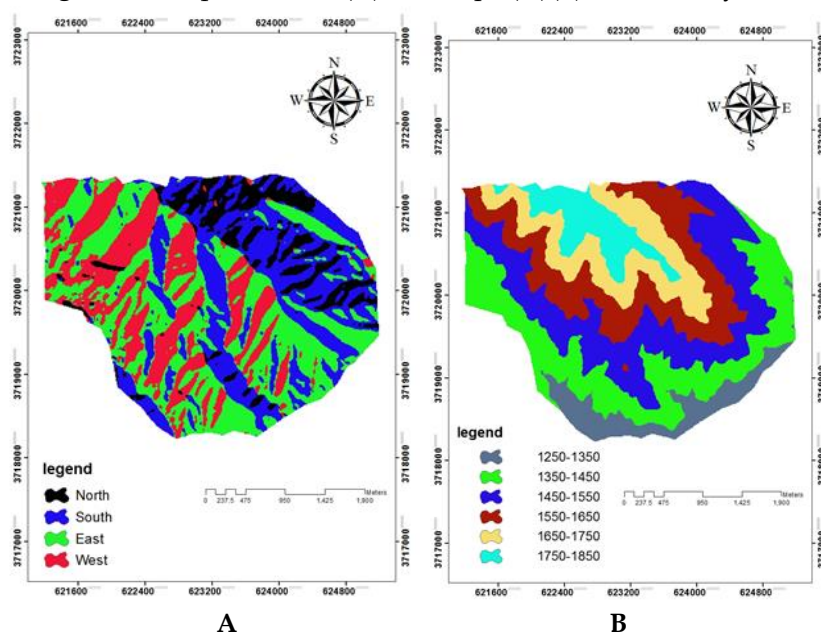


Fig. 7. The map of aspect (A) and elevation (B) in the study area.

## RESULTS

### Results of soil tests

The results for soil samples characteristics are shown in Table 1.

### Determination of the potential habitat for studied species

After providing the land uses map, the area of different land uses in the region were measured as follow: dry farming 42 ha, mixed of dry and

irrigated farming 10 ha, rocks and unplatable 12 ha and plantable areas 890.36 ha.

### Identification of the best suitable areas for *Q. persica*

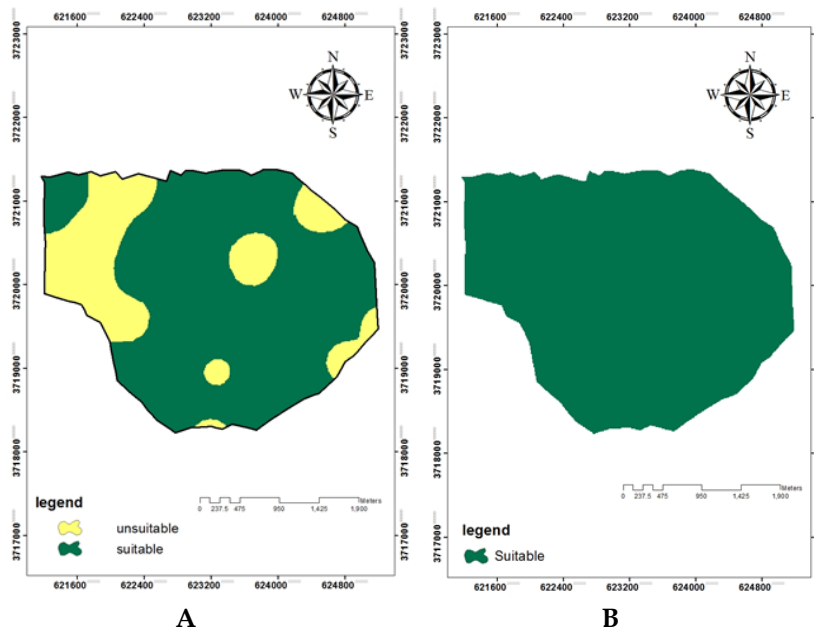
The result of combination of soil data layers showed that in terms of EC, organic matters and texture, 890.36 ha (100 %) of the total plantable area had the suitable condition for *Q. persica*.

For other characteristics such as pH, depth, slope, aspect and elevation, the best suitable areas were defined as follow, 674.26 ha (75.72 %), 200 ha (24.47 %), 686.31 (77.8 %), 98.82 (11.9 %), 777.44 (87.31 %) of the total plantable areas,

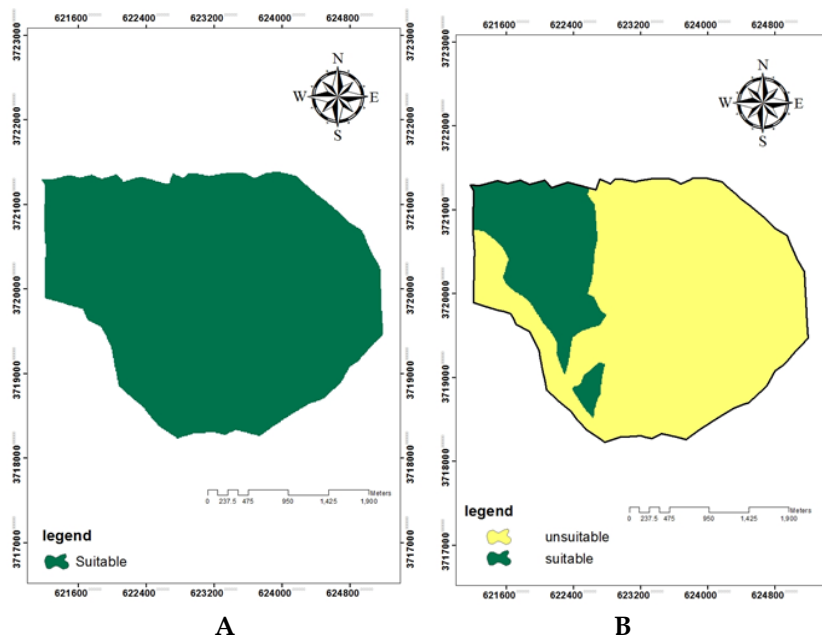
respectively. Finally, after combining all these data layers, 368.72 ha (41.4 %) of the plantable areas had the best conditions for *Q. persica* afforestation and reforestation activities (Figs. 8-12).

**Table 1.** Soil analysis results.

Clay (%)	Silt (%)	Sand (%)	Organic matter (%)	EC (dS .M <sup>-1</sup> )	pH	Studied Factors
13.33 - 23.33	12.5 - 36.67	47.5 - 64.17	1.19 - 4.46	0.19 - 0.06	7 - 7.56	35 - 0 cm depth



**Fig. 8.** The map of suitable area for *Q. persica* in terms of pH (A) and EC (B).



**Fig. 9.** The map of suitable area for *Q. persica* in terms of soil texture (A) and depth (B).

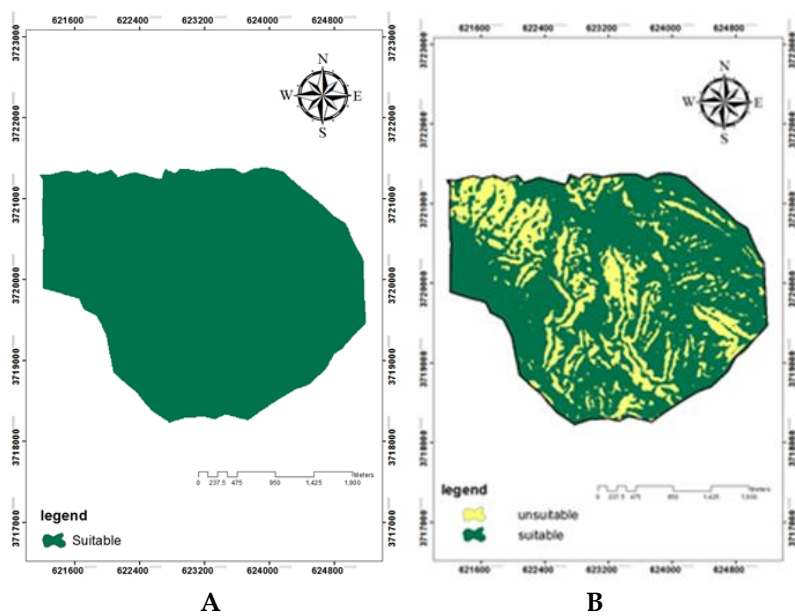


Fig. 10. The map of suitable area for *Q. persica* in terms of soil organic matters (A) and slope (B).

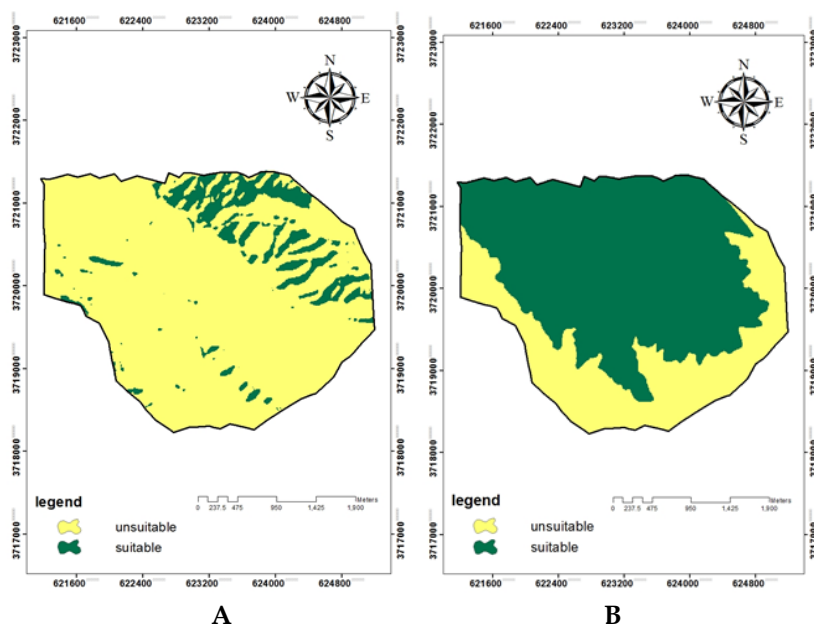


Fig. 11. The map of suitable area for *Q. persica* in terms of aspect (A) and elevation (B).



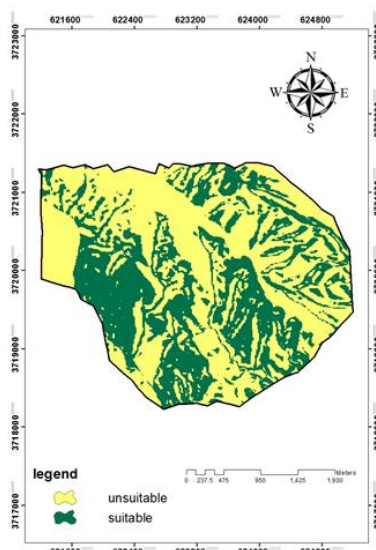


Fig. 12. The final map of the most suitable area for *Q. persica*.

**Identification of the most suitable area for *P. atlantica***

According to the extracted soil data layers based on ecological needs of wild pistachio and combining all data layers for this species, the best suitable conditions areas were determined. The results of integration of all produced maps showed that in terms of EC and organic matters 890.36 ha (100 %) of the total plantable area has the suitable conditions for *P. atlantica*

reforestation and afforestation activities. For other characteristics such as pH, texture, depth, slope, aspect and elevation, the best suitable areas were defined as follow, 864.35 ha (97.7 %), 806.42 ha (90.79 %), 145.3 ha (16.31 %), 818.78 (91.96 %), 257.79 (32.8 %), 285.67 (32.8 %), of the total plantable areas, respectively. Finally, after combining all the data layers, 353.44 ha (36.69 %) of the plantable areas had the best conditions for *P. atlantica* plantation activities (Figs. 13-17).

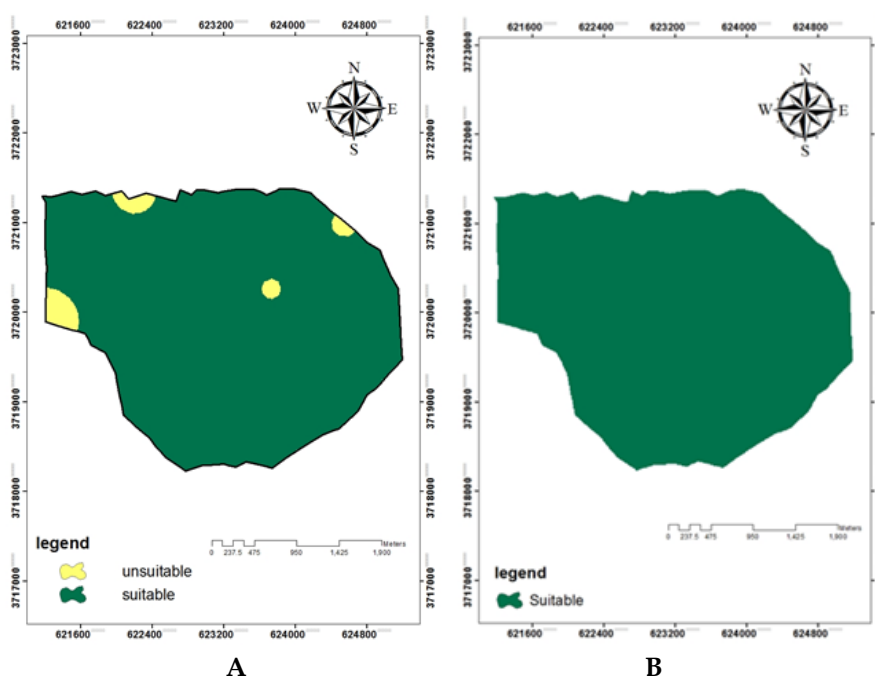


Fig. 13. The map of suitable area for *P. atlantica* in terms of pH (A) and EC (B).

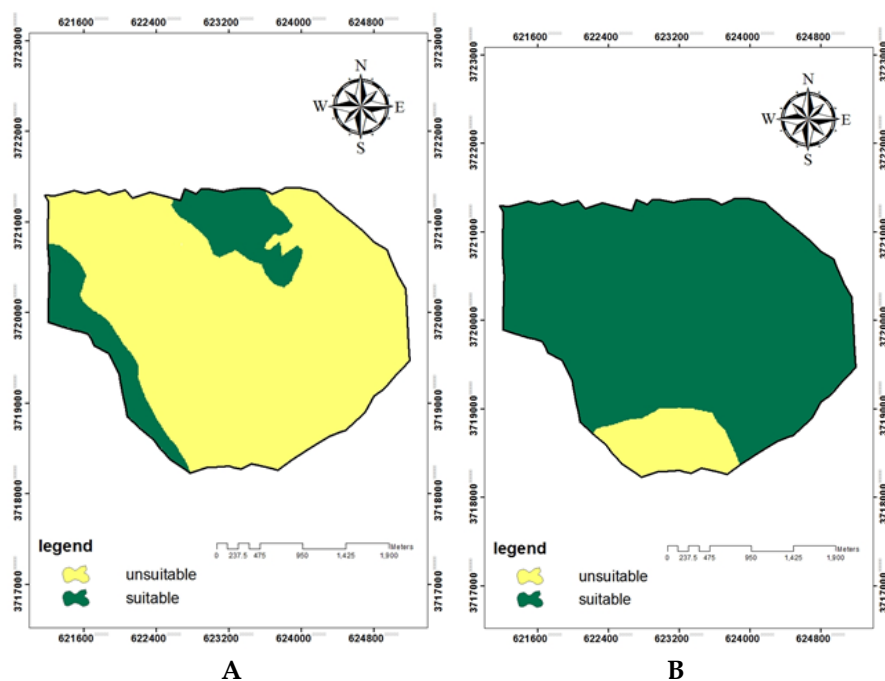


Fig. 14. The map of suitable area for *P. atlantica* in terms of depth (A) and soil texture (B).

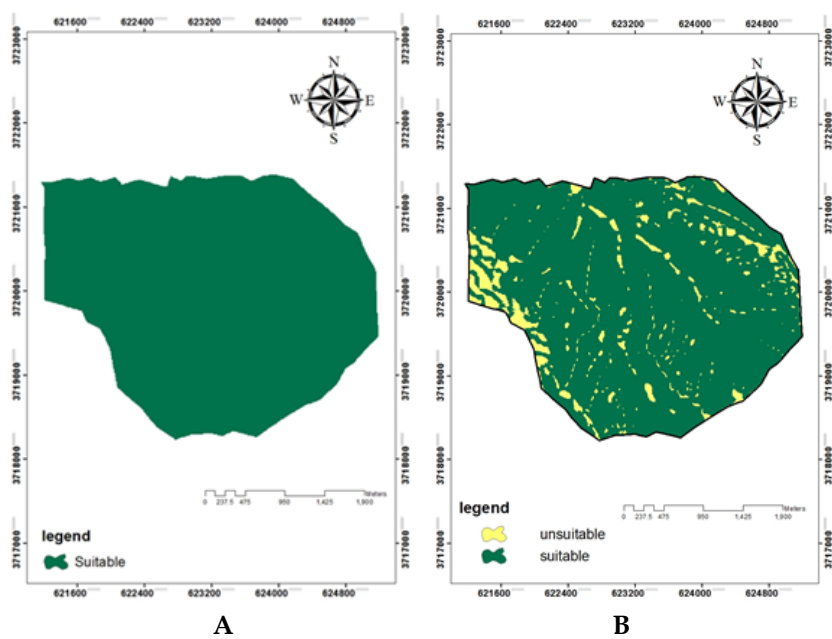


Fig. 15. The map of suitable area for *P. atlantica* in terms of soil organic matter (A) and slope (B).

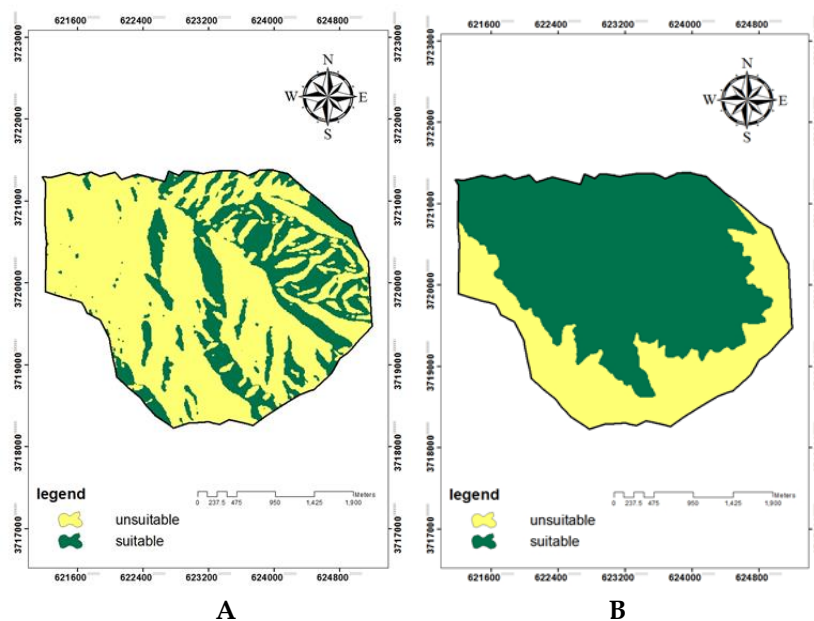


Fig. 16. The map of suitable area for *P. atlantica* in terms of aspect (A) and elevation (B).

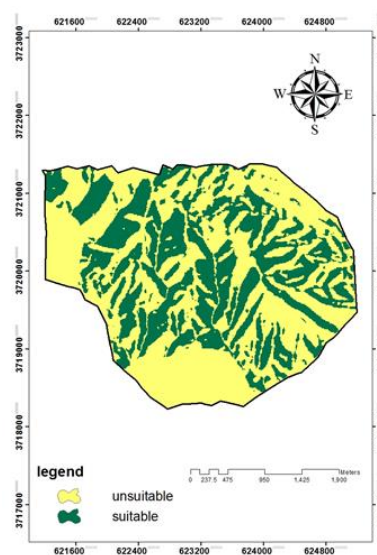


Fig. 17. The final map of the most suitable area for *P. atlantica* in the study area.

#### Identification of the most suitable area for *A. scoparia*

The result of soil layers' combination for this species showed that 223.69 ha (25.12 %), 890.36 ha (100 %), 528.19 ha (59.32 %), 497.4 ha (55.82 %), 723.53 (82.38 %), 400.85 (45.2 %), 416.9

(46.73 %) and 487.25 ha (54.72 %) of total studied rangeland area had suitable conditions for *A. scoparia* in terms of pH, EC, organic matters, soil texture, depth, slope, aspect and elevation, respectively (Figs. 18-22).

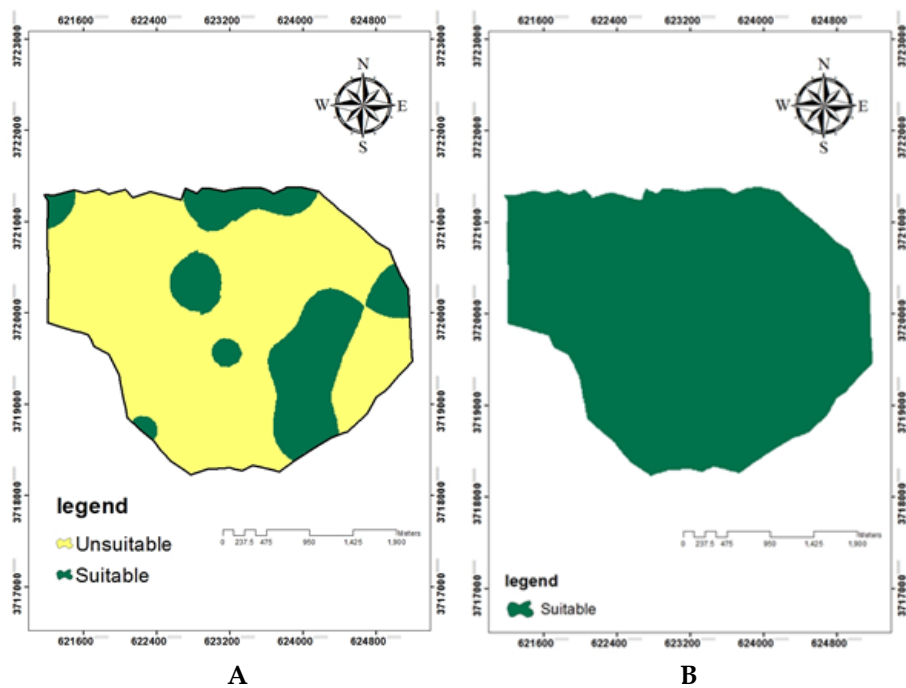


Fig. 18. The map of suitable area for *A. scoparia* in terms of pH (A) and EC (B).

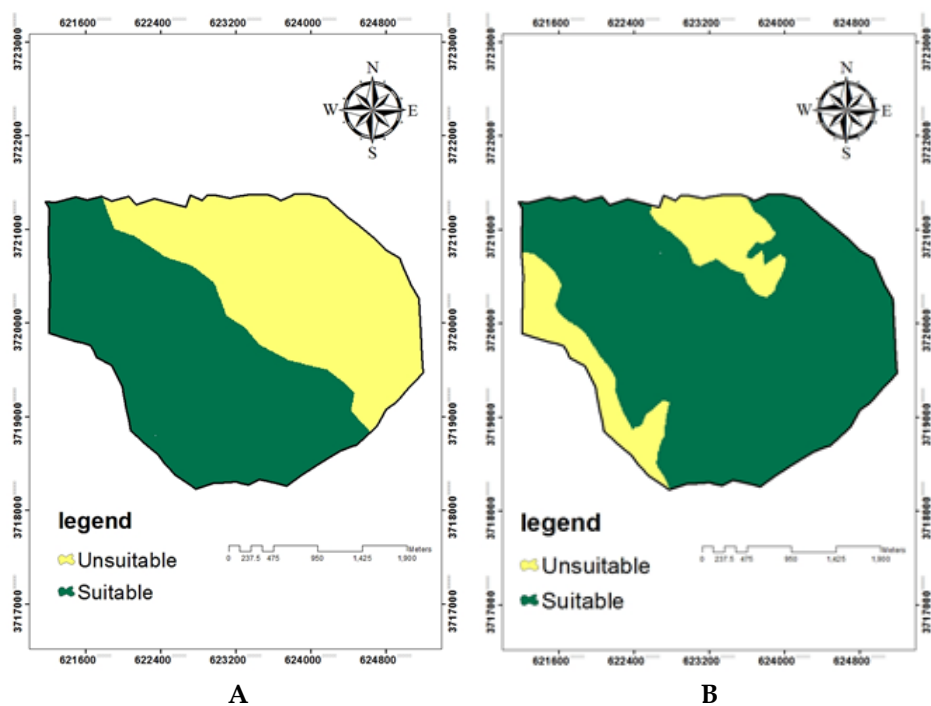


Fig. 19. The map of suitable area for *A. scoparia* in terms of soil texture (A) and depth (B).

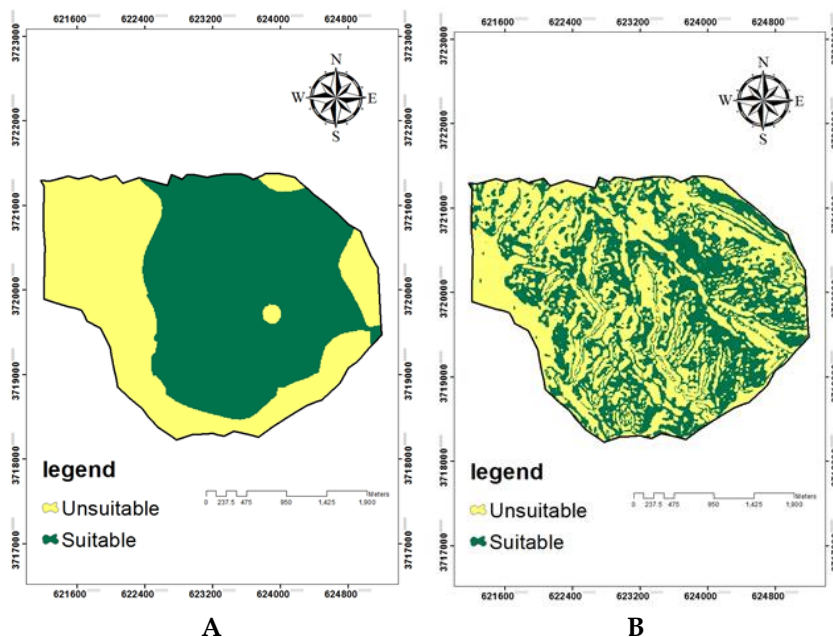


Fig. 20. The map of suitable area for *A. scoparia* in terms of soil organic matters (A) and slope (B).

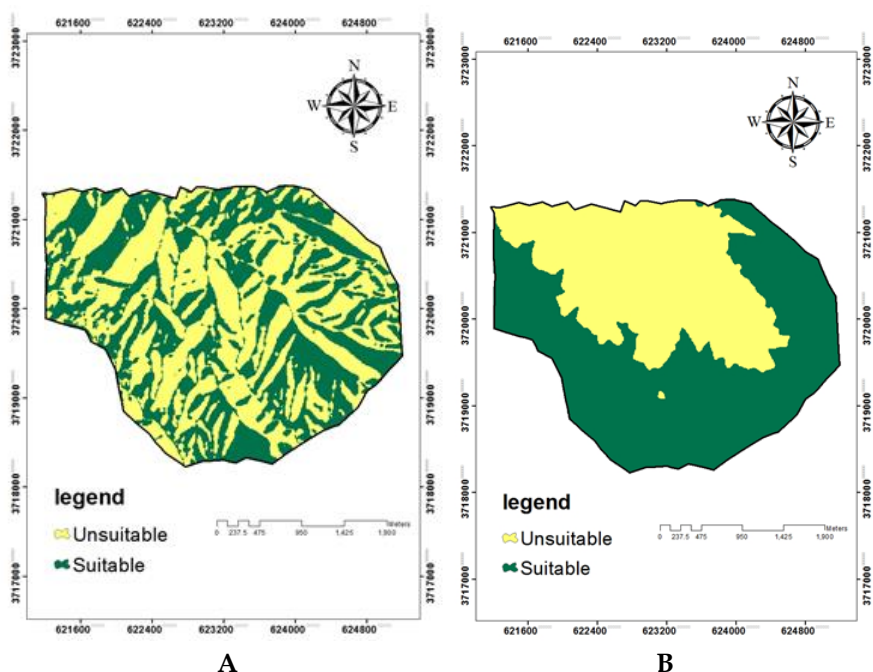


Fig. 21. The map of suitable area for *A. scoparia* in terms of aspect (A) and elevation (B).

The results of combining all the prepared maps for *A. scoparia* showed that 176.20 ha (about 19.78 % of the total plantable area) had the best condition for almond afforestation and reforestation activities (Fig. 22).

**The comparison of existing plantation boundaries with resulted suitable maps in the study area**

In this stage, the areas of existing plantation of the three species in the study area were compared with their extracted suitable areas. The results showed that from 10 ha plantation in the study area, 7.65 ha, 4.25 ha and 3.11 ha were located in suitable areas for *Q. persica*, *A. scoparia* and *P. atlantica*, respectively (Fig. 23).

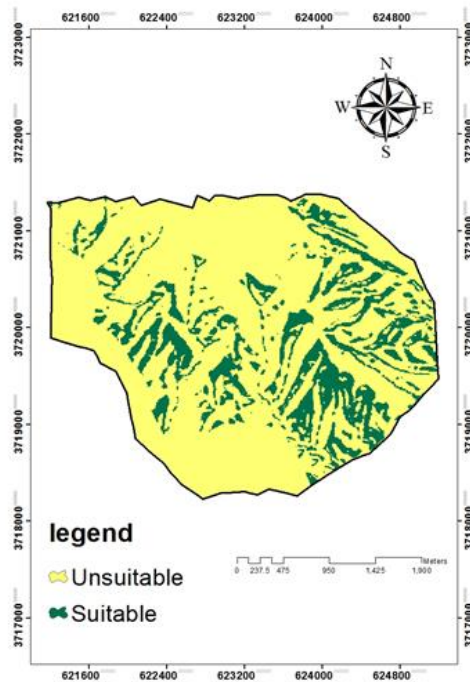


Fig. 22. The final map of the most suitable area for *A. scoparia* in the study area.

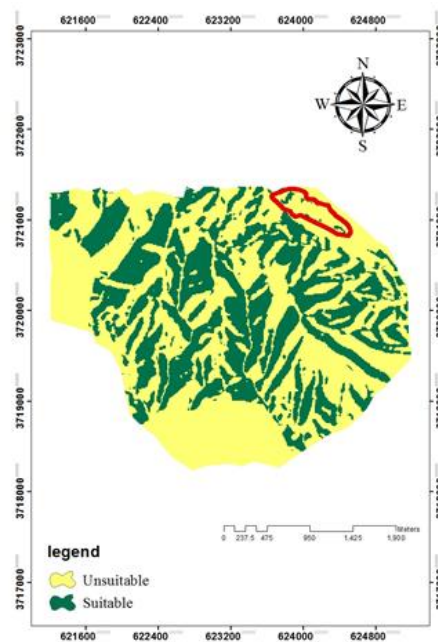


Fig. 23. The map of existing plantation of *P. atlantica* in the study area.

## DISCUSSION

A considerable proportion of the remaining natural forests in Zagros regions has been severely degraded by the rural communities to produce primary materials. In their current restricted and degraded state, the remaining native forests face the potentially rapid and extreme stress of climate changes, droughts, pest outbreaks and forest fires. Therefore,

reforestation and afforestation with native species is an important approach for reducing and reversing biodiversity loss and mitigating climate changes. Afforestation and reforestation if done with proper planning and at appropriate sites with suitable native species can become a commercially viable good solution for many human needs without harming the balance and biodiversity of nature



(Cunningham *et al.* 2015). The purpose of this study was to identify the suitable areas for plantation (reforestation and afforestation) of the three native important species in Siahkoh region of Ilam County.

The choice of appropriate species of trees and shrubs is a major factor determining success of an afforestation program.

Choice of species is therefore a decision that should be made while keeping in view the objectives of the program as well as the edaphic-climatic and socio-economic conditions prevailing in the area (Siyag 2014).

In this research, the selection of studied species was based on this fact that introduction of exotic species may cause major loss in biodiversity and species extinction either due to direct replacement by exotics or indirect effects on the forest ecosystem. In addition, there are 30 ha plantations of the selected species in the study area and we could examine the prepared suitable area maps with the existing plantation map of examined species.

The method of determining suitable areas for the three species was based on a multi-layered GIS approach, so that, after accessing to soil, terrain and climate species needs (Siyag 2014), we started searching the similar areas in the range of soil conditions and environmental characteristics. The applied approach in the study could be quite valuable in determining potential sites for the tree species with specialized habitat requirements.

It is important to find the suitable habitats for growing plants in order to establish successful reforestation and afforestation in Zagros regions. So, the relatively new techniques such as GIS and RS can be used to accelerate plantation activities.

Development of GIS could simplify the analysis of environmental gradients over large spatial scales and provides a tool to digitize the gradients.

These methods are reducing the failure possibility in reforming the plans and reducing costs with their acceptable accuracy.

GIS was used in this study to digitize and analyze the environmental variables. The

results presented here was close to the hypothesized estimation that this approach would be able to predict habitat suitability for the three species. Most of the reviewed studies (inside and outside of Iran) have used this method to analyze the distribution of plant species and plant communities and determination of their potential habitat along environmental gradients (Franklin 1995; Austin 1998; Irvani 1999; Abbasi *et al.* 2009; Mahdavi & Jamshidifard 2014).

## CONCLUSION

Afforestation and reforestation are important activities for restoration of terrestrial ecosystem productivity in arid and semiarid areas. Application of appropriate technology, institutional arrangements, and enabling conditions for participation by local communities are the necessary conditions of successful afforestation and reforestation programs in arid and semiarid zones. As a result of large-scale degradation of forest resources and widespread concern among governments and public institutions, afforestation and reforestation are considered as serious money - expending practices to prevent the land degradation.

A regional scale habitat mapping approach should be developed to meet this need using RS and GIS, and soil properties. These potential habitat maps provide effective tools for conservation and development planning as well as monitoring and management of plants (such as rare plant) habitat.

## Recommendations for success of plantations

As global climate is changing, plant distributions are dynamic in both spatial and temporal dimensions which may need to be carefully interpreted, re-evaluated and updated by the new-available potential maps. It means that an exotic species may be sometimes preferable for afforestation and reforestation programs. A number of potential risks that may affect the accuracy of the method must be considered in the future researches, as follow: the location of potential habitat may be limited to one region which may result in the

perception that the species grow under certain conditions when other areas were simply not examined. Selected environmental variables may not be sufficient to describe all the parameters of species habitat requirements. Most land areas in the developing countries in arid and semiarid regions are likely to be grazed by livestock or by wild animals. Therefore, the plantation site may need to be fenced at least for several years till trees were too tall to be reached by the animals.

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## تعیین نواحی مناسب جنگل کاری با گونه‌های بومی

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### چکیده

برای موفقیت در استقرار درختان، لازم است که یک ارزیابی از متناسب بودن اراضی داشته باشیم. هدف اصلی این مطالعه تعیین رویشگاه‌های مناسب و بالقوه‌ی سه درخت بومی بلوط ایرانی، پسته وحشی و بادام کوهی در منطقه سیاه‌کوه شهرستان ایلام با استفاده از سامانه‌ی اطلاعات جغرافیایی و روش بولین بوده است. برای این منظور، نقشه‌های شیب، جهت و ارتفاع منطقه با استفاده از نقشه‌های توپوگرافی تهیه شد. برای تهیه نقشه خصوصیات خاک منطقه ۴۰ نمونه خاک از عمق صفر تا ۳۰ سانتی‌متر به طور تصادفی از منطقه مورد مطالعه (۹۵۴ هکتار) برداشت شد. سپس خصوصیات نمونه‌های خاک مانند اسیدیته، بافت، هدایت الکتریکی و مواد آلی خاک اندازه‌گیری شدند. نقشه‌های خاک و لایه‌های اطلاعاتی خاک در محیط سامانه اطلاعات جغرافیایی تهیه شدند. با توجه به نیازهای اکولوژیک گونه‌های انتخابی و ترکیب و روی هم گذاری تمامی نقشه‌های تهیه شده، در حدود ۸۹۰ هکتار از کل مساحت منطقه برای جنگل کاری‌ها مناسب بودند. نتایج نشان داد که از مجموع مناطق مناسب جنگل کاری ۳۶۸/۷۲ هکتار (۴۱/۴۱٪) برای گونه بلوط ایرانی، ۳۵۳/۴۴ هکتار (۳۶/۶۹٪) برای گونه پسته وحشی و ۱۷۶/۲ هکتار (۱۹/۷۸٪) برای گونه بادام کوهی به عنوان مناسب‌ترین مناطق برای جنگل کاری مشخص شدند. نتایج مقایسه نقشه‌های نهایی مناطق مناسب با ۳۰ هکتار از جنگل کاری‌ها موجود این گونه‌ها در منطقه نشان داد که از ۱۰ هکتار جنگل کاری‌های هر گونه، بلوط ایرانی، پسته وحشی و بادام کوهی، به ترتیب ۷/۶۵، ۳/۱۱ و ۴/۲۵ هکتار از این جنگل کاری‌ها در بهترین رویشگاه برای این گونه‌ها قرار گرفتند.

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