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Range of soil and climate characteristics appropriate for *Pistacia atlantica* forest development and rehabilitation (case study: Fars province, Iran)

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Abstract

Investigation of ranges of soil and climate characteristics appropriate for the tolerant species: *Pistacia atlantica subsp. mutica* according to field study was the main objective of this research. This study was carried out based on random sampling across 20×20 km wild pistachio forests of Fars province (Iran). Results showed that mountainous and hilly lands are the main land types that pistachio species have evolved on. Statistical analysis of physical and chemical soil characteristics based on principal component analysis (PCA) method showed that wide ranges in soil characteristics, even up to about 40% differentiation in some measured properties, did not restricts this subspecies natural growth. The main growth limiting factors were shallow soil depth and light soil texture that decreased storage capacity of soil moisture, necessary for wild pistachios survival during drought and long dry periods. Climatic elements were analysed through the same approach and showed that temperature, precipitation and wind with overall variability of 85.9% were the most effectual factors. *Pistacia atlantica subsp. mutica* is one of the species refractory to various soil conditions and adapted to weak soils for the establishment and rehabilitation of forests in semi-arid regions.

Key words: *climatic elements, drought, forest soils, principal component analysis (PCA), semi-arid regions, soil physical and chemical properties*

INTRODUCTION

Wild pistachio forests are distributed in some parts of semi-arid zone at Eurasia plateau. This type of forest with *Pistacia atlantica* species is observed and reported from Northern Africa (Western Sahara, Morocco and Tunisia), Eastern Europe (Macedonia and Greece) Anatolian plateau (Turkey), Zagros plateau (Iran) and Hindu Kush plateau (Afghanistan and Pakistan) [BAHRANI *et al.* 2010]. Zagros growth regime is one of the most important forest lands in Iran and wild pistachio (*Pistacia atlantica subsp.mutica*) is main plant species in this area, which grows at the altitude between 1000 to 2300 m a.s.l. Deforestation for overuse logging and changing land use has been altered that they are in the danger of total destruction [ALIOWLAD *et al.* 2007].

Fars province, located in southern part of Zagros Mountains, is the main habitat for *Pistacia atlantica* which is disseminated over than 1,200,000 hectares of lands. The habitats of *Pistacia atlantica* are spread out in two third of the central and northern parts of Fars province and can be mainly found in cold semi-arid, intermediate desert and intermediate semi-arid climate

conditions [AMIRI 1999]. There are four pistachio forest types in this region including pistachio atlantica; pistachio-acer; pistachio-almond and pistachio-oak. These wild pistachios are of different varieties which have been greatly affected by climatic, geomorphologic and pedological factors [NEGAHDARSABER, FATTAHI 2003].

Wild pistachio species are also grown in Irano--Turani region that has low rainfall and the length of dry seasons has significantly separated this area from other regions. Heat variation is high in such regions and this is the reason life activities of plants have been reduced due to cold and freezing winters and long dry summers. This area (Irano-Turani region) has covered three fourth of Iran lands and More than 300 different types of trees and shrubs are found in this area [SABETI 1993]. Climate can directly or indirectly affects environmental factors those influences on growth of plants [YAGHMAIE *et al*. 2008]. Experiments conducted in recent decades indicate the whether condition has potential to control the distribution of plant species [MORRISON, MORECROFT 2006]. Wild pistachio is a xerophyte plant and dominant species which covers South-West Asia and North-Africa at margin of desert to Mediterranean climate [MONTAZERI *et al.* 2014]. WALKER *et al.* [1987] study showed that wild pistachio is one of the resistant species to adverse environmental conditions such as different climates (arid, semi-arid and sub-humid).

The altitude at which *Pistacia atlantica* can be grown is variable in different parts of the world. ZOHARY [1995] states that altitude of 900–3000 m a.s.l. is suitable for the growth of these types of plants in Iran. Combination of wild pistachios distribution map and hypsometric maps through geographic information system of Fars province indicated 57% of these bed growths are located in 1000–2000 m a.s.l. [NEGAHDARSABER *et al.* 2009]. This study also revealed that, 25.5% of these forests are located on 15–30% slope and 66% of the geographical direction of such plantations is towards the north.

A severe decrease in vegetation cover of Fars province because of the drought it has faced in the last couple of years, has led to increased soil erosion in this region. Due to the loss of forest vegetation, *Pistacia atlantica* and oak forests in particular, furnishing the necessary conditions for the recovery of these species is required. In order to retrieval these forests baseline, updated information on desire ecological conditions needs to be obtained. The objective of this study was to find relationships between climate and soil characteristics on wild pistachio natural growth in the Fars province and identifying the main limiting factors.

MATERIAL AND METHODS

The study area is located in the southern part of the Irano-Turani growth region (in southern part of Iran), and occupied over 124,000 km^2 of Fars province (Iran) at 50°37' to 55°40' east longitude and 27°7' to 31°45' north latitude with average elevation of 1491 m a.s.l. (Fig. 1). Investigation of soil status (the current situation of this type of forest soil) was designed according to analysis of sampled soils. To locate sampling sites, digital maps of wild pistachio forest of Fars province at scale of 1:250 000 were obtained. Selecting a geographic vertical grid (Universal Transfer Mercator (UTM) coordinates) based on habitat of *Pistacia atlantica* (pistachio distribution map of Fars province) intersection with 20×20 km network was the next step (Fig. 2). After finding the corresponding point in the field, an area with 2000 m^2 was investigated. The general and specific characteristics of land, forest type and land geomorphology was reported and soil sampling was carried out.

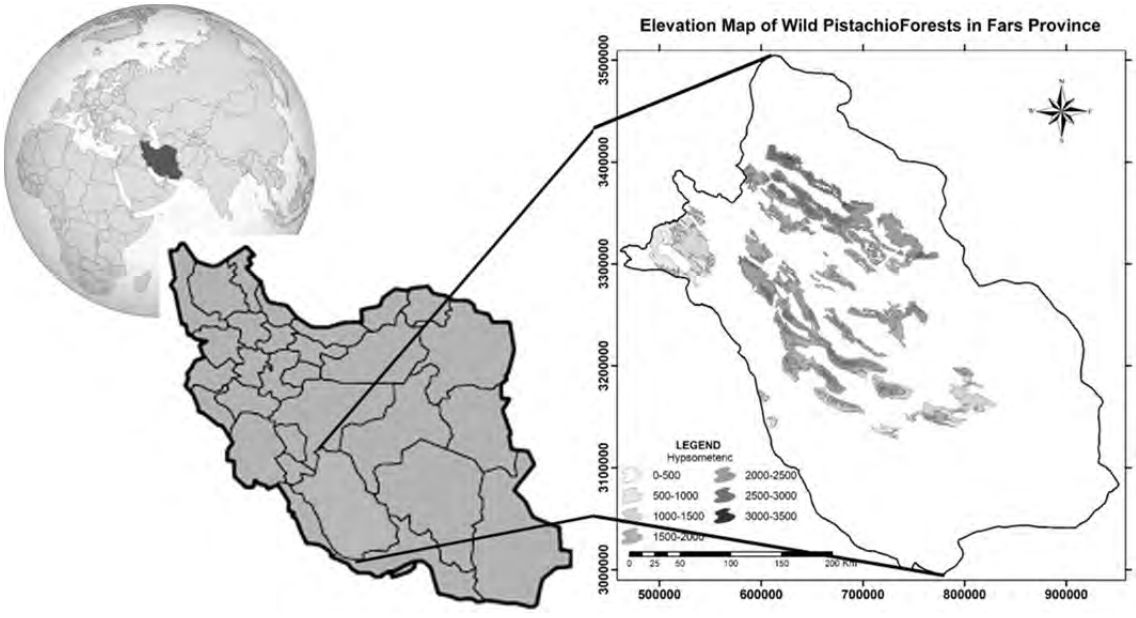

Fig. 1. Location and elevation ranges of Fars Province; source: own elaboration

Soils were sampled in the canopy shadow of *Pistacia atlantica* trees based on the criteria that the effective soil depths should be 30 cm [BROWN 1999; HOSSEINI *et al*. 2012]. The sampled soils taken from field for physio-chemical analysis were delivered to the laboratory.

Soils texture (percent of sand, silt and clay) were identified by GEE and BAUDER [1986] method. To determine the percentage of organic carbon and soil organic matter, dichromate oxidation method was used [NELSON, SOMNERS 1996]. Calcium carbonate equivalent percentage and bicarbonate concentrations were measured and reported using acid neutralization method [LEOPPERT, SUAREZ 1996]. Salinity based on electrical conductivity defined by RHOADES [1996] method. The statistical study of the soil experimental results was carried out based on principal component analysis (PCA) that can synthesize environmental data according to their matrix [KENT, COKER 2001]. These statistical analyses were performed in Minitab software.

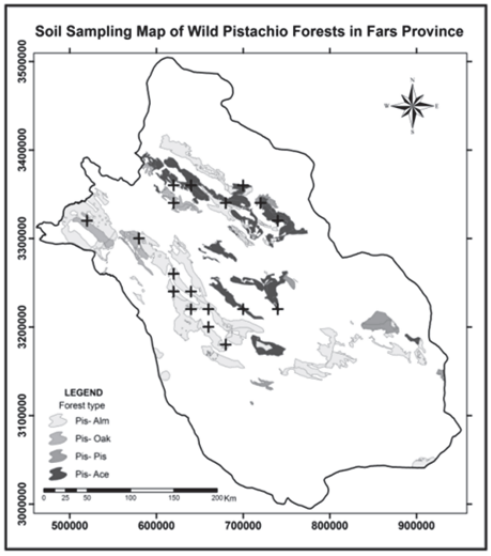

Fig. 2. Map of natural growth fields for *Pistacia atlantica*, accompanying species, and sampling points in Fars Province (20-km grids); source: own elaboration

RESULTS

Field studies of the sites covering about three percent of Fars wild pistachio forest area, showed that soil erosion and land degradation of these regions are moderate to high. Based on the geomorphological studies most of these sites are located on lands with high to moderate slope and shallow soil depth. Settlements elevations of wild pistachio were found to be at 500 to 2000 m a.s.l. (Fig. 1). The study sites near villages, residential areas and the safe passage of nomads in pasture and shrubs were poor condition and wild pistachio trees per unit area was low (Photo 1).

Photo 1. A general view from the studied area near Morgh village (phot. *M. Nejabat*)

During the absent of more detail maps, land resources (land types) and land units (land units) was distinct from field observations. According to integration land recourses map with *Pistacia atlantica* distribution map, the presence of this species was observed in almost all of the land units. Based on land type, different habitat of *Pistacia atlantica* were divided into four main groups: mountainous lands, hilly lands, trace lands and debris coin. According to field studies the general description of sites (chosen clusters) are presented in Table 1. Generally, the density of range covers, shrubs and *Pistacia atlantica* is low in land with lower slopes (less than 10%), compared to higher slop (more than 40%).This is due to easier access for animals grazing, destroying the bushes, and harvesting hardwood for fuel.

Soil depth in most of these lands is low (less than 30 cm) and soil surface is gravelly (more than 35% of components is formed by pebbles, gravels and boulders). Mountainous and hilly lands include rocks (about 30% out cropped rocks) can be easily seen. Due to poor vegetation and initial stage of soil formation and shortage of organic matter, soils structures are week and severe water erosion can be observed in most of the study areas.

Table 1. Typical measured environmental characteristics in the study regions

Cluster name	Eastern longitude	Northern latitude	Land type	Origin	Soil depth	Stone and gravel type	Erosion
Sarpaniran	53°29'16"	29°59'15"	alluvial plain and terrestrial area	Dolomite and gypsum	low	more than 15% sound rock and more than 30% gravel	medium
Sivand dam	52°52'10"	30°10'4"	mountainous leading to low plain areas	Dolomite	very low	more than 30% sound rock, more than 10% outcrop	high due to water flow
Meimand old road	52°38'29"	28°55'04"	flat terrestrial and alluvial plains	Dolomite	low	more than 10% sound rock, more than 20% rock and gravel, more than 15% bolder	medium

Source: own study.

Asmari and Jahrom Asmari which are the dominating geological formations in this region causes calcareous soil (generates from calcareous parent material) in all of specimens. Weak reaction of soils to 0.1 normal choleric acid shows the low bicarbonate and poor amount or nonexistence of gypsum in the soils. A typical view of *Pistacia atlantica* growth, distribution, and land resources in the studied forest field is shown in Figure 3.

Soil physical and chemical analysis showed that loam or medium is dominant soil texture type and organic matter percentage is very low (0.3% to 0.74%). The acidity of saturated soils is around neutral (7.25–7.54) that is consequence of high Equivalent Calcium Carbonate (31.7–40.2). Saline soil is not observed in any places of study area and concentration of Bicarbonate is less than 0.35 meq·(100 g)$^{-1}$ (Tab. 2).

The statistical analyses of these results according to PCA method [KENT, COKER 2001] are showed in Table 3 and Figure 3. Application of PCA for statistical analysis on soil data results showed after three initial steps, Eigenvalue went to less than 1 and in first 4 steps; cumulative proportion was 92% as shown in Table 3. The results of PC1 (greatest and main proportion percentage), soil texture (sand, silt and clay) and salinity have the most diffraction and saturation percentage have the least diffraction.

Table 2. Physico-chemical characteristics of studied soil specimens

Location (Cluster name)	Percent soil content			Texture	Saturation percentage (SP)	Electrical conductivity (*EC*), dS·m^{-1}	Organic carbon (OC), %	Saturated acidity pH	Organic matter (OM), %	Equivalent calcium carbonate (CCE), %	Bicarbonate HCO_3^- meq·(100 g)$^{-1}$
	sand 50–2000 µm	silt 2–50 µm	clay <2 µm								
Sarpaniran	52.56	26	21.44	silty clay loam	54.7	1.05	0.32	7.46	0.55	32.4	0.19
Sivand dam	62.56	24	13.44	silty loam	47.2	2.86	0.49	7.59	0.84	28.7	0.34
Morghvilage	62.56	26	11.44	silty loam	42.8	1.83	0.58	7.31	1.00	26.9	0.16
Ghaderabad	58.56	30	11.44	silty loam	45.2	1.96	0.43	7.54	0.74	34.8	0.18
Chenaroo	46.56	26	27.44	clay loam	50.3	0.97	0.24	7.37	0.41	36.1	0.10
Mamoo	48.56	25	26.44	loam	48.1	0.91	0.36	7.32	0.63	38.5	0.13
Mahjan	44.56	34	21.44	loam	44.2	1.23	0.27	7.46	0.48	32.9	0.20
Khaniman	46.56	31	22.44	loam	37.6	1.33	0.31	7.39	0.54	31.7	0.20
Bakan	40.56	29	30.44	clay loam	50.3	0.83	0.17	7.25	0.30	40.2	0.18
Honeifaghan	60.56	22	17.44	silty loam	31.8	0.59	0.24	7.32	0.42	27.4	0.12
Maximum	62.56	34	30.44	clay loam	54.7	1.96	0.43	7.54	1.00	40.2	0.20
Minimum	40.56	25	11.44	loam	37.6	0.83	0.17	7.25	0.30	31.7	0.10
Variation, %	64.83	73.53	37.58	–	68.74	42.35	39.53	96.15	30	78.86	50

Source: own study.

Table 3. Summation coefficient of principal component analysis based on correlation matrix

Variable	PC1	PC2	PC3	PC4
Sand	0.412	0.270	–0.194	0.023
Silt	–0.115	–0.402	0.682	0.435
Clay	–0.434	–0.110	–0.132	–0.261
SP	–0.106	–0.476	–0.618	0.177
EC	0.398	–0.309	–0.040	0.059
OC	0.393	–0.014	–0.189	0.575
PH	0.306	–0.397	0.089	–0.265
CCE	–0.356	–0.321	–0.215	0.208
HCO_3^-	0.289	–0.414	0.075	–0.513
Eigenvalue	5.364	2.029	1.094	0.763
Proportion%	51.2	22.6	11.7	6.6
Cumulative%	51.2	73.8	85.5	92

Source: own study.

Results of using principal component analysis on 26 climatic elements of Fars province showed, 4 main component cover more than 89% of cumulative proportion (Tab. 4) and eigenvalue of remained elements are less than one those deleted from more statistical analysis. Precipitation, temperature and wind make more than 85% proportion of climatic elements. Results of crossing map of wild pistachio forest of Fars province (Fig. 2) and corresponding cells of those three elements for determining of the mean score of the three components is shown in Table 5.

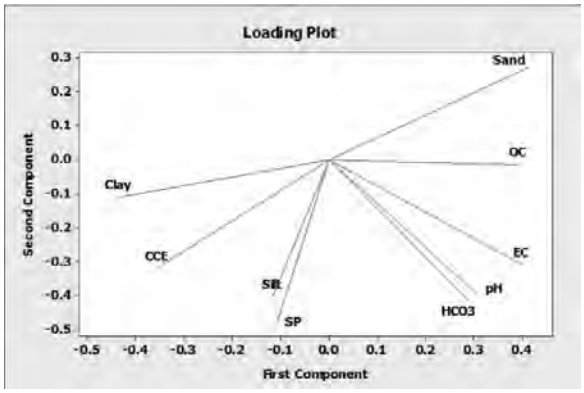

Fig. 3. Diagram of loading plot based on soils physical and chemical properties; source: own study

Table 4. The relative importance of climatic elements

Parameter	PC1	PC2	PC3	PC4
Eigenvalue	3.657	2.774	1.116	0.933
Proportion%	51.5	29.6	4.8	3.3
Cumulative%	51.5	81.1	85.9	89.2

Source: own study.

Table 5. The most effective climatic elements range for wild pistachio

Value	Annual precipitation	Annual mean temperature	Average minimum temperature	Average maximum temperature	Prevailing wind direction	Prevailing wind speed
	mm	°C			degree	Not
Max	695.50	25.98	17.68	33.42	317.98	10.31
Min	180.45	13.82	6.31	20.20	138.85	6.66
Average	340.16	19.92	12.35	26.85	274.01	7.80

Source: own study.

DISCUSSION AND CONCLUSIONS

Results of the field study revealed a higher density of wild pistachio trees on gradient lands, especially land types such as: mountain, hilly and piedmont plains, because stakeholder's accessibility in these lands is not easy. A study in western Zagros (Kermanshah province) also showed higher presence of these species trees on the hilly areas, mountainous and high slop pediments [BAHRANI *et al*. 2010].

Shallow depth of the soil which is caused by the sever soil erosion in the last couple of decades is the main land limiting factor that reduces the regeneration of this species. Shallow soils with light texture also limits the moisture storage (from rain) necessary for wild pistachio survival during drought and long dry periods. Due to poor vegetation cover, initial stage of soil formation and hence low organic matter, soil structure is week (low soil aggregation and high soil erodibility) and severe water erosion was observed in most of the study areas. Results of REZAEYAN *et al.* [2009] research also presented same conditions in most of Zagros Mountains that causes weakness of soil structure and decreases erosion resistance. SALEHI *et al.* [2008] and LE POLAIN DE WAROUX, LAMBIN [2012] also believe that deforestation in Zagros region or semi-arid forests always proceed to land degradations, so conservation of one protects another. SHEKARCHIAN, ESFANDIARPOUR [2006] studies showed that due to decrease in the trees density in arid and semi-arid regions of Zagros forests, soil erosion increased significantly. ZANGANEH [2001], who conducted such a study in Ghalajeh (Kermanshah province), also indicated that *Pistacia atl antica* has a better chance of growth with higher quality in the northern slopes of this region than the southern slopes.

According to SALEHI *et al.* [2005] and MAHMOUDI *et al.* [2005], physical and chemical properties of soil are the most important factor that affected wild pistachio growth. Therefore, the natural presence of *Pistacia atlantica* in these regions insists the appropriateness of the chemical and physical conditions and geomorphological situation. SCHOENHOLTZ *et al.* [2000] emphasized that the natural growth deficiency followed the undesired interaction between plants and the soil physico-chemical properties. Furthermore, based on BINKLEY and GIARDINA'S [1998] finding similar soil test results, despite the difference in their locations, shows their vulnerability towards the growth of a particular species of tree that is compatible with ecological conditions.

The cluster analysis showed that the percentage of clay, sand and saturation percentage (SP) have high variety. TAHERI ABKENAR *et al.* [2013] studies also did not indicate significant differences among samples soil texture and saturation percentage in Khojir wild pistachio national park. LIMANE *et al.* [2014] research confirmed large difference in soil texture of wild pistachio forest in Algeria.

Most of wild pistachio species are tolerant to soil salinity and keep natural growth and development [SEPASKHAH, KARIMI-GOGHARY 2003], but ECe of sampled soils are low too. The percentage of equivalent calcium carbonate (CCE) tolerance (due to the calcareous parent materials of most soil samples) is high (8.5%) and also, high buffering capacity of the soils (causes from lime presence) leaded pH close to neutral, with little change. TAHERI ABKENAR *et al.* [2013] studies confirmed a wide range of variety in these three factors in the wild pistachio forest.

Cluster analysis (CA) showed that Chenaroo and Mamoo regions have the most similarity level (96.47%) and the least distance (1.87) from each other. On the other hand, the minimum similarity and maximum distance of soil properties occurred in Sivand Dam's region (Fig. 4). The salinity and bicarbonate concentration are the main cause of this difference. Measured characteristics of the soil samples in this study did not have any overlap with the ecological limits explained by ZANGENEH [2001]. Even so, CA and PCA statistical procedures indicate that about 40% of the variations in soil characteristics do not impose any specific restrictions for this species.

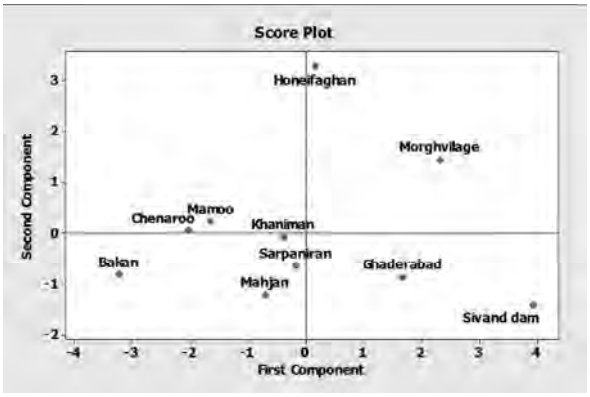

Fig. 4. Cluster analysis for soil mean characteristics; source: own study

The main limiting factor in natural growth of wild pistachio is shortage of soil moisture storage from rain. OWLIAIE [2010] studies presented the influence of semi-arid climate on forest ecosystems (southern part of Zagros pistachio forests in) is more important than soil chemical and physical conditions. GHOLAMI *et al.* [2007] studies indicate that low soil depth and sandy soil texture are inappropriate n for wild pistachio natural growth. BODAGHI [1995] believes that the most important factors for poor natural development of wild pistachio in protected Zagros region is the shortage of soil water content.

The three climatic components (temperature, precipitation and wind) are the most important factors those lead the behaviour of the climate in the study areas. HATAMI BAHMAN BIGLU, KHOSHAL DASTJERDI [2010] studies according to application of principal component analysis on 25 whether elements showed, four climatic factors in Fars province are the most influence. Their results showed that the four components (temperature, precipitation, wind and summer precipitation mechanism) are the main factors regionalized Fars province. The PCA results showed the annual precipitation is the most important climatic element affecting distribution of wild pistachio and the temperature with the lowest value (the biggest negative effects) indicates sensitivity of wild pistachio to temperature rise. ROSTAMIKIA *et al.* [2010] investigation in Ardabil province (Khalkhal forest) showed the temperature is the main limiting factor in whether elements in wild pistachio lodgement.

Inappropriate changes in Landuse at the Zagros zone of Fars province such their use as gardens, miss management in wood harvesting, excessive grazing by livestock, and poor soil and water conservation operations, are the most significant factors that have led to the deterioration and degradation of wild pistachios in these areas. Soil conservation and watershed management projects can improve condition to rehabilitate and develop wild pistachio forest even in a semi-arid region as Fars province.

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Zakres charakterystyk glebowych i klimatycznych odpowiednich dla rozwoju i rekultywacji lasów *Pistacia atlantica* na przykładzie prowincji Fars w Iranie

STRESZCZENIE

Głównym celem badań terenowych prezentowanych w niniejszej pracy było przeanalizowanie zakresu wartości charakterystyk glebowych i klimatycznych odpowiednich dla podgatunku *Pistacia atlantica subsp. mutica*. Próby pobierano losowo z poletka w lesie pistacjowym o wymiarach 20×20 km w prowincji Fars w Iranie. Wyniki dowodzą, że pistacja wyewoluowała na ziemiach górskich i na terenach pagórkowatych. Statystyczna analiza fizycznych i chemicznych właściwości gleb prowadzona metodą składowych głównych (PCA) wykazała, że duża zmienność badanych cech, sięgająca w niektórych przypadkach 40%, nie ograniczała naturalnego wzrostu badanego podgatunku. Głównymi czynnikami ograniczającymi były płytkie gleby o lekkiej strukturze, które zmniejszały zdolność gleb do zatrzymywania wilgoci niezbędnej dziko rosnącej pistacji do przetrwania długich okresów suszy. Czynniki klimatyczne analizowano tą samą metodą i stwierdzono, że najbardziej istotne były

temperatura, opady i wiatr o ogólnej zmienności 85,9%. *Pistacia atlantica subsp. mutica* jest jednym z gatunków najbardziej odpornych na różne warunki glebowe, co może mieć znaczenie dla stabilizowania i rekultywacji lasów na terenach półpustynnych.

Słowa kluczowe: *analiza składowych głównych (PCA), czynniki klimatyczne, fizyczne i chemiczne właściwości gleb, gleby leśne, susza, tereny półpustynne*