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Impacts of Hyrcanian forest ecosystem loss: the case of Northern Iran

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Abstract
Land use change (LUC) of forest ecosystems and their deforestation are global crises that have had many consequences in Asia at the twentieth century. The purpose of this research is to identify, weigh, and prioritize the forest LUC consequences in northern Iran. Therefore, the study applied the Delphi method to identify the consequences of forest LUC. In addition, the weight of consequences was calculated with Stepwise Weight Assessment Ratio Analysis (SWARA). Moreover, the priority of consequences of the Hyrcanian forest ecosystem land use change (HFELUC) was determined with Simple Additive Weighting (SAW), Additive Ratio Assessment (ARAS), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods. Research data were collected by completing a questionnaire by 30 specialists of forest science. Finally, 18 important consequences of the HFELUC in northern Iran were identified based on the specialist's opinions. The results showed that the consequences of decreasing plant and animal biodiversity, reducing water quality and quantity, and changes in biological, physical, and chemical soil properties were the most important consequences of HFELUC. According to the forest LUC consequences, it is suggested that the effective factors in the forest LUC and the preservation of Hyrcanian forests should be considered and identified by the experts and officials of Iran.

Keywords Forest land use · Prioritization · Hyrcanian forest · Triple integration method · Berda · Copeland

1 Introduction

The forest ecosystem is one of the most important natural resource that provides different services and functions to humanity, so its preservation and maintenance should be the main goal of human activities (Haines-Young & Potschin, 2018; Zeki Baskent, 2020). The

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functions and services, such as climate regulation, production of food, medicine, water, timber, bioenergy, ecotourism, education, psychological benefits, and other services, are not free, and they have economic value and price (Grammatikopoulou & Vackarova, 2021). If these services are considered free, the forest ecosystem will be harvested indiscriminately. However, nowadays, various pressures arising from economic activities such as fuelwood and wood harvested, mining, increasing agricultural land demand for food production and fragmentation from small roads have led to the decline and destruction of forest ecosystems all over the world (Burivalova et al., 2019). In recent decades, with population growth and the need to expand the area of agricultural land and settlements, the process of deforestation has intensified (Acheampong et al., 2019). Population growth and the need for agricultural land and settlements have led to the destruction of large areas of forests, severe biophysical changes, and their transformation into other land uses. In other words, increasing the area of crop agricultural and garden lands will cause a reduction in the forest land area (Acheampong et al., 2019). Land use change (LUC) is a process in which humans change the use of land and convert it to other lands to bring more profit (Thapa, 2021).

The conversion of forest lands to urban and residential uses is one of the most important and common types of LUC, which has serious social, economic, and environmental consequences. During the past years, the effects of LUC have increased more than past. Nevertheless, the most important subject is that inappropriate human activities which create consequences such as desertification, acidification, climate change, increasing the greenhouse effect, and destruction of biodiversity (Mirakhorlu & Akhavan, 2017). The consequences of these environmental problems are serious for human societies in the short and long term. Food security, human vulnerability, health and safety are at risk in the short term, and the land stability is threatened in the long term (Vu et al., 2022).

Food and Agriculture Organization (FAO) listed Iran as one of the countries whose agricultural lands and forest resources have been severely affected by degradation in a 1994 report (FAO, 2000). Therefore, forest land use in countries like Iran where the living space is limited, it must be managed, properly planned and fully optimized like water use. Therefore, forest LUC is one of the important concerns after climate change for the development of sustainable management strategies in Iran in the twenty-first and twenty-second centuries (Mirakhorlu & Akhavan, 2017). Iran should attation to sustainable development goals (SDGs) in order to decrease poverty, protecting the environment and climate (SDG-13) and life on land (SDG-15) to achieve peace and welfare of the people.

Iran ranks 45th among 156 countries with forests in the world, and forests cover 7.8% of Iran's area. These forests are distributed in five vegetation regions including Hyrcanian (Khazari), Arasbarani, Irano-Turanian, Zagros and Khalije, and Omani (Oman Gulf). Iran's forests are mostly located in the northern strip and the Hyrcanian vegetation regions (Marvi Mohajer, 2017).

The Hyrcanian forests are the densest forest area that they are located in the south of the Caspian Sea. The importance of Hyrcanian forests in Iran in terms of forest cover, biodiversity, and landscape is known in the world. It is also one of the richest forests in terms of tree species and shrubs (Zarandian et al., 2016). However, in recent decades, there have been extensive changes in the distribution of forests in the north of Iran, because of population growth, economic development, changes in the social and political situation especially in the highlands (the mountain range is limited to rangelands) and downstream (plains limited to agricultural lands). The findings of Mirakhorlu and Akhavan (2017) showed that 161,290 ha of the Hyrcanian forest destroyed during the last 12 years. The forest cover amount in Gilan, Mazandaran, and Golestan provinces is equal to 48,543, 79,558, and 33,189 ha, respectively. According to the information, the rate of forest area reduction (destruction) in the whole Hyrcanian forest range was 0.74%. This statistic showed that the increasing rate of deforestation and its conversion to other land uses in Hyrcanian forests is an undeniable fact in recent years (Mirakhorlu & Akhavan, 2017). In Iran, various studies (Vafaie and Darvishsefat 2013; Komeil Jahanifar et al., 2018; Faraj Elahi et al., 2020; Molaei & Alinaghipour, 2020, Azizi & Panahandeh, 2020; Jafarian & Karami, 2021; Yaghoobi Bayekolaee et al., 2022) have shown that the rate of forest land use conversion to different land uses in Iran has grown rapidly in recent decades. Therefore, due to the significance of the Hyrcanian forests, it is imperative to identify and prioritize the consequences of Hyrcanian forest ecosystem land use change (HFELUC) in northern Iran to plan, manage, and preserve this ecosystem. However, the scientific study of LUC factors and their effects is not limited to the international level. This issue has attracted the attention of scientists in most countries of the world.

In the field of management and planning to reduce environmental consequences, the situation is so complex that the opinions of the person who is responsible for analyzing it are different from the manager who has to make the final decision. Therefore, it is very important to identify and prioritize the consequences for decision making. There are various methods for identifying, weighing, and prioritizing environmental consequences like LUC including multi-criteria decision making (MCDM) (Hosseini et al., 2016). MCDM methods are able to consider the conditions, criteria, and quantitative and qualitative indicators of the problem at the same time, which are widely used in the field of environmental planning and management. MCDM methods include methods that their aim is weighting criteria, indicators, outcomes and prioritizing them. Among the weighting methods, this can refer to entropy methods, linear programming technique for multidimensional analysis of preference (LINMAP), analytic hierarchy process (AHP), step-wise weight assessment ratio analysis (SWARA), integrated determination of objective criteria weights (IDOCRIW). Also, technique for order preference by similarity to ideal solution (TOPSIS), Vlse Kriterijumsk Optimizacija Kompromisno Resenje (VIKOR), ELimination and Choice Translating Reality (ELECTRE), simple additive weighting (SAW), additive ratio assessment (ARAS), and complex proportional assessment (COPRAS) are prioritization methods of criteria and indicators (Jalili Asle et al., 2022).

Numerous studies investigated forest LUC but a few studies identified forest ecosystem land use change. For example, Benini et al. (2010) evaluated land use change's consequences and their environmental impacts on the forest of the Lamone basin. They used the DPSIR framework for the consequence's evaluation. The study result indicated that transforming the forests into agriculture produced a water deficit equal to 0.89 million m^3 in 2003. Yaolin et al. (2016) identified LUC as an effective factor in Ningbo forest degradation in central China from 1979 to 2014 using satellite images and metric data. Their results showed that factors such as population growth, urban unsuitable planning, economic growth, and increasing consumption of agricultural products are the most important factors of forest LUC.

Rodriguez-Echeverry et al. (2018) investigated LUC impacts on Chilean temperate forests biodiversity by using satellite images. The finding indicated that forest LUC led to a loss of biodiversity (12%), erosion control services (34%), and a reduction in water supply services (11%). Ngaba et al. (2019), Bazgir et al. (2020), and Fitts et al. (2021) surveyed the effects of changing the use of natural forest lands to farms on soil carbon and nitrogen in eastern China, the USA, and Zagros forest of Iran, respectively. Their results showed that soil C and N rates and contents are influenced by human activities such as forest LUC to agriculture. Smiraglia (2020) investigated

LUC effects on forest biodiversity. The results showed that LUC causes the loss of biodiversity and reduces the effectiveness ecosystem services on social and profitable costs, which affects not only environmental sustainability, but also mortal well-being. In addition, Solar et al. (2016) and Gurgel et al. (2021) examined agriculture and forest LUC effects on biodiversity, carbon storage, runoff, ecosystem values, forest, and agriculture ecosystem services in the USA. Also, Vu et al. (2022) investigated the impact of LU/ LC in Ghana. The results indicated that 7% of the forest lands decreased from 1986 to 2019 and agricultural and residential lands increased 37%. Liaqat et al. (2021) evaluated LU/ LC effect on groundwater resources in Al Ain region of the United Arab Emirates using remote sensing (RS) and geographic information system (GIS) techniques. The findings indicated that the average depth of underground water has decreased by 40.44% with the increase in urban and agricultural areas during the last 10 years.

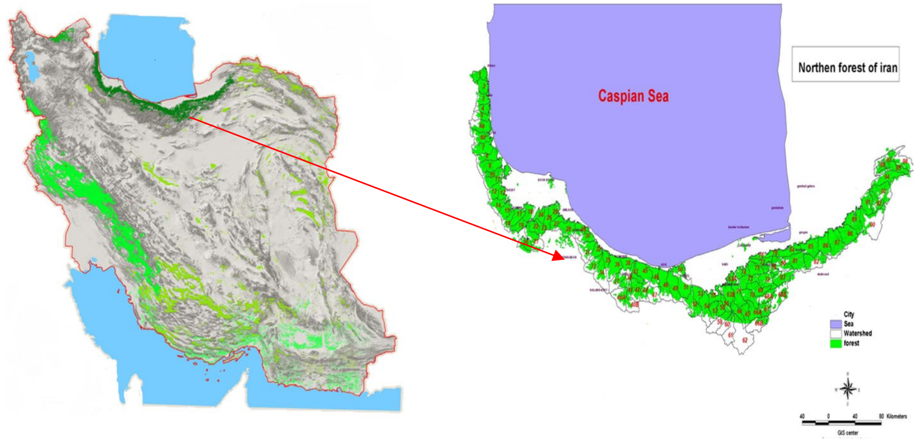
Noh et al. (2022) investigated the challenges of forest ecosystem fragmentation in Tropical Andean. The result showed that LUC is one of the critical reasons for forest fragmentation. Ren et al. (2022) and Li et al. (2022) surveyed LUC effects on China and Selenga ecosystem services, respectively. Findings showed that LUC is significantly correlated to ecosystem services.

A review of previous studies indicated that one of the serious problems of Hyrcanian forest lands is LUC but few studies have been done to evaluate, identify, and prioritize the consequences of the Hyrcanian forest ecosystem land use change (HFELUC) so far in northern Iran. Despite research on LUC, few studies have identified and prioritized the forest LUC consequences, especially in the Hyrcanian forest ecosystem of northern Iran as a part of the global forests. Therefore, in this study, according to the importance of Hyrcanian forests, their LUC consequences investigated, identified, weighted, and prioritized using Delphi and multi-criteria decision making (MCDM) techniques such SWARA, SAW, ARAS, and TOPSIS techniques.

2 Material and method

2.1 Study area

Hyrcanian forests are located at the Caspian Sea's southern boundary and along Alborz Mountain. They have 800 km long and 20–70 km wide (Fig. 1). Their area is 3.8 million ha which 1.2 million ha are commercial, and the rest are considered protection and conservation forests. These forests are found in the temperate climate and 100 to 2800 m above sea level. Currently, the Hyrcanian forests are the habitat of 296 species of birds and 98 species of mammals. Approximately 80 trees species and 50 shrubs species are found in these forests. The most famous trees of Hyrcanian forests are Fagus, Quercus, Carpinus, Parrotia Persica, Alnus, Ulmus, Fraxinus, Buxus, and other trees (Marvi Mohajer, 2017). The Hyrcanian forests cover three Northern provinces of Iran, including Mazandaran, Gilan, and Golestan that most of the Hyrcanian forests are located in Mazandaran province. The area of these forests is extensive and is about 1.9 million ha. These forests are stretched from Astara in the north of Gilan province to Glidagh in the east of Golestan province in Iran (Fig. 1).



A: Iran B: Hyrcanian Forest

Fig. 1 Location of the study area (Natural Resources and Watershed Management Organization website, 2022)

2.2 Data collection and statistical analysis

In the first step, a set of consequences of the Hyrcanian forest ecosystem land use change (HFELUC) was extracted using library research, reviewing past sources, and using the opinions of specialists. Then, the Delphi technique was used to identify forest land use change's main consequences. To score HFELUC consequences, the Delphi questionnaire was distributed among 30 forest science specialists, including forest managers and forest experts who researched and had experience in forest lands use change. Then, considering their expertise and experience, they were asked to score each of the consequences according to the Likert scale (not important (1), low importance (2), important (3), high importance (4), and very high importance (5)). Moreover, if there is a new consequence, they add them to the list of consequences (Profillidis et al. 2019).

In this research, the Delphi questionnaire was completed in three periods using the opinions of 30 specialists. Finally, to consensus on their opinions, the mean and standard deviation of each consequence is calculated at each stage (Hosseini et al., 2021). Then, standard deviation and Kendall's concordance coefficient indexes were used to determine the degree of consensus among Delphi members. Moreover, the questionnaire's validity was determined according to the specialist's opinions, and its reliability was evaluated using Cronbach's alpha reliability technique (Momeni et al., 2008). The reliability of the questionnaire was confirmed with a coefficient $\alpha = 0.89$.

In the research, for weighting HFELUC consequences used Stepwise Weight Assessment Ratio Analysis (SWARA) and Simple Additive Weighting (SAW) models, Additive Ratio Assessment (ARAS) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) were used for prioritizing which are described below:

(a) Stepwise Weight Assessment Ratio Analysis (SWARA).

Stepwise Weight Assessment Ratio Analysis is the newest MCDM technique presented by Kersuliene et al., (2010). The SWARA technique is introduced in the following (Kersuliene et al., 2010):

- A: Sorting a list of criteria (consequences)
  First, the criteria identified by specialists in the Delphi method are written in order of importance. The most significant criteria are in the higher classes and the less important criteria are in the lower classes (Kersuliene et al., 2010).
- B: Specifying the relative importance of every criterion (Sj)
  The relative importance of each criterion was compared to the last criterion. In the step-wise weight assessment ratio analysis, relative importance was indicated by Sj (Kersuliene et al., 2010).
- C: Estimating the kj coefficient
  Kj is a function of the relative importance of every criterion, which is calculated using Eq. 1 (Kersuliene et al., 2010).

$$K_j = S_j + 1 \tag{1}$$

- D: Determination of the initial weight of every function
  The initial weight (Qj) is estimated using Eq. 2. Moreover, the first criterion weight is considered equal to one (Kersuliene et al., 2010).

$$Q_j = Q_j - 1/K_j \tag{2}$$

- G: Calculating the final normal weight
  In this step, the final weight is estimated using Eq. 3 (Kersuliene et al., 2010).

$$W_j = Q_j / \sum_{k}^{n} Q_k \tag{3}$$

(b) Additive Ratio Assessment (ARAS)

Zavadskas and Turskis (2010) proposed the ARAS method for estimating the mass ratio. This method is one of the best MCDM methods for choosing the best alternative (Zavadskas et al., 2010). Implementation of the ARAS technique is explained in the following (Zavadskas et al., 2010):

- Step 1: Formation of decision matrix

The first step of the additive ratio assessment method is the creation of the decision matrix. The decision matrix is for the evaluation of several options based on some criteria. A decision matrix is a matrix in which each alternative is scored based on many criteria. The decision matrix is represented by X and its alternatives are indicated by xij (Eq. 4) (Zavadskas et al., 2010).

$$X = \begin{bmatrix} x_{01} & x_{0j} & x_{0n} \\ x_{i1} & x_{ij} & x_{in} \\ x_{m1} & x_{mj} & x_{mn} \end{bmatrix} i = 0, 1, 2 \ldots, \ m; j = 1, 2, \ldots, \ n \rightarrow X = \begin{bmatrix} x_{11} & x_{12} & x_{1n} \\ x_{21} & x_{22} & x_{2n} \\ x_{m1} & x_{m2} & x_{mn} \end{bmatrix} \tag{4}$$

In Eq. 4, the alternatives number is indicated by m, and the criteria number is stated by n.

- Step 2: Creating a normalized decision matrix

Normalization is the second step in solving all MCDM methods based on the decision matrix (Zavadskas et al., 2010). Positive criteria (Eq. 5) and negative criteria

(Eq. 6) must be normalized separately, which is done from the two relations below this process.

$$\bar{x}_{ij} = \frac{x_{ij}}{\int_{i=0}^{m} x_{ij}}, \forall_j \in B \tag{5}$$

$$\bar{x}_{ij} = \frac{1/x_{ij}}{\int_{i=0}^{m} 1/x_{ij}}, \forall_j \in B \tag{6}$$

$$\text{Normalized decision matrix}: N = \begin{bmatrix} n_{11} & n_{12} & n_{1n} \\ n_{21} & n_{22} & n_{2n} \\ n_{m1} & n_{m2} & n_{mn} \end{bmatrix} \tag{7}$$

- Step 3: Formation of a weighted normalized decision matrix

In the third step of the ARAS technique, the normalized decision matrix must be weighted and the weighted normalized decision matrix is created as Eq. 8. For this purpose, the weight of each criterion is multiplied by all the alternatives below the same criterion. The weight of the criteria must be determined in advance. For this purpose, in this study, the SWARA technique was used to estimate the standard weight. The criteria weight must be specified previously. For this purpose, the SWARA technique was used to determine the criteria weight (Zavadskas et al., 2010).

$$\text{Weighted normalized decision matrix}: \begin{bmatrix} v_{11} & v_{12} & v_{1n} \\ v_{21} & v_{22} & v_{2n} \\ v_{m1} & v_{m2} & v_{mn} \end{bmatrix} \tag{8}$$

- Step 4: Calculating the utility of each alternative

In the fourth step of the ARAS method, the utility of each alternative is estimated by the utility function. The best alternative is to have a greater utility. Finally, the degree of utility must be calculated. The total utility of each option is denoted by Si and is calculated as Eq. 9:

$$\mathrm{S_i} = \sum \mathrm{V_{ij}}\ \mathrm{i} = 0, 1, 2, ..., \mathrm{m} \tag{9}$$

The degree of the utility of the alternatives ($\mathrm{K_i}$) is calculated based on comparison with an optimal value ($\mathrm{S_o}$) using Eq. 5. The optimal value can be obtained based on the alternative of specialists or the best values of the weighted matrix (Zavadskas et al., 2010). The utility degree (K*i*) of an alternative a_i is calculated using Eq. 10:

$$\mathrm{K_i} = \mathrm{S_i}/\mathrm{S_o} \tag{10}$$

$\mathrm{K_i}$ is in the spacing [0, 1] and can be arranged in an increasing sequence.

(c) Simple Additive Weighting (SAW)

The simple additive weighting technique is the easiest, most well-known, and most usable method of MCDM techniques to select the best alternative (Arsyah et al., 2021). To use the SAW method to prioritize the identified criteria, first, the decision matrix is converted to a normalized decision matrix. Then, for prioritizing the significant criteria, the weight calculated by the SWARA technique is multiplied by a normalized decision matrix (Ameri et al., 2018). In this method, the score of each criterion (Si) is calculated by the weighted average of its values in all consequences based on Eq. 11 (Hosseini et al., 2021).

$$S_i = \sum_{i=1}^{m} n_{ij}.w_j j = 0, 1, 2, \ldots \ldots .n \tag{11}$$

Wj: Weight of each consequence; nij: Score of each consequence.

When *wj* shows the j_{th} criterion weight, *m* is the number of alternatives, and *nij* shows the alternative value *i* related to criteria *j*.

(d) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS):

Technique for order of preference by similarity to the ideal solution is one of the MCDM techniques which has high power in separating alternatives and prioritizing preferences based on their similarity to the ideal solution (Hosseini et al., 2016). Hwang & Yoon, 1981 introduced the TOPSIS technique (Hwang & Yoon, 1981). The steps of the method can be described as follows (Hwang & Yoon, 1981):

- Step 1: Converting the decision matrix into a normalized decision matrix based on Eq. 12:

$$\frac{r_{ij}}{\sqrt{\sum_{i=1}^{m} r_{ij}^2}} = n_{ij} \tag{12}$$

nij: a normalized decision matrix; r_{ij}: score of each indicator.

- Step 2: Create a weighted normalized decision matrix by assuming the vector "w" as input to the algorithm (Ameri et al., 2018):

$$W = \{W_1, W_2, \ldots W_n\} \tag{13}$$

W: Weight of each indicator.

Thus, ND is a matrix in which the scores of the criteria are scaleless and comparable, and W_{n*n} is a matrix whose only original diameter elements are nonzero (Bera et al., 2022).

$$V = N_D.W_{n*n} = \begin{bmatrix} v_{11} & v_{12} & v_{1n} \\ v_{21} & v_{22} & v_{2n} \\ v_{m1} & v_{m2} & v_{mn} \end{bmatrix} \tag{14}$$

V: weighted normalized decision matrix.

- Step 3: Identifying the positive ideal solution (A^+) and the negative ideal solution (A^-) based on Eqs. 15 and 16, respectively (Ameri et al., 2018):

$$A^+ = \{(\max V_{ij} | j \in J), (\min V_{ij} | j \in J') \mid i = 1, 2 \ldots m\} = \{V_1^+, V_2^+, \ldots, V_j^-, \ldots, V_n^+\} \tag{15}$$

$$A\text{-}^- = \{(\min\ v_{ij} | j \in J), (\max V_{ij} | j \in J') | i = 1, 2, \ldots, m\} = \{V_1^-, V_2^-, \ldots, V_j^-, \ldots, V_n^-\} \tag{16}$$

J′ and j are related to decreasing and increasing criteria, respectively.

- Step 4: Calculating the distance between the ideal and negative ideal solution distance using Eqs. 17 and 18, respectively:

$$d_{i+} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j)^2}; i = 1, 2, \ldots, m \tag{17}$$

$$d_{i-} = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j)^2}; i = 1, 2, \ldots, m \tag{18}$$

- Step 5: Estimating the relative proximity of A_i to the ideal solution (cl_{i+}) using Eq. 19:

$$cl_{i+} = \frac{d_{i-}}{(d_{i+} + d_{i-})}; 0 \le cl_{i+} \le i = 1, 2, \ldots m \tag{19}$$

where di^+ is a positive ideal solution, di^- is a negative ideal solution, and cli^+ is the closeness coefficient.

- Step 6: Ranking options based on descending order of cli^+

In this study, prioritizing the consequences of the Hyrcanian forest ecosystem land use change (HFELUC) with SAW, ARAS, and TOPSIS models led to different results. Therefore, a triple integration method (Mean ranking, Berda, and Copeland methods) is used for reaching a consensus and comprehensive prioritization of the consequences (Jalili Asle et al., 2022). Furthermore, it should be noted that in this study, code was used to prevent the repetition of the consequence's name. In this study, Spss16 and excel were used for information statistical analysis. The flowchart of the methodology for identification, weighing, and prioritization of consequences of the HFELUC using integrated MCDM is shown in Fig. 2.

3 Results

The Delphi group of the study included specialists in forest sciences, environment, and natural resources with at least five years of job experience. In this study, at each stage, 30 people created the Delphi group and expressed their views and opinions (Table 1).

In this study, 18 important consequences of the Hyrcanian forest ecosystem land use change (HFELUC) were identified using the Delphi method (Table 1). The results indicated that the standard deviation of the Delphi group answers about the importance of consequences in the third period of the Delphi method was less than the second period. In other words, the convergence of the participants in choosing the answers was much higher than the second period. In addition, Kendall's correlation coefficient of the answers of the Delphi group regarding the importance of outcomes in the third period was higher than 0.7 (0.96), which indicates a strong consensus among specialists about the consequences of the HFELUC. The analysis of the answers received from the specialist's opinions (the questionnaire results) in the second and third periods of the Delphi method is shown in Table 2.

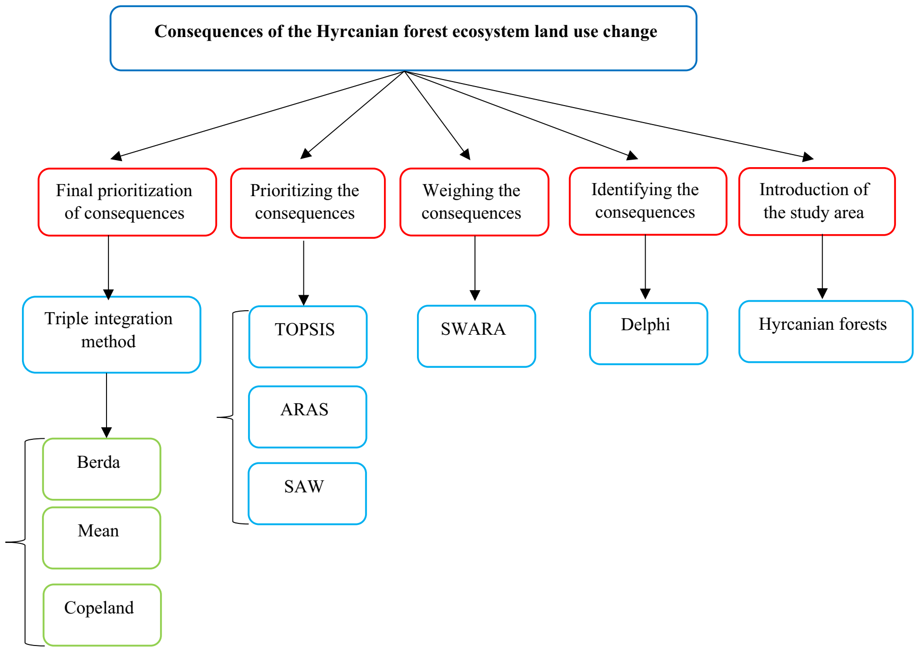


Fig. 2 Flowchart of the methodology

Table 1 Delphi group members

Education	Respondents	Frequency
PhD	Faculty members	16
MSc	Environmental protection organization of Iran	6
PhD and MSc	Natural resource and water management specialists	8

Results of the MCDM techniques such as SWA, SWARA, ARAS, and TOPSIS used for weighting and prioritizing the HFELUC are shown in Table 3. The weighting results of the HFELUC using the SWARA method showed that the consequences of increasing soil erodibility, surface runoff, and floods (A_3) with weight 0.0729; decreasing plant and animal biodiversity (A_4) with weight 0.0705; reducing water quality and quantity (A_8) with weight 0.0704; and changing biological, physical, and chemical soil properties (A_1) with weight 0.0701 obtained the greatest weight among 18 important consequences of the HFELUC, respectively.

Furthermore, the findings of Table 3 indicated that the priorities of consequences in the three models (SWARA, ARAS, and TOPSIS) are different from each other. Therefore, the triple integration method including the average ranking method, Berda method and Copeland method used for the final prioritization of the consequences of LUC in Hyrcanian forest ecosystem.

Mean ranking method: The method prioritizes the consequences based on the average rank obtained from the different MCDM methods. The priority obtained for each consequence is indicated in Table 4.

Table 2 Standard deviation and average consequences of the HFELUC

Code	Consequences	Standard deviation		Average	
		Second	Third	Second	Third
A1	Changing biological, physical, and chemical soil properties	0.95	0.78	1.70	3.87
A2	Impact on above and below-ground carbon reserves (emission of soil organic carbon into the atmosphere)	1.06	1.01	1.67	3.47
A3	Increasing soil erodibility, surface runoff, and floods	0.74	0.73	4.27	4.13
A4	Decreasing plant and animal biodiversity	0.82	0.80	3.87	3.90
A5	Forest ecosystems fragmentation	0.92	0.86	2.10	2.77
A6	Increasing dust	1.34	1.05	2.17	2.73
A7	Increasing landslides and a variety of mass wasting	0.78	0.69	3.53	2.73
A8	Reducing water quality and quantity (physically, chemically, and biologically) in downstream forest lands	0.92	0.91	1.90	3.93
A9	Prevalence of plant pests	0.75	0.66	1.70	1.67
A10	Increasing greenhouse gases	0.97	0.96	1.53	2.63
A11	Drought	0.75	0.73	2.50	2.50
A12	Rising wood prices	0.94	0.93	4.13	3.40
A13	Reduction in land available for wood production	1.01	0.78	1.87	2.73
A14	Migration of non-natives to villages and change of local culture and their social identity	0.76	0.72	1.63	2.60
A15	Unbalanced development of cities and towns and the growth of the problem of marginalization	0.75	0.73	3.30	2.50
A16	Rising housing prices and their unaffordability for low-income households	0.80	0.79	3.67	3.70
A17	Decreasing the value of forest ecosystem services	0.99	0.88	2.17	1.90
A18	The increasing cost of rural and urban infrastructure services in the event of a flood	0.76	0.75	3.20	2.83

Table 3 Calculation of weight and priority consequences of the HFELUC

Models								
	Prioritization						Weighing	
	ARAS		SAW		TOPSIS		SWARA	
Code	S_i	Priority	S_i	Priority	Cl_i^+	Priority	w_j	Priority
A_1	0.069	3	0.5934	14	0.6847	4	0.0701	4
A_2	0.064	6	0.6300	10	0.5928	7	0.0640	6
A_3	0.067	5	0.5763	17	0.7407	1	0.0729	1
A_4	0.072	1	0.5922	16	0.6894	2	0.0704	2
A_5	0.053	10	0.6679	4	0.5671	10	0.0531	11
A_6	0.051	12	0.6720	2	0.5526	13	0.0510	12
A_7	0.054	8	0.6471	8	0.5643	11	0.0543	9
A_8	0.072	2	0.5934	15	0.6880	3	0.0704	3
A_9	0.025	18	0.5287	18	0.3856	17	0.0252	18
A_{10}	0.049	15	0.6818	1	0.5317	14	0.0490	15
A_{11}	0.048	16	0.6683	3	0.6551	5	0.0483	16
A_{12}	0.061	7	0.6274	11	0.5822	9	0.0637	7
A_{13}	0.053	9	0.6580	6	0.5613	12	0.0533	10
A_{14}	0.051	13	0.6641	5	0.5272	15	0.0508	13
A_{15}	0.049	14	0.6551	7	0.5000	16	0.0491	14
A_{16}	0.068	4	0.6078	12	0.6495	6	0.0679	5
A_{17}	0.031	17	0.5946	13	0.3551	18	0.0308	17
A_{18}	0.053	11	0.6463	9	0.5889	8	0.0558	8

Berda method: In this method of decision making, a pairwise comparison matrix is created between the consequences. This means that by using pairwise comparison, that is, by comparing the ranking of each index in each method with other rankings obtained in other methods for the same index, a comprehensive prioritization of rankings is obtained. The comparison number is equal to $m(m-1)/2$, and m is the winning consequences number. Index M, which prioritizes row over column, and index X, which prioritizes column over row. If the votes in this comparison are equal, we call it by the code X. The result indicated that the consequences of decreasing plant and animal biodiversity (A_4); increasing soil erodibility, surface runoff, and floods (A_3); reducing water quality and quantity (A_8); and changing biological, physical, and chemical soil properties (A_1) had the highest priority among other consequences of the HFELUC, respectively. The results of this ranking are indicated in Table 5.

Copeland method: The Copeland technique estimates not only the wins number, but also the losses number for each consequence. The last line of Table 6 shows the total losses (ΣR) for each consequence. The rank that the Copeland method gives to each consequence is calculated by subtracting the number of losses of each consequence (ΣR) from the number of wins of each consequence (ΣC) (Table 6). Finally, based on the results of the Copland method, the criteria of rising wood prices (A12), reducing

Table 4 Findings of prioritization by the mean ranking method in different MCDM methods

Model					Final priority
Code	ARAS	SAW	TOPSIS	Average methods	
A1	3	14	4	7.00	16
A2	6	10	7	7.67	13
A3	5	17	1	7.67	14
A4	1	16	2	6.33	18
A5	10	4	10	8.00	11
A6	12	2	13	9.00	7
A7	8	8	11	9.00	8
A8	2	15	3	6.67	17
A9	18	18	17	17.67	1
A10	15	1	14	10.00	5
A11	16	3	5	8.00	12
A12	7	11	9	9.00	9
A13	9	6	12	9.00	10
A14	13	5	15	11.00	4
A15	14	7	16	12.33	3
A16	4	12	6	7.33	15
A17	17	13	18	16.00	2
A18	11	9	8	9.33	6

the land available for wood production (A13), and increasing dust (A6) have the lowest priority, and other criteria have the highest priority.

3.1 Merging of the MCDM results (Integration method)

At this stage, according to the three prioritization methods (Mean rankings, Berda, and Copeland), a consensus was reached for the final ranking of consequences through the formation of a partial ranking. Then, the results of the three methods were combined, and the priorities were obtained by the average rank of the three methods for the consequences of the Hyrcanian forest ecosystem land use change (HFELUC) (Table 7). According to the results of final prioritization consequences with triple integration in Table 7, consequences of decreasing plant and animal biodiversity (A_4) had the highest priority among the three prioritization methods (Integration methods).

Based on the merging of the results of methods, consequences of decreasing plant and animal biodiversity; reducing water quality and quantity; and changing biological, physical, and chemical soil properties were the most important consequences of the HFELUC (Fig. 3).

4 Discussion

As it is known, economic growth and optimal management of natural and environmental resources are fundamentally interdependent. Economic activities can have an impact on these resources, so that if economic growth is synchronized with the progress of

Table 5 Findings of prioritization by the Berda method

Model	Code A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	EC
A1		x	x	m	x	x	X	m	x	x	x	x	x	x	x	x	x	x	15
A2	m		m	m	m	x	X	m	x	x	x	x	x	x	x	x	x	x	12
A3	m	m		m	x	x	X	m	x	x	x	x	x	x	x	m	x	x	12
A4	x	x	x		x	x	X	x	x	x	x	x	x	x	x	x	x	x	17
A5	m	m	m	m		x	X	m	x	x	m	x	x	x	x	m	x	x	10
A6	m	m	m	m	m		M	m	x	x	m	m	m	x	x	m	x	x	6
A7	m	m	m	m	m	m		m	x	x	m	m	m	x	x	m	x	x	6
A8	x	x	x	m	x	x	X		x	x	x	x	x	x	x	x	x	x	16
A9	m	m	m	m	m	m	M	m		m	m	m	m	m	m	m	m	m	0
A10	m	m	m	m	m	m	M	m	x		m	m	m	x	x	m	x	m	4
A11	m	m	m	m	m	x	X	m	x	x		x	x	x	x	m	x	x	10
A12	m	m	m	m	m	m	M	m	x	x	m		m	x	x	m	x	x	6
A13	m	m	m	m	m	m	M	m	x	x	m	m		x	x	m	x	x	6
A14	m	m	m	m	m	m	M	m	x	m	m	m	m		x	m	x	m	3
A15	m	m	m	m	m	m	M	m	x	m	m	m	m	m		m	x	m	2
A16	m	x	x	m	x	x	X	m	x	x	x	x	x	x	x		x	x	14
A17	m	m	m	m	m	m	M	m	x	m	m	m	m	m	m	m		m	1
A18	m	m	m	m	m	m	M	m	x	x	m	m	m	x	x	m	x		5
ER	5	1	13	2	3	9	9	11	4	0	16	9	9	12	17	13	13	15	

Table 6 Results of prioritization by the Copeland method

Model	Code																	
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18
EC	2	4	4	0	6	8	8	1	17	13	6	8	8	14	15	3	16	12
ER	2	5	5	0	6	11	10	1	17	13	7	11	11	14	15	4	16	12
EC-ER	0	−1	−1	0	0	−3	−2	0	0	0	−1	−3	−3	0	0	−1	0	0
Priority	1	2	2	1	1	4	3	1	1	1	2	4	4	1	1	2	1	1

Table 7 Final prioritization with triple integration

Code	Consequences	Mean rankings	Berda	Copeland	Average methods	Final priority
A1	Changing biological, physical, and chemical soil properties	16	16	1	11.0	3
A2	Impact on above and below-ground carbon reserves (emission of soil organic carbon into the atmosphere)	13	13	2	9.3	6
A3	Increasing soil erodibility, surface runoff, and floods	14	14	2	10.0	5
A4	Decreasing plant and animal biodiversity	18	18	1	12.3	1
A5	Forest ecosystems fragmentation	11	11	1	7.7	9
A6	Increasing dust	7	7	4	6.0	12
A7	Increasing landslides and a variety of mass wasting	8	8	3	6.3	11
A8	Reducing water quality and quantity (physically, chemically, and biologically) in downstream forest lands	17	17	1	11.7	2
A9	Prevalence of plant pests	1	1	1	1.0	18
A10	Increasing greenhouse gases	5	5	1	3.7	14
A11	Drought	12	12	2	8.7	7
A12	Rising wood prices	9	9	4	7.3	10
A13	Reducing land available for wood production	10	10	4	8.0	8
A14	Migration of non-natives to villages and change of local culture and their social identity	4	4	1	3.0	15
A15	Unbalanced development of cities and towns and the growth of the problem of marginalization	3	3	1	2.3	16
A16	Rising housing prices and their unaffordability for low-income households	15	16	2	11.0	4
A17	Decreasing the value of forest ecosystem services	2	2	1	1.7	17
A18	The increase in the cost of rural and urban infrastructure services in the event of a flood	6	6	1	4.3	13

environmental indicators, it is a sufficient condition for the progress of natural resources and environmental will be created. On the other hand, the existence of numerous threats during consecutive years has led to a significant decrease in the extent and quality of these resources, which causes irreparable damage to human societies. In recent years, due to increasing population, expansion of urbanization, and development of urban and industrial spaces, forest lands have been severely destroyed and transformed. Therefore, natural resources LUC is a topic that has increased especially in the northern and central regions of Iran during the last two or three decades because these regions have been developed in terms of tourism. Therefore, forest lands that have a high economic value are converted to other uses such as residential, agricultural, industrial, and tourism (Amirnejad, 2014). Therefore, land use change (LUC) is certainly the most important factor that affects natural ecosystem protection such as forests and has various consequences.

Nowadays, Hyrcanian forests' transformation into other land uses has become one of the significant concerns in the field of environmental degradation and global climate change in the world. The findings of Mirakhorlu and Akhavan, 2017, showed a rapid trend of change. Therefore, identifying its consequences is the basis for a better understanding of the relationships and interactions between humans and natural forest ecosystems. In addition, identifying the consequences of Hyrcanian forest land use change (HFELUC) provides good information for their management, protection, restoration, and development. Also, identifying LUC consequences and increasing suitable measures to reduce them have importance for land use planning (Wubie et al., 2016).

In this study, 18 important consequences of the HFELUC are identified using the Delphi method. These results indicated that HFELUC had negative effects that have widely affected environmental characteristics such as natural ecosystem services and functions.

The Hyrcanian forest ecosystem is a natural habitat for plant and animal species from the tertiary geological period that has high biodiversity. That is why these forests are so important to human society, and UNESCO has listed the Hyrcanian forests as a world heritage site. However, according to experts' opinions, HFELUC has decreased plant and animal biodiversity. The results of a recent study also confirmed this subject. The results of the triple integration method showed that the consequences of reducing plant and animal biodiversity (A_4), reducing the quality and quantity of water (A_8), and changing the biological, physical, and chemical characteristics of the soil (A_1) with the highest final average are the first to third priority in among other consequences. In other words, they are one of the most fundamental consequences of the HFELUC. Results of studies by Wubie et al. (2016), Rodriguez-Echeverry et al. (2018), and Gurgel et al. (2021) confirm these results. The findings showed that biodiversity reduction, soil degradation, and change in water quantity and quality are the most important forest LUC consequences. They explained that the decrease in forest cover due to LUC caused a decline in plant and animal biodiversity, water quantity and quality.

The Hyrcanian forest ecosystem as a natural ecosystem can regulate the qualitative and quantitative behaviors of water resources. The Hyrcanian forest cover helps to minimize floods by stabilizing the soil, minimizing sedimentation, absorbing some of the rainfall, and allowing it to penetrate the soil. Therefore, LUC, especially in the Hyrcanian forest lands, is considered one of the effective factors in enhancing the amount of surface runoff and the number of floods and increasing the amount of soil erosion in Iran. Moreover, in this regard, Thompson et al. (2016); Alamdari et al. (2022) and Kang and DeviKanniah (2022) said that the combination of decreased precipitation associated with climate change and increased evapotranspiration (ET) due to forest land use change led to decreases in the average annual water yield.

Hyrcanian forest ecosystem soils have always been of interest to soil science researchers due to their high organic matter content and suitable structure, but changes in their management and land use have generally had a major impact on the amount of organic matter and other chemical and physical properties of soil. The HFELUC in the northern of Iran has caused a decrease in the amount of soil organic matter and soil nutrients and has led to the destruction of the soil structure and changes in the distribution and stability of soil grains. The results of the study showed that according to specialists' opinion, changing biological, chemical, and physical soil properties (A_1) are important consequences of the HFELUC. The result is similar to the research findings of Melo et al. (2017). They demonstrated how the conversion of native forests to diverse uses resulted in changes in physical and chemical soil attributes. Therefore, considering many functions and services of the Hyrcanian forest ecosystem, preventing deforestation and changing their land use should be one of the primary goals of Hyrcanian forest policy and management.

Water and soil as the main sources of human life, national capital, and the origin of life, play an essential role in the growth of living organisms and human societies. Also, water and soil are the basis of the food chain of humans, and other animal and plant organisms. Forest lands are the national capital that belongs not only to the present generation, but also to the future generations. Therefore, all elements of the natural resources, environment, and all members of the society are responsible for water and soil protection, and preventing the change of their use is considered a legal matter. Also, according to the role of Hyrcanian forest lands in water and soil protection; the protection of these forests is necessary.

The results showed that the consequence of the rising housing prices and the inability of low-income people on the edge of the forest to buy housing (Inability to buy housing by low-income households) (A_{16}) is one of the other consequences of HFELUC. In other words, Hyrcanian forests with suitable climate and favorable location for the ecotourism development due to the presence of natural landscapes (such as elevations, rocks, vegetation, wildlife, waterfalls) have attracted many tourists to this area. Therefore, it has faced unauthorized LUC including the construction of residential and commercial buildings, recreational villas and other places. Also, the expansion of the purchase of land on the edge of the Hyrcanian forest by non-natives due to the climate changes in other provinces of Iran, the intensification of the desire to build villas and second homes outside the urban environment has increased housing prices and changed the use of Hyrcanian forest lands to residential land. Therefore, proper duties and taxes should be considered for this issue to get out of this situation.

5 Conclusion

Forest lands, rangelands, and gardens are considered natural ecosystems. The biological performance of many of these ecosystems depends on the behavior of indigenous communities on the planet. Therefore, changes in each land uses should be made based on the land potential. The land use change (LUC) without considering land potential and land use needs can have adverse consequences. According to the results, the most important consequences of LUC in Hyrcanian forest lands are reduction in plant and animal biodiversity; reduction in water quality and quantity; and changing biological, physical, and chemical soil properties. Therefore, HFELUC can be a warning sign for biodiversity, water, and soil protection of the region. Therefore, timely and accurate detection of these types of changes is the basis for a better understanding of the relationship between humans and natural ecosystems, such as forest ecosystems, and provides better management and more appropriate use of natural resources and the reduction in future environmental consequences. Since the issue of changing the forest lands use was one of the natural resources sector threats from the past to the present, therefore basic and serious solutions should be taken to prevent HFELUC which some of them are suggested in the following:

- Identifying the factors affecting the HFELUC and confronting, controlling, and controlling them
- Paying attention to the consequences of the HFELUC in management programs, education, and natural resource policies
- Preparation of comprehensive educational programs related to the Hyrcanian forest protection and management
- Encouraging human communities and developing and implementing laws to prevent the HFELUC
- Accurate and continuous monitoring of Hyrcanian forests
- Investigating forest LUC using remote sensing from the past to the present
- Budget allocation by the government to conserve the Hyrcanian forests
- Using plans and procedures from other countries with similar conditions to prevent the HFELUC
- A financial and economic evaluation of plans to prevent forest LUC
- Increasing the income of the communities on the edge of the forests by adopting appropriate wealth distribution policies, giving low interest financial facilities and long-term return period
- Monitoring policies on mining and obliging mine owners to protect and restore destroyed natural resources
- Improving existing laws or enacting new legislation to prevent LUC in Hyrcanian forests

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