JOURNAL OF FOREST SCIENCE, *64*, 2018 (3): 129–138

https://doi.org/10.17221/117/2017-JFS

Assessment of land suitability for Norway maple and black locust plantations in the northeast of Iran

Ali BAGHERZADEH[1,2]*

[1]*Department of Agronomy and Plant Breeding, Faculty of Agriculture, Mashhad Branch, Islamic Azad University, Mashhad, Iran*

[2]*Arid Environments Research Center, Mashhad Branch, Islamic Azad University, Mashhad, Iran*

**Corresponding author: abagherzadeh@mshdiau.ac.ir*

Abstract

Bagherzadeh A. (2018): Assessment of land suitability for Norway maple and black locust plantations in the northeast of Iran. J. For. Sci., 64: 129–138.

In the present study the qualitative land suitability evaluation by parametric and analytic hierarchy process (AHP) approaches was investigated for two tree species including Norway maple and black locust in the Toroq watershed, a semiarid region, in the northeast of Iran. The values of land suitability indices by the parametric approach for Norway maple and black locust plantations ranged from 22.46 to 67.50 and 23.23 to 75.11 respectively, while by the AHP approach they varied between 35.91 and 84.58 for Norway maple and from 32.87 to 94.31 for black locust plantations. The suitability classes for both tree species by the parametric approach were classified into moderately suitable in the eastern part of the basin, and not suitable in the middle and western parts of the study area. According to the AHP approach the suitability classes varied from highly suitable in some parts in the east to moderately suitable in the middle, east and some parts in the west and not suitable in some parts in the north and southwest of the basin.

Keywords: evaluation; Toroq watershed; parametric; analytic hierarchy process; GIS

Norway maple (*Acer platanoides* Linnaeus) is one of the northern temperate zone hardwood deciduous species. Norway maple is the most widespread maple in Europe where it occurs from southern Scandinavia to the Caucasus Mountains, Turkey, and northern Iran (Rushforth 1999). Although Norway maple occurs in a number of forest types and forest communities, most of the studies on the environmental growth conditions of Norway maple have been carried out within or close to the core area of the natural range of Norway maple (Mitchell 1982). Norway maple tree is easily transplanted, grows quickly and has brilliant yellow fall colour unmatched by most trees. It tends to be located at the base of hills where it receives surface runoff and subsurface soil water flow. It thrives at higher elevations with sufficient precipitation. It also grows in hot and dry conditions and can tolerate ozone and sulphur dioxide air pollution. Norway maple trees grow in part shade/part to full sun habitat. It germinates and grows quickly in shade, even under close canopy. When mature, it becomes more light-demanding (Hytteborn et al. 2005). The height increment is about 1 m·yr^{-1} in the first 10 years. With its wide crown it tends to shade and suppress other slow-growing competitor species. Its adventitious roots are suitable to be exploited for soil bioengineering to increase the stability of slopes and mitigate erosion. Norway maple is tolerant to a wide range of light and soil conditions, and seedlings can invade and persist within the interior of intact forest. It thrives best in deep, fertile, moist soils, which are adequately drained and with low pH. Exposure to strongly calcareous soils is well tolerated (Praciak et al. 2013). It is well adapted to various soil extremes, such as sand, clay or acid soil. Occasionally wet, alkaline, well-drained soils are also tolerable. The drought and soil salinity tolerance of the trees are considered as moderate to good. Black locust (*Robinia pseudoacacia* Linnaeus) is native to North America, but it has been widely planted and naturalized in Europe and Asia. Black locust grows naturally on a wide range of soils and topography but does best on rich moist limestone soils. The range includes cool temperate moist forest, warm temperate mountain moist forest, warm temperate mountain wet forest, and warm temperate moist forest zones. Black locust is adapted to a wide variety of soil types, but grows best on sites that are deep, well drained, and derived from limestone. This tree tolerates a pH range of 4.6 to 8.2. It is very sensitive to poorly drained or compact plastic soils. Excessively dry sites are also poor for the species. Silt loams, sandy loams, and lighter-textured soils are superior to clay, silty clay loams, and heavier soils. Growth was best on limestone-derived soils and soils without pronounced subsoil development. Its N fixing effect can generally influence soil fertility and can improve the growth of associated trees positively by enriching N and organic matter and other nutrient elements like P in soil (Wang et al. 2005). The marginal populations of these species are of special interest for species self-survival, as they comprise genetic traits of a population required for adaptation to environmental change (Rajora, Mosseler 2001). Black locust is a frequently used species in semi-arid afforestation projects in Iran due to its tolerance to ecological stresses like high temperatures and droughts (Hanover 1990). It has also the ability to rehabilitate degraded lands via erosion control and soil stabilization (Dagar 1998). Furthermore, black locust is a well suited species for agroforestry because of its ability to fix over 75–150 $kg \cdot ha^{-1} \cdot yr^{-1}$ of atmospheric N in soil (Boring et al. 1981) and to establish easily from seeds or coppicing (Nair 1993) and it has a great capacity to increase the organic carbon content in soil (Tabari, Salehi 2008). However, the precise information about plantation areas for this species in semi-arid regions of Iran is not well known. Norway maple is a fast-growing tree species, able to grow well across a wide range of soil conditions, shade, drought and pollution. Norway maple is used in many afforestation projects in Iran. However, there is still insufficient knowledge about the response of this species to different ecological conditions. Therefore, it would be of interest to investigate land suitability in terms of the growth features including climate and soil requirements of Norway maple and black locust in semi-arid climate conditions in the northeast of Iran, which is close to the southern boundary of their geographical range. Hence, the aim of the present study is to evaluate land suitability for Norway maple (*A. platanoides*) and black locust (*R. pseudoacacia*) trees and probe the parametric and analytic hierarchy process (AHP) approaches in describing the suitability of these plantations in Torogh watershed, a semi-arid region in the northeast of Iran.

MATERIAL AND METHODS

The Toroq watershed is located closely to the southward of Mashhad, Khorasan-e-Razavi province, Iran (Fig. 1). The study site lies between the 36°04'N to 36°16'N latitude and the 59°18'E to 59°39'E longitude, consisting of an area of about 394 km^2 and a total main stream length of 35 km.

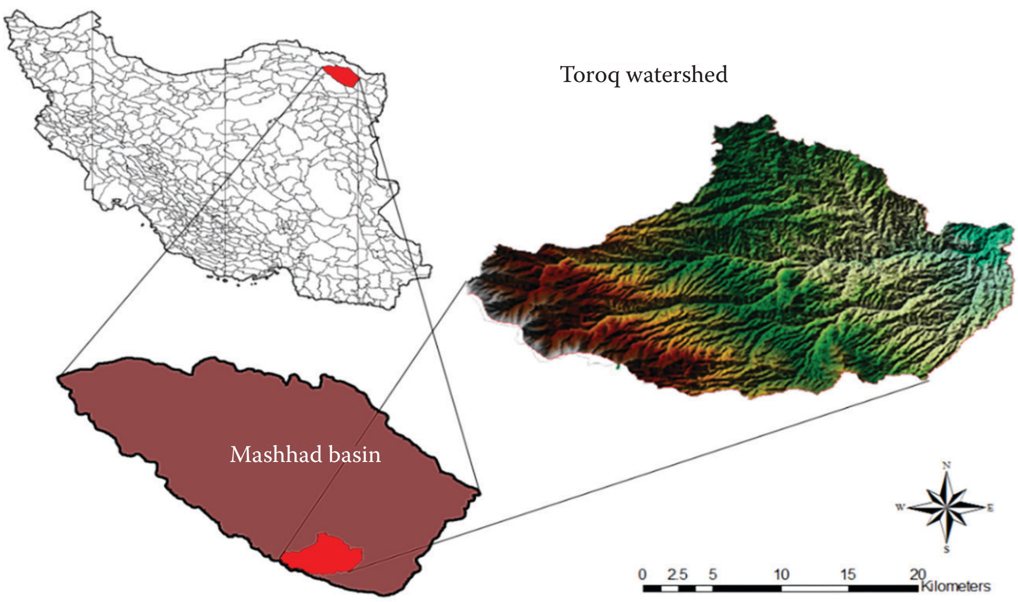

Fig. 1. The location and geographical position of the study area

Based on the visual interpretation of the satellite image and field observations the general physiographic trend of the basin extends in a SW-NE direction and lies on closely southward Mashhad Plain. The study area is covered mainly by shale and dark grey phyletic formations, dated to the Jurassic period (> 51%). The main texture class of the soil is silty loam. The topographical elevation values of the study area vary between 1,019 m a.s.l in the east and 2,653 m a.s.l in the west. Based on the Iran meteorological organization, the study area has a semi-arid climate with mean annual precipitation of 221 mm and mean annual temperature of 15.8°C.

Climate, soil and terrain database

The study area was gridded into 1 km^2 pixels in Arc-GIS (Version 10.5, 2016). The database for climate parameters for each grid was collected from long-term WorldClim – Global Climate Data (Version 2, 2016) in which the climate variables were taken at spatial resolutions of 30 s (~ 1 km^2) for the study area. The soil data were gathered from the Harmonized World Soil Database (Version 1.2, 2013) and SoilGrids – global gridded soil information at 1 km^2 spatial resolutions. On this basis, 417 points were selected by gridding the basin into 1 km^2 pixels to get precise climate, soil and terrain data in GIS. The terrain data of the basin including elevation, slope and aspect were identified from 30 m digital elevation model maps in Arc-GIS.

The procedure of land suitability evaluation

The process of land suitability evaluation for both species included the following steps: (1) identification of land qualities and characteristics, (2) assessing tree ecological requirements, (3) matching process.

Identification of land qualities/characteristics: (*i*) climate suitability analysis, (*ii*) terrain and soil suitability analysis.

(*i*) The thermal suitability was assessed through matching thermal requirements of individual tree species with average thermal conditions of the study area. The thermal conditions considered were: mean temperatures of the coldest and the warmest month, length of frost-free period, length of vegetation period, length of dormancy period and temperature sums during vegetation and frost-free period. The moisture suitability analysis was essentially based on the comparison of tree species specific drought tolerances with the moisture conditions during the respective vegetation period. For each of the tree species two thresholds have been set, one between optimum and sub-optimum conditions for growth and one between sub-optimum growth and not suitable conditions. The climatic requirements of tree species were expressed as optimum (highly suitable), medium range (moderately suitable) and not suitable including the following factors: mean temperatures of the coldest and warmest months, minimum temperature of the coldest month, frost-free period (days with T_{mean} > 10°C), periods of biological activity (days with T_{mean} > 5°C), accumulated temperatures (base temperatures of 5 and 10°C), length of growing periods (days) and annual precipitation (mm) (Woods, Hall 1994; Burschel, Huss 1997; Stolbovoi et al. 1998; Schuett 1999). Based on trees climatic requirements, the climate index and subsequently the climate rate were determined as implemented factors in estimating the land index;

(*ii*) Soil suitability was assessed by matching the basic soil requirements of the selected tree species with a number of soil characteristics which are related to growth and biomass production. The soil suitability assessment is based on the comparison of soil requirements of the selected tree species and prevailing soil conditions. A number of soil characteristics affecting growth and production of tree species have been classified in terms of optimal, medium range (sub-optimal) and not suitable conditions for Norway maple and black locust tree species including: terrain elevation, slope, slope aspect, water logging/flooding conditions, erosion condition, soil texture/structure, soil internal drainage, soil depth, soil reaction (pH), soil coarse fragments, soil salinity, $CaCO_3$ content and organic carbon.

Assessing tree ecological requirements. The ecological requirements of Norway maple (*A. platanoides*) and black locust (*R. pseudoacacia*) including climate requirements, land terrain and soil qualities/characteristics requirements were derived from Fischer et al. (2001) (Tables 1–4).

Matching process: (*i*) parametric approach to land suitability evaluation, (*ii*) AHP technique in land suitability evaluation. After characterizing land terrain and soil qualities/characteristics requirements of the tree species, the next process was evaluating the land by comparing land qualities/characteristics in each point with tree requirements to determine the land suitability classes for the given trees. To interpret the combination

Table 1. Climate requirements for the Norway maple (*Acer platanoides* Linnaeus) plantation

	Degree of limitation (land index)		
	S1 (75–100)	S2 (50–75)	N (0–50)
T_{mean} of the coldest month (°C)	> –20	–25 to –20	< –25
T_{mean} of the warmest month (°C)	16–24	14–16 24–25	< 14 > 25
T_{min} of the coldest month (°C)	> –30	–35 to –30	< –35
Frost-free period (days with T_{mean} > 10°C)	> 150	120–150	< 120
Periods of biological activity (days with T_{mean} > 5°C)	> 180	150–180	< 150
Accumulated *T* (base *T* of 5°C)	> 2,400	2,200–2,400	< 2,200
Accumulated *T* (base *T* of 10°C)	> 2,000	1,800–2,000	< 1,800
Length of growing periods (day)	> 150	135–150	< 135
Annual precipitation (mm)	500–750	250–500 > 750	< 250

T_{mean} – mean temperature, T_{min} – minimum temperature, S1 – highly suitable, S2 – moderately suitable, N – not suitable

Table 2. Terrain and soil requirements for the Norway maple (*Acer platanoides* Linnaeus) plantation

		Degree of limitation (land index)		
		S1 (75–100)	S2 (50–75)	N (0–50)
Land terrain	elevation (m a.s.l.)	600–800	400–600 800–1,000	> 1,000 < 400
	slope (%)	0–10	10–32	> 32
	aspect	N, NW, NE, flat	W, E	S, SE, SW
	flooding class	F0	F1	F2, F3
	erosion	very low, low	moderate	high, very high
Soil physical characteristics	soil texture	SiCL, CL, Si, SiL, SC, L, SCL, SL	SiC, LS	S, C
	coarse fragments (%)	0–15	15–40	40–100
	soil depth (cm)	100–200	50–100	0–50
	drainage class	W, MW	SE, I	E, P, VP
Soil chemical and fertility characteristics	$CaCO_3$	0–10	10–30	> 30
	EC_e ($dS\cdot m^{-1}$)	0–2	2–4	> 4
	organic carbon (%)	1.9–2.7	0.7–1.9	0–0.7
	pH	5.0–7.0	4.0–5.0 7.0–8.5	< 4.0 > 8.5

EC_e – soil salinity, S1 – highly suitable, F0 – no flood limitations, SiCL – silty clay loam, CL – clay loam, Si – silt, SiL – silty loam, SC – sandy clay, L – loam, SCL – sandy clay loam, SL – sandy loam, W – well, MW – moderately well, S2 – moderately suitable, F1 – slight flood limitations, SiC – silty clay, LS – loamy sand, SE – somewhat excessive, I – imperfect, N – not suitable, F2 – moderate flood limitations, F3 – severe flood limitations, S – sand, C – clay, E – excessive, P – poor, VP – very poor

of land suitability classes, screening based on the priority of regional development and existing land use was necessary. To evaluate land suitability for Norway maple and black locust plantations in the study area parametric and AHP approaches were implemented. To evaluate land suitability, the natural soil conditions excluding any inputs or specific soil management were considered.

(*i*) Land suitability evaluation is the process of predicting land performance over time according to specific types of use (van Diepen et al. 1991; Rossiter 1996). The process of evaluation is based on comparing the climatic conditions and land qualities/characteristics including topography, erosion hazard, wetness, soil physical and chemical properties, soil salinity and alkalinity with each specific requirement of trees. The parametric land evaluation consists in a numerical rating of different limitation levels of land qualities/characteristics according to a numerical scale between the maximum value of 100 and the minimum value of 0. Finally, the climate index and climate rate as well as the land index for each study point is calculated

Table 3. Climate requirements for the black locust (*Robinia pseudoacacia* Linnaeus) plantation

	Degree of limitation (land index)		
	S1 (75–100)	S2 (50–75)	N (0–50)
T_{mean} of the coldest month (°C)	> –10	–12 to –10	< –12
T_{mean} of the warmest month (°C)	16–27	14–16 27–30	< 14 > 30
T_{min} of the coldest month (°C)	> –15	–18 to –15	< –18
Frost-free period (days with T_{mean} > 10°C)	> 165	150–165	< 150
Periods of biological activity (days with T_{mean} > 5°C)	> 225	210–225	< 210
Accumulated *T* (base *T* of 5°C)	> 2,750	2,500–2,750	< 2,500
Accumulated *T* (base *T* of 10°C)	> 2,300	2,100–2,300	< 2,100
Length of growing periods (day)	> 135	120–135	< 120
Annual precipitation (mm)	500–750	250–500 > 750	< 250

T_{mean} – mean temperature, T_{min} – minimum temperature, S1 – highly suitable, S2 – moderately suitable, N – not suitable

Table 4. Terrain and soil requirements for the black locust (*Robinia pseudoacacia* Linnaeus) plantation

		Degree of limitation (land index)		
		S1 (75–100)	S2 (50–75)	N (0–50)
Land terrain	elevation (m a.s.l.)	700–1,100	600–700 1,100–1,200	< 600 > 1,200
	slope (%)	0–10	10–32	> 32
	aspect	N, NW, NE, flat	W, E	S, SE, SW
	flooding class	F0	F1	F2, F3
	erosion	very low, low	moderate	high, very high
Soil physical characteristics	soil texture	SiCL, CL, Si, SiL, SC, L, SCL, SL	SiC, LS	S, C
	coarse fragments (%)	0–15	15–40	40–100
	soil depth (cm)	> 150	50–150	0–50
	drainage class	W, MW	SE, I	E, P, VP
Soil chemical and fertility characteristics	$CaCO_3$	0–30	> 30	–
	EC_e ($dS \cdot m^{-1}$)	0–8	8–10	> 10
	organic carbon (%)	1.3–2.7	0.7–1.3	0–0.7
	pH	5.5–7.5	5.0–5.5 7.5–8.5	< 5.0 > 8.5

EC_e – soil salinity, S1 – highly suitable, F0 – no flood limitations, SiCL – silty clay loam, CL – clay loam, Si – silt, SiL – silty loam, SC – sandy clay, L – loam, SCL – sandy clay loam, SL – sandy loam, W – well, MW – moderately well, S2 – moderately suitable, F1 – slight flood limitations, SiC – silty clay, LS – loamy sand, SE – somewhat excessive, I – imperfect, N – not suitable, F2 – moderate flood limitations, F3 – severe flood limitations, S – sand, C – clay, E – excessive, P – poor, VP – very poor

from these individual ratings. To estimate the land suitability index, the following formula was applied (Bagherzadeh, Paymard 2015). On this basis the land index of each land unit was calculated by multiplying the geometrical mean value of the scores given to each land quality/characteristic and climate rate in the n^{th} root of interaction values of scores according to Eq. 1:

$$LI = \prod_{i=1}^{n} x_i^{\left(\frac{1}{n}\right)} \times \sqrt[n]{\frac{\prod_{i=1}^{n} x_i}{100^n}} \quad (1)$$

where:

LI – land index,

n – number of land qualities/characteristics,

x – score given to each land quality/characteristic.

The land suitability indices were characterized by the highly suitable (S1), moderately suitable (S2) and not suitable (N) symbols (Table 5).

(*ii*) The AHP developed by Saaty (1980) considers a one-level weighting system through a pairwise comparison matrix between the parameters as described by Saaty and Vargas (2001). The method

Table 5. Land suitability classes according to land index

Class	Intensity of limitation	Land index
S1	highly suitable	75–100
S2	moderately suitable	50–75
N	not suitable	0–50

employs an underlying nine-point recording scale to rate the relative preference on a one-to-one basis of each criterion and assigns a linguistic expression to each corresponding numerical value (Malczewski 1999). The weights of factors are calculated from the pairwise comparison matrix undertaking specific values and vectors calculation. The sum of criteria weights should be equal to 1. The results of the pairwise comparison matrix and the factor weights are shown in Table 6. In the AHP approach, the index of consistency, known as the consistency ratio (CR), is a ratio between the consistency index of the matrix and the random index. CR is used to indicate the probability that the matrix judgments were randomly generated (Malczewski 1999), as Eq. 2:

$$CR = \frac{CI}{RI} \qquad (2)$$

where:

CI – consistency index,

RI – average of the resulting consistency index depending on the order of the matrix.

The consistency index can be expressed as follows (Eq. 3):

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (3)$$

where:

λ_{max} – the largest or principal specific value of the matrix and it can be easily calculated from the matrix,

n – order of the matrix.

Consistency ratio ranges from 0 to 1 (Malczewski 1999). A CR close to 1 indicates the probability that the matrix rating was randomly generated. A CR of 0.10 or less is a reasonable level of consistency (Malczewski 1999). A CR above 0.1 requires a revision of the judgments in the matrix. In the present study, the CR of the matrix of paired comparisons between the 14 influential factors in our land suitability assessment is 0.04. Once the satisfactory CR was obtained, the resultant weight of each factor was multiplied by its layer and consequently the suitability maps for the given tree species were produced by a summation function of the factor layers in GIS.

Table 6. Pairwise comparison matrix for calculating factor weights (consistency ratio = 0.04)

	Climate	Elevation	Slope	Soil depth	Soil texture	Aspect	Soil salinity	pH	Organic carbon	$CaCO_3$	Coarse fragments	Drainage	Erosion	Flooding	Weight
Climate	1														0.270
Elevation	0.50	1													0.173
Slope	0.33	0.50	1												0.121
Soil depth	0.33	0.50	0.50	1											0.093
Soil texture	0.20	0.25	0.33	0.50	1										0.062
Aspect	0.20	0.25	0.33	0.50	0.50	1									0.054
Soil salinity	0.20	0.25	0.33	0.33	0.50	0.50	1								0.046
pH	0.17	0.20	0.25	0.33	0.33	0.50	0.50	1							0.037
Organic carbon	0.17	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1						0.033
$CaCO_3$	0.17	0.20	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1					0.029
Coarse fragments	0.14	0.17	0.20	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1				0.024
Drainage	0.13	0.14	0.17	0.20	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1			0.021
Erosion	0.13	0.14	0.17	0.17	0.20	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1		0.020
Flooding	0.11	0.13	0.14	0.17	0.17	0.20	0.20	0.25	0.25	0.33	0.33	0.50	0.50	1	0.017

Land suitability zonation

A kriging interpolation technique using the ArcGIS was applied to map the spatial data and to visualize the land suitability indices for the given trees.

RESULTS

The zonation of land suitability by parametric approach

The results revealed sub-optimal climate conditions in most parts of the basin, where the climate rates ranged from 61.66 to 90.15 with a mean value of 80.94 for Norway maple and from 40.96 to 89.31 with an average of 71.42 for black locust plantations. The values of land suitability indices based on the parametric approach for Norway maple and black locust plantations varied from 22.46 to 67.50 and 23.23 to 75.11, respectively. The zonation of land suitability for Norway maple plantations by the parametric approach revealed that 27.97% (110.46 km^2) of the surface area were classified into sub-optimal suitability class S2 and 72.03% (284.48 km^2) of the basin were categorized into not suitable class N (Fig. 2a) (Table 7). The zonation map of black locust plantations by the parametric approach revealed that 34.42% (135.94 km^2) of the basin were classified into S2 class, while 65.58% (259.00 km^2) of the region were not suitable for conservational practices (Fig. 2b). The most important limiting factors for conservational practices in the study area were elevation and slope aspect for both tree plantations (Table 4). The geographical distribution of the classes revealed the same pattern for both species, where from the east of the basin to the west the values of limiting factors increase and the suitability classes decrease subsequently.

Table 7. The surface area of each suitability class for Norway maple (*Acer platanoides* Linnaeus) plantations by parametric and analytic hierarchy process (AHP) approaches

Suitability class	Parametric area (km^2)	Parametric (%)	AHP area (km^2)	AHP (%)
S1	0	0	12.91	3.27
S2	110.46	27.97	286.84	72.63
N	284.48	72.03	95.19	24.10
Total	394.94	100	394.94	100

S1 – highly suitable, S2 – moderately suitable, N – not suitable

The zonation of land suitability by AHP technique

The values of land suitability indices based on the AHP approach varied between 35.91 and 84.58 for Norway maple plantations which categorized the basin into the not suitable class N in the southwest and north of the basin, moderately suitable class S2 in the middle and east and highly suitable class S1 at scattered parts in the east of the study area (Fig. 3a). The produced land index values for black locust plantations ranged from 32.87 to 94.31 which classified into the not suitable class N in some areas in the north and southwest of the basin, moderately suitable class S2 in the middle and eastern parts and highly suitable class S1 in some parts

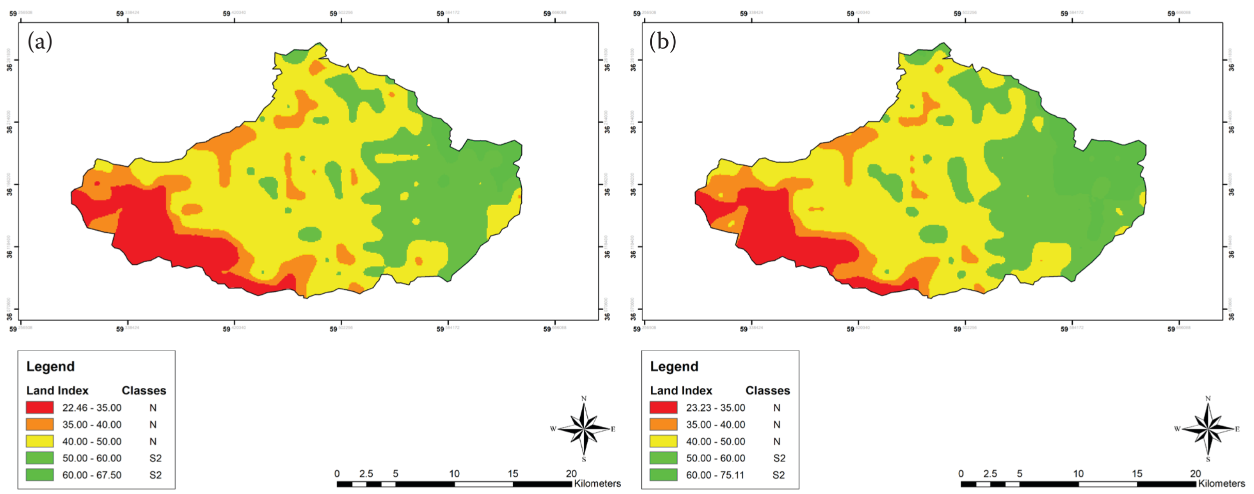

Fig. 2. The zonation of land suitability for Norway maple (a), black locust (b) plantations by the parametric approach in the study area

N – not suitable, S2 – moderately suitable

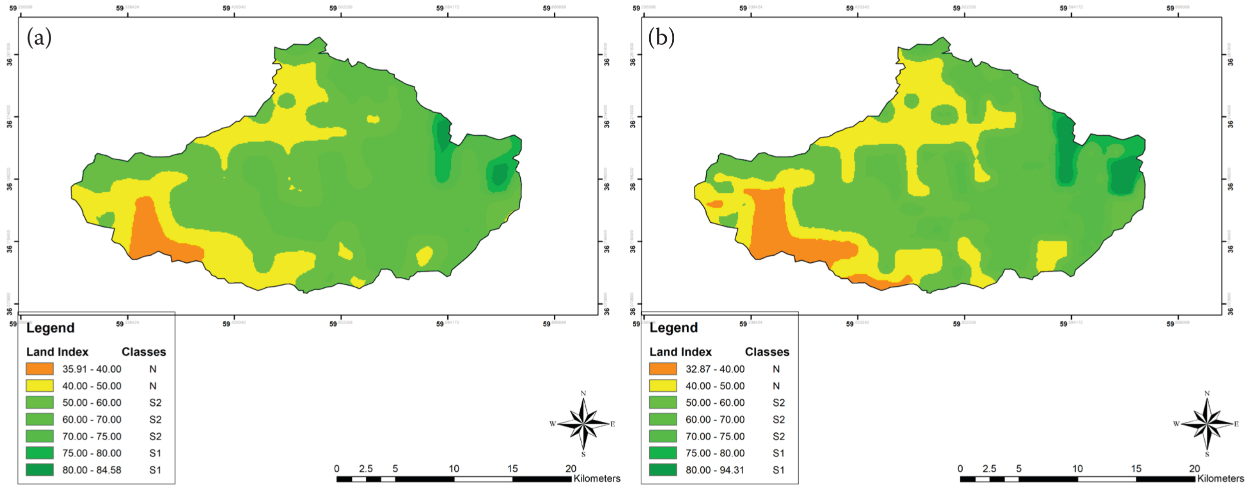

Fig. 3. The zonation of land suitability for Norway maple (a), black locust (b) plantations by the analytic hierarchy process approach in the study area

N – not suitable, S2 – moderately suitable, S1 – highly suitable

in the east of the study area (Fig. 3b). The zonation of land suitability for Norway maple plantation revealed that 3.27% (12.91 km^2) of the surface area were classified into optimal suitable class S1, 72.63% (286.84 km^2) sub-optimal suitability class S2 and 24.10% (95.19 km^2) were categorized into the not suitable class N. The zonation map of black locust plantation revealed 5.13% (20.25 km^2) of the basin were classified into S1 class, 63.13% (249.33 km^2) into S2 class and 31.74% (125.36 km^2) of the study area were categorized into N class (Table 8).

Table 8. The surface area of each suitability class for black locust (*Robinia pseudoacacia* Linnaeus) plantations by parametric and analytic hierarchy process (AHP) approaches

Suitability class	Parametric		AHP	
	area (km^2)	(%)	area (km^2)	(%)
S1	0	0	20.25	5.13
S2	135.94	34.42	249.33	63.13
N	259.00	65.58	125.36	31.74
Total	394.94	100	394.94	100

S1 – highly suitable, S2 – moderately suitable, N – not suitable

Model validation

The coefficient of determination (R^2) between the land suitability indices by parametric and AHP approaches for Norway maple and black locust plantations was 0.869 and 0.893 respectively, which shows a high correlation between the obtained results by the two approaches (Figs 4a, b). Field inventories also revealed similar fitness of both approaches in describing the land suitability zonation for both tree plantations. The prediction of land index by the two approaches was compared by calculating R^2 defined by Nash and Sutcliffe (1970) as follows (Eq.4):

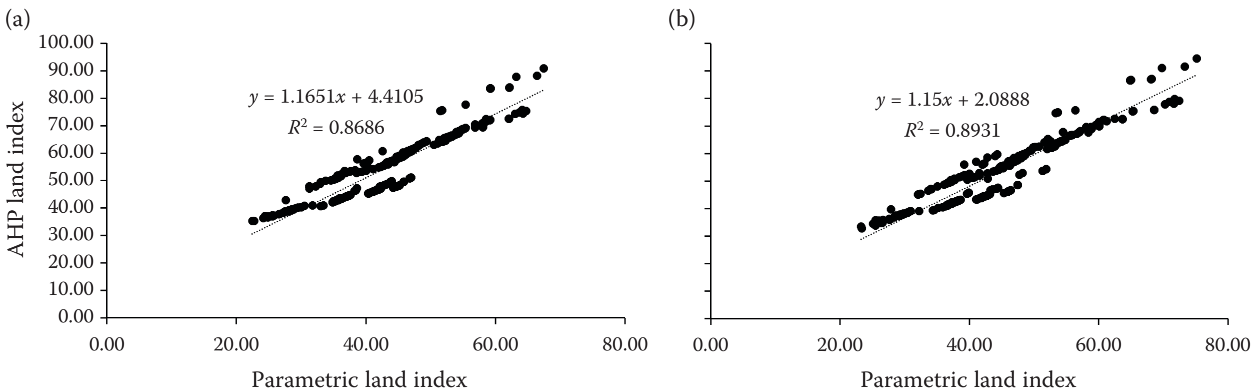

Fig. 4. The regression between the land suitability indices by parametric and analytic hierarchy process (AHP) approaches for Norway maple (a), black locust (b) plantations

$$R^2 = 1 - \frac{\left[\sum_{i=1}^{n}\left(\left(\mathrm{LI}_{\mathrm{AHP}}\right) - \left(\mathrm{LI}_{\mathrm{param}}\right)\right)^2\right]}{\left[\sum_{i=1}^{n}\left(\mathrm{LI}_{\mathrm{AHP}}\right) - \left(\overline{\mathrm{LI}_{\mathrm{AHP}}}\right)\right]^2} \quad (4)$$

where:

$\mathrm{LI}_{\mathrm{AHP}}$, $\mathrm{LI}_{\mathrm{param}}$ – computed values of sample *i*, based on the parametric and AHP approaches, respectively,

$\overline{\mathrm{LI}_{\mathrm{AHP}}}$ – mean of the measured values.

The R^2 estimated from Eq. 4 equals 0.98 in our study, which shows a high correlation between the estimated values by the two approaches.

DISCUSSION

Interpretations and complications of land suitability in the study area

As demonstrated above, the suitability classes of the tree species by two approaches were categorized mainly into S2 and N classes. This can be ascribed to the shallow soil depth which can minimize the water holding capacity of soil and makes it more susceptible to drought. As well, steep slopes, intensity of the southward aspects especially in the middle and western parts of the basin and semiarid climate conditions with < 230 mm·yr^{-1} precipitation which is limited mostly to the winter months are considered as important limiting factors affecting tree growth and development in the study area. The climatic conditions can impact directly and indirectly on the forest plantation development. The inventory field observations also revealed that the growth and productivity of tree species correspond well with the level of land suitability classes. According to Lavalle et al. (2009), there is a close relationship between local climatic conditions and growth requirements of trees. The obtained results are in agreement with Mueller et al. (2010), who stated that components of natural climate factors including solar radiation, air temperature, evapotranspiration and precipitation account for the main indicators of forest plantation development. Moreover, it was also found that the tree species show different responses to the interaction between land qualities, soil characteristics and climatic factors in the region. This is due to the fact that the soil and climate factors, especially precipitation, have significant roles to support the plant growth process and species productivity (Lavalle et al. 2009). Physical environmental parameters and land use management in the region can also affect the suitability of the basin for tree species. According to Rounselvell and Reay (2009) ineffective land use is closely related to climate change and can lead to a decrease in land productivity. Hence, land use patterns and management programs for example selecting appropriate tree species for afforestation and implementing modern technologies of irrigation can compensate the restricted effects of environmental factors such as climate and soil in rehabilitation programs of the region. In fact, the term of land suitability is not only related to the terrain, soil and climatic conditions, but also it should be ecologically suitable for the physical environment and be economically viable and socially acceptable (FAO 1984).

CONCLUSIONS

In the present study, the land suitability for Norway maple and black locust plantations was assessed by parametric and AHP approaches. The zonation of land suitability revealed a similar pattern of suitability classification for both tree species. The classes of land suitability for tree species by two approaches were categorized into moderately suitable and not suitable. It was indicated that most lands of the basin have limitations which in combination are too severe for the sustained afforestation including shallow soil depth, steep slope, aspect trend and tough climatic conditions. The obtained results can help land use planners to rehabilitate the basin by planting tree species which tolerate ecologically hard conditions of the region.

Acknowledgement

I appreciate the Islamic Azad University, Mashhad branch for their cooperation.

References

Bagherzadeh A., Paymard P. (2015): Assessment of land capability for different irrigation systems by parametric and fuzzy approaches in the Mashhad Plain, northeast Iran. Soil and Water Research, 10: 90–98.

Boring L.R., Monk C.D., Swank W.T (1981): Early regeneration of a clear-cut southern Appalachian forest. Ecology, 62: 1244–1253.

Burschel P., Huss J. (1997): Grundriss des Waldbaus: Ein Leitfaden für Studium und Praxis. Berlin, Parey Buchverlag: 487.

Dagar J.C. (1998): Nitrogen fixing fodder trees for degraded and problematic lands. In: Daniel J.N., Roshetko J.M. (eds):

Nitrogen Fixing Trees for Fodder Production. Morrilton, Winrock International Institute for Agricultural Development: 73–81.
FAO (1984): Land Evaluation for Forestry. Rome, FAO: 123.
Fischer G., van Velthuizen H., Prieler S. (2001): Assessment of Potential Productivity of Tree Species in China, Mongolia and the Former Soviet Union: Methodology and Results. Interim Report IR-01-015. Laxenburg, International Institute for Applied Systems Analysis: 74.
Hanover J.W. (1990): Physiological genetics of black locust (*Robinia pseudoacacia* L.): A model multipurpose tree species. In: Werner D., Müller P. (eds): Fast Growing Trees and Nitrogen Fixing Trees. Marburg, Springer: 175–183.
Hytteborn H., Maslov A.A., Nazimova D.I., Rysin L.P. (2005): Boreal forests of Eurasia. In: Andersson F. (ed.): Ecosystems of the World 6: Coniferous Forests. Amsterdam, Elsevier: 23–99.
Lavalle C., Micale F., Houston T.D., Camia A., Hiederer R., Lazar C., Conte C., Amatulli G., Genovese G. (2009): Climate change in Europe. 3. Impact on agriculture and forestry. A Review. Agronomy for Sustainable Development, 29: 433–446.
Malczewski J. (1999): GIS and Multicriteria Decision Analysis. New York, John Wiley & Sons: 392.
Mitchell A.F. (1982): The Trees of Britain and Northern Europe. New York, Collins: 416.
Mueller L.U., Schindler W., Mirschel T.G., Shepherd B.C., Ball K., Helming J., Rogasik F., Eulenstein H., Wiggering. (2010): Assessing the productivity functions of soils. A Review. Agronomy for Sustainable Development, 30: 601–614.
Nair P.K.R. (1993): An Introduction to Agroforestry. Dordrecht, Kluwer Academic Publishers: 499.
Nash J.E., Sutcliffe J.V. (1970): River flow forecasting through conceptual models part I – a discussion of principles. Journal of Hydrology, 10: 282–290.
Praciak A., Pasiecznik N., Sheil D., van Heist M., Sassen M., Correia C.S., Dixon C., Fyson G., Rushford K., Teeling C. (eds) (2013): CABI Encyclopedia of Forest Trees. Wallingford, CABI: 536.
Rajora O.P., Mosseler A. (2001): Challenges and opportunities for conservation of forest genetic resources. Euphytica, 118: 197–212.
Rossiter D.G. (1996): A theoretical framework for land evaluation (with discussion). Geoderma, 72: 165–202.
Rounselvell M.D.A., Reay D.S. (2009): Land use and climate change in UK. Land Use Policy, 26: S160–S169.
Rushforth K. (1999): Trees of Britain and Europe. London, Harper Collins Publishers: 1336.
Saaty T.L. (1980): The Analytical Hierarchical Process: Planning, Priority Setting Resource Allocation. New York, McGraw-Hill: 287.
Saaty T.L., Vargas L.G. (2001): Models, Methods, Concepts and Applications of the Analytic Hierarchy Process. New York, Springer: 333.
Schuett P. (1999): Enzyklopädie der Holzgewächse: Handbuch und Atlas der Dendrologie. Landsberg am Lech, John Wiley & Sons: 5388.
Stolbovoi V., Fischer G., Ovechkin S., van Minnen J., Rojkova S. (1998): The IIASA-LUC Project Georeferenced Database of the Former U.S.S.R., Volume 4: Vegetation. Interim Report IR-98-114. Laxenburg, IIASA: 32.
Tabari M., Salehi A. (2008): Soil carbon sequestration potential of Eldar pine and black locust afforestation in a semi-arid zone of Iran. Research Journal of Environmental Sciences, 2: 483–490.
van Diepen C.A., van Keulen H., Wolf J., Berkhout J.A.A. (1991): Land evaluation: From intuition to quantification. In: Stewart B.A. (ed.): Advances in Soil Science. Volume 15. New York, Springer-Verlag: 139–204.
Wang Q.F., Niu D., Yu G.R., Ren C.Y., Wen X.F., Chen J.M., Ju W.M. (2005): Simulating the exchanges of carbon dioxide, water vapor and heat over Changbai Mountains temperate broadleaved Korean pine mixed forest ecosystem. Science in China Series D – Earth Sciences, 48 (supplement I): 148–159.
Woods J., Hall D.O. (1994): Bioenergy for Development – Technical and Environmental Dimensions. Rome, FAO: 78.

Received for publication August 27, 2017
Accepted after corrections February 26, 2018