

Using Remote Sensing to Evaluate the Impact of Uncontrolled Utilization on Zawita Forest Landscape Change during (2003-2024)

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Abstract

This study addresses the impacts of human and non-human (climatic) factors on the landscape of Zawita pine forest of Duhok district, Kurdistan region of Iraq, from 2003 to 2023. The study focused on the effect of the independent variables, (including forest landscape development X_1 , shifting cultivation X_2 , forest fires X_3 , barren lands X_4 , water bodies X_5 , and shrub lands X_6), on the dependent variable represented by the Zawita pine forest landscape (Y_1). Statistically, the stepwise multiple regression analysis was used depending on quantitative data of satellite imagery obtained from remote sensing. The results of statistical analysis indicate that the final model was highly significant ($F= 14.98$, $p < 0.001$), with an explanatory power of 72.55% according to the (R^2), and showed that the three following variables, shifting cultivation (X_2) ($p = 0.0001$, $\beta = -1.285$, $T = -4.96$), forest fires (X_3) ($p = 0.005$, $\beta = -0.916$, $T = -3.22$), and bare lands (X_4) ($p = 0.001$, $\beta = -880$, $T = -4.20$), had a strong and significant effect on the dependent variable represented by forest landscape (Y_1). Including these variables improved the statistical model of the study. These findings align with recent studies that emphasize that forest fires are the major cause of forest cover loss, which globally, are caused by human practices and climate change. Many studies indicate that shifting cultivation has a significant impact on the forest coverage degradation, and the extent of barren land area also reveals evidence of the decline of forest landscape. It seems that shifting cultivation and forest fires have various mechanisms of occurrence, but they are related in terms of forest landscape loss. The study results emphasize the need to develop urgent policies for implementation to manage the forest plan sustainably, to decrease the degradation of forest landscape area, and control the ongoing environmental deterioration.

Keywords: Zawita Forest, Forest Landscape Change, Forest Utilization, Remote Sensing, Stepwise Multiple Regression

1. Introduction

The impact of both human and non-human (anthropogenic and climatic) factors on the changing forest landscape is considered one of the most important biological components of ecosystems. This is because forests are a primary source of biodiversity, which plays a central role in regulating the carbon, water, and energy cycles on the Earth's surface. However, forest cover is subject to large-scale changes caused by a combination of human and non-human factors that interact to affect its structure and function. Recent scientific literature shows that understanding the nature and essence of these changes requires conducting in-depth analysis of the factors and their mechanisms affecting this relationship. The goal is to develop a sustainable and effective policy for managing forest land coverage areas [1].

[2] confirm that over the past two decades, more than 27% of global forest coverage area loss was due to the large-scale commercial agriculture, while shifting cultivation and other uses contributed to varying degrees. This has resulted in increased loss of carbon stock of trees, increasing carbon emissions and global warming occur.

Traditionally, land use has had a material effect on the climate system with human action playing a transformative role on ecosystems [3]. This paper also argues that we could not interpret recent environmental changes without considering the historical background of environment changes related to land use. Forestry is an integral part of climate change mitigation and essential for the future ecosystems (adaptation and mitigation). A variety of human activities that influence the area of forests had been investigated in several studies. This undermines forest resilience and capacity to

recover from environmental stress [4]. Human induced overgrazing is also common. It restricts plants from regenerating and reduces the soil's capacity for holding nutrients which harms forests in the long term [5]. Forests are being destroyed faster than they can recover, with the rate of deforestation exceeding that of reforestation by far —believingly in conflict with the Sustainable Development Goals recommended by [1]. Forest area was recently inventoried in four regions, to the northeast of Erbil in Iraqi Kurdistan by [6]. These threats result in higher average temperatures and more severe periods of drought. In addition, such climatic conditions have also been shown to slow tree growth, reduce the ability of forests to store carbon and change where forest plant species are found [7].

In addition, wildfires are considered one of the main drivers of forest cover change. This hinders the regeneration process and transforms a natural environmental phenomenon into a cause of forest degradation [8]. Forest fires are the result of both anthropogenic and climatic factors.

A study by [9] focused on the degradation of forests in the Amadi District of the Kurdistan Region of Iraq. Between 2000 and 2024, the degradation has been attributed to factors such as fires, climate change, and unsustainable land use practices. Applying remote sensing and (GIS) techniques, the study monitored changes in forested and non-forested land areas using various indicators, including the normalized difference vegetation index (NDVI), modified soil-adjusted vegetation index (MSAVI2), normalized difference moisture index (NDMI), and land surface temperature (LST). The study underscores the need for urgent strategies for forest protection to limit

deforestation, rising temperatures, and enhancement of ecosystem resilience. Projections using the ARIMA model suggest that forest coverage area will continue to decline, emphasizing the necessity for preventive actions.

On the contrary, [10] emphasize that forest fires in Kurdistan region of Iraq have significant environmental, economic, and social risks, necessitating monitoring efforts to safeguard the ecosystem. The study used MODIS data and the NDVI index to assess vegetation vulnerability to fires by developing a fire probability map.

It is important to clarify the interaction between anthropogenic and climatic factors because they usually interact in a complex manner, supporting each other's roles. A study by [11] found that changes in forest coverage area in southeastern Asia occurred due to the interaction between human interaction factors and climatic factors. The study results showed the role of temperature and human practices in this regard, as well as the fact that these impacts can be effectively managed in protected forest areas.

The consequences of changes in forest coverage area, extend beyond environmental dimensions to include economic and social aspects. From an environmental perspective, deforestation is the cause of reducing biodiversity and decreasing the ability of forests for providing ecosystem services, such as producing O₂ and regulating the local climate. From a climate perspective, deforestation contributes to increased CO₂ emissions and reducing ecosystems' capacity to absorb them, accelerating the pace of climate change [2]. From a social perspective, local communities that depend on forests for their livelihoods face economic and living losses, which exacerbate poverty levels [1].

Moreover, [12] found in a study that the rapid expansion of urban areas in Pune, India caused a loss of about 34% of carbon sequestration capacity and 13% of flood mitigation capacity from 2013 to 2022, due to the conversion of shrublands into developed areas.

Similarly, forest coverage plays a fundamental role in maintaining the ecological balance between released O₂ and stored CO₂. This issue has been addressed by many previous studies. For example, forest landscapes, and forest ecosystems in particular, in general, provide one of the most important services through carbon sequestration, whether naturally or artificially, due to their role in mitigating the impacts of climate change. In this manner, [13] examined a field study to measure the amount of carbon sequestered by two species of urban trees in Duhok district. The results showed that these trees have a high carbon storage capacity, suggesting they could be integrated as a sustainable solution for reducing carbon emissions. Furthermore, [14] explained the need to develop species-specific tables for sites aiming to enhance carbon sequestration from *Salix nigra* and *Salix alba* trees in Duhok district. The results showed that the efficiency of carbon sequestration varies among tree species depending on the environmental conditions and location.

Compatible with previous studies, preserving forest coverage area needs sustainable management strategies that address the interaction between human and non-human factors. These strategies lead to sustainable management policies, encouraging reforestation campaigns, and adopting farming practices that reduce and avoid deforestation. They also include effective development and adaptive plans in response

to the impacts of climate change. [1] confirms that forest ecosystem restoration is key to achieving a “green recovery” and diversifying sustainable utilization in forests, whether naturally or artificially [15].

The importance of Zawita, in Dohuk district as a study area is due to its experience of noticeable changes in the forest landscape because of interaction between human and non-human factors, which affects forest degradation and reduces its effectiveness in performing environmental functions such as carbon storage and O₂ release. Therefore, it was necessary to investigate this issue.

In this regard, [16] conducted a study to understand the impact of unregulated utilization in oak forests in Zawita district on the environmental balance, by examining the causing of human and non-human factors. The results emphasized the existence of a direct relationship between the reduction in forest landscape area and the studied factors. Therefore, this study is important for monitoring and tracking changes in forest landscape area, understanding their environmental and economic impacts, and developing environmental and forest protection policies.

A recently study by [17] investigated the dynamics causing vegetation disruption and subsequent regrowth due to logging, shifting cultivation, and forest fires in Tripura, a state in northeastern India, from 1991 to 2020. Shifting cultivation has diverse environmental, social, and economic impacts due to repetitive cycles of forest removal. While meanwhile, [18] examined the spatial relationship between changes in forest coverage in Mjumbe, Tanzania, from 1992 to 2020 and the occurrence of ecological fires using fire and land cover data. The results showed that the expansion in agricultural

area was the main cause of change during most of the period.

In another recent study by [19] used predictive models to study future land use and land coverage area (LULC) scenarios in a specific area of Turkey's Aydin province. The study investigated how the different economic development patterns affect ecosystem services, such as carbon sequestration and habitat quality. The study showed that changes in land use (e.g., shifting cultivation, deforestation, and urban expansion) affect the system's capacity for providing environmental services, reflecting the environmental and economic aspects of land-use decisions.

In addition, [20] examined the changes in land use and land coverage area in the Ethiopian highlands. The study linked human factors, such as rapid population growth, weak planning, and expansion of agriculture, with natural factors, such as extreme weather events, to explain forest coverage area loss. The study showed that the interplay between population growth, expansion of agriculture, and ineffective land use policies results in forest degradation, soil erosion, biodiversity loss, and reduced water availability. Moreover, an analytical study conducted by [21] investigated changes between 2002 and 2022 in a specific region of Africa. The study showed that forest coverage area decreased by about 5%, while shifting cultivation and developed urban areas increased.

[22], in **their** study, **covered** a long period (1974–2019) and **demonstrated** that the conversion of forests to shifting cultivation or other land uses significantly affects ecosystem services, such as biodiversity, soil quality, carbon storage, and water quality. Furthermore, a study conducted by [23] analyzed the temporal and

projected changes in land use and land coverage area (LULCA) in the Finchaa sub-basin in Ethiopia between 1989 and 2050. The study applied Landsat imagery and a multi-layer Markov chain model to predict future changes. The results of the study showed a 40% decrease in forest land area and a 13% decrease in shrubland area over the past 30 years due to the expansion of shifting cultivation. The study also projected a 70% decrease in forest area and a 20% decrease in shrubland by 2050, which would be replaced by increased pastureland and urban expansion.

2. Methodology

Technically the method of applying the methodology, as demonstrate in Figure 1 below, was used as a flowchart model to measure the relationship between multiple dependent variable and independent variables by applying approved stepwise multiple regression analysis. This approach aims to determine the relationship between the variables and their effect on forest landscape coverage area in the study area. The Quantitative measurement models determine the regression coefficient between variables to estimate the validity/ suitability of the proposed model. If the model is deemed suitable, then the relationship between the proposed variables is reasonable. After consulting prior research on this topic, we applied a specific theoretical measurement model to identify elements that influencing forest landscape coverage area. This required collecting necessary data from several sources. After the treatment and processing, the data was converted into special maps. The SPSS program was applied to analyze the data for evaluating and correcting. We depended on the results of the study to clarify the relationship between the variables under study.

2.1. Methodology Used

This study depended on the quantitative analytical approach for measuring and analyzing the processes of forest land use change due to human and non-human (climatic) factors. The selection of the approach was based on its ability to establish the correlations between quantitative variables and illustrate the causal relationships between them by applying statistical analysis tools.

2.2. Theoretical Measurement Modelling

The theoretical model for detecting changes in the Zawita forest landscape due to human and non-human factors was developed based on the following hypothesis:

The independent variable (X_1 , X_2 , and X_3), representing construction development, shifting cultivation, and forest fires from 2003 to 2024, have direct and significant positive effects on the Zawita forest landscape. Figure 1 below illustrates the theoretical measurement model of the impact of human factors on the landscape.

The independent variables (X_4 , X_5 , X_6) represent random non-human factors in the Zawita forest landscape during the period from 2003 to 2024 and have a direct and significant positive effect on the Zawita forest landscape. Figure 1 below illustrates the theoretical measurement model of the impact of non-human factors on the landscape, representing forest land (Y_1). Figure 1 below illustrates the theoretical measurement model of the impact of non-human factors on the landscape.

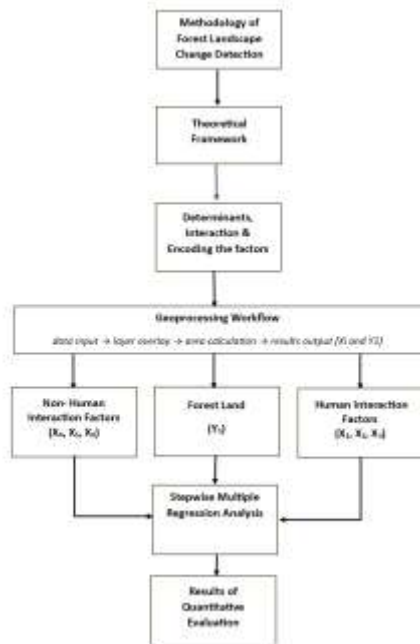


Figure: (1) Flowchart measurement model for Zawita landscape change in Duhok province, Kurdistan Region of Iraq.

Source: Prepared by the researchers.

The following are key hypotheses in the theoretical measurement model for the impacts of human and non-human factors:

- The relationship between the observable variables (X_1 , X_2 , and X_3) and the forest landscape, as represented by the dependent variable (Y_1), was tested using stepwise multiple regression analysis. This is a widely used statistical technique for evaluating model accuracy.
- The relationship between the observable variables (X_4 , X_5 , and X_6) and the forest landscape, as represented by the dependent variable (Y_1), was tested using stepwise multiple regression analysis. This is a widely used statistical technique for evaluating model accuracy.
- All independent variables (X_1 , X_2 , X_3 , X_4 , X_5 , and X_6) were observed to support the

hypotheses in the analysis. These hypotheses represent human and non-human (climatic) factors which were utilized randomly. These factors were shown to impact the dependent variable (Y_1), which is represented by forest landscape coverage area.

- This study can offer decision-makers, urban planners, and environmental official advantages by providing the tools to formulate important strategies for preserving forest landscape coverage areas.

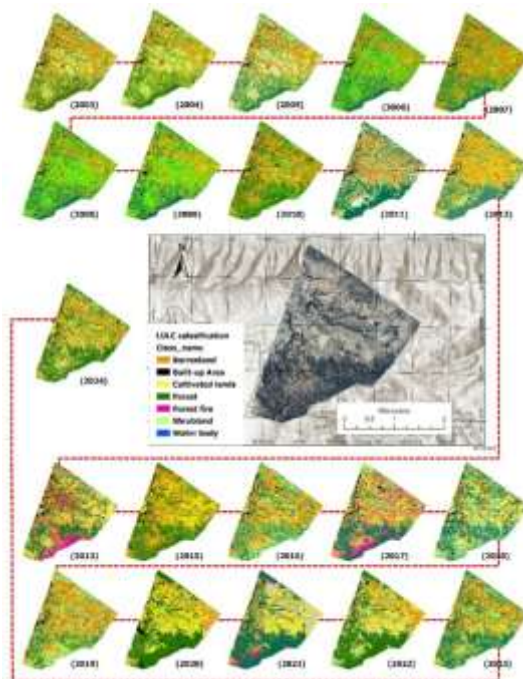
3. Materials and Methods

3.1. Area Study

The Zawita district area is located in the north of Duhok City in the Kurdistan Region,

Iraq. It is about 17 kilometers from the city center and extends between the coordinates $36^{\circ}55' - 37^{\circ}10' N$ and $43^{\circ}00' - 43^{\circ}20' E$. The area is characterized by mountainous terrain with elevations ranging from 700 to 1,500 meters intersected by seasonal valleys. The area has a semi-arid Mediterranean climate with hot, dry summers and cold, rainy winters, and annual rainfall ranging from 600 to 900 mm. Natural forests, especially Oak Forests of various species and Pine Forest, cover most of northern Iraq. Other plant species, such as Pistacia and juniper, are also present, giving the area environmental importance as a carbon sequestration and supporter of biodiversity. In our study area, pine trees (*Pinus brutia*) dominate the forest. Local residents utilize the forest land for rainfed agriculture (wheat and barley) and grazing, depending on forest products such as

firewood and charcoal. Additionally, Zawita is a popular tourist destination due to its mountains, waterfalls, and forests. However, the region faces increasing environmental challenges, including unregulated utilization, fires caused by natural factors and human interaction, overgrazing, and rapid urban expansion in recent years. These interaction practices have contributed to the deterioration of parts of the forest, increasing the risk of soil erosion, carbon emissions, and changes in forest landscape areas. Zawita was selected as a study area because it exemplifies the impact of human activities on mountain forests in northern Iraq. The area is also important for environmental, economic, and tourism reasons. Additionally, reliable field data and satellite imagery are available to help achieve the research objectives.



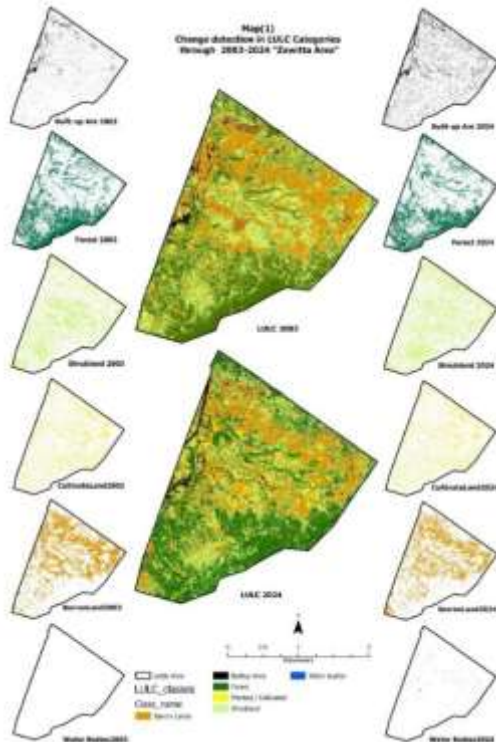
The Map (1) illustrates research time line study area including uncontrolled utilization area (human and non-human factors) in Zawita district.

3.2. Data Analysis:

- Remote sensing was used to prepare the required maps of the research area, represented by Zawita pine forest landscape.
- Using SPSS program, a stepwise multiple regression model was implemented. The independent variable (X_1, X_2, X_3), which represents the construction development, shifting cultivation and forest fire during (2003- 2024), on impact of human factors on the landscape. Meanwhile the independent variables (X_4, X_5, X_6) representing random non-human factors on Zawita forest landscape during (2003- 2024), were used to examine the impact of human factors on the landscape.
- A significant test was conducted for the proposed model. Through (F, T) tests, the validity of the model was determined through the (R^2) coefficient.

3.3. Sample construction:

The research area of forest land was identified through a field visit to the Zawita district. Using Land Sat 7 ETM+ (Path: 170, Row: 34), and Land Sat 8 OLI satellite images (Path: 170, Row: 34), the necessary map of the research area was prepared and the samples were determined in the same period date for all years. This map included areas of random utilization in the Zawita forest, as well as human factors such as developed land, shifting cultivation, and forest fires (X_1, X_2 , and X_3). Non-human factors included barren land, water bodies, and shrublands (X_4, X_5 , and X_6) (see Map 1). Based on this, the independent variables were selected to represent random human and non-human pressures on the forest landscape, respectively. The dependent variables (Y_1) represent Zawita's forest landscape, as shown in Figure 1 and Map 1.



The Map (2) illustrates research study area including uncontrolled utilization area (human and non-human factors) in Zawita district.

3.4. Data Collection and Variable Extraction:

Data were collected for the dependent variables (Y_1), representing the area of Zawira forest land, and the six independent variables (X_1 , X_2 and X_6), representing the area of developed land, shifting cultivation, forest fires, barren land, water body, shrublands, respectively.

Satellite imagery was used to extract variables for identify and determine the areas of both dependent and independent variables during the period 2003–2024, as follows:

1. Forest area of Zawita district (Y_1): The dependent variable represents the area of forest land.
2. Developed land (X_1): The independent variable represents the area of

3. Shifting cultivation (X_2): This variable represents the area of randomly utilized cultivation in Zawita forest landscape.
4. Forest fires (X_3): The independent variable represents the area forest fires in Zawita forest landscape.
5. Barren land (X_4): The independent variable represents the area changed to barren land in Zawita forest landscape.
6. Water body (X_5): The independent variable represents the area of water body in Zawita forest landscape.
7. Shrublands (X_6): The independent variable represents the area of shrubs in Zawita forest landscape.

4. Results

The results of the analysis of stepwise multiple regression through the general description of the input data and variables used in the research as follow:

- Number of observations (21).
- Dependent variable = Forest landscape (Y_1).
- The independent variables studied in the research were six (6) variables; variable (X_5), represented by Water Body, was excluded

during the statistical analysis using the stepwise regression program, which performs a step-by-step comparison among all variables and then excludes the variable with zero effect. Thus, the remaining five independent variables were retained as follows:

X_1 = Developed Land, X_2 = Shifting Cultivation, X_3 = Forest Fires, X_4 = Barren Land and X_6 = (additional variable—as defined in your research).

A stepwise multiple regression analysis was conducted with entry and removal criteria set at $\alpha = 0.15$. The final model retained three predictors: X_2 , X_3 , and X_4 .

Table 1: Estimated Coefficients, S- Error, T- Value, P-Value of X_2 , X_3 and X_4

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	65.65	7.71	8.52	0.000	
X_2	-1.285	0.259	-4.96	0.000	1.24
X_3	-0.916	0.284	-3.22	0.005	1.06
X_4	-0.880	0.209	-4.20	0.001	1.21

All retained predictors were statistically significant at the 0.05 level. The coefficients of X_2 , X_3 , and X_4 were negative, indicating inverse relationships with Y_1 . Variance Inflation Factor (VIF) values ranged between 1.06 and 1.24.

Table 2: Model Summary for X_2 , X_3 and X_4

S	R-sq	R-sq(adj)	R-sq(pred)
5.82855	72.55%	67.70%	55.39%

Table 3: Analysis of Variance (ANOVA) for X_2 , X_3 and X_4

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	1526.2	508.75	14.98	0.000
X_2	1	834.6	834.55	24.57	0.000
X_3	1	352.3	352.28	10.37	0.005
X_4	1	599.9	599.86	17.66	0.001

Error	17	577.5	33.97		
Total	20	2103.8			

The overall regression model was statistically significant ($F = 14.98, p < 0.001$).

Sequential sums of squares indicated that X_2 contributed the largest portion of explained variance (Adj SS = 834.6), followed by X_4 (Adj SS = 599.9) and X_3 (Adj SS = 352.3).

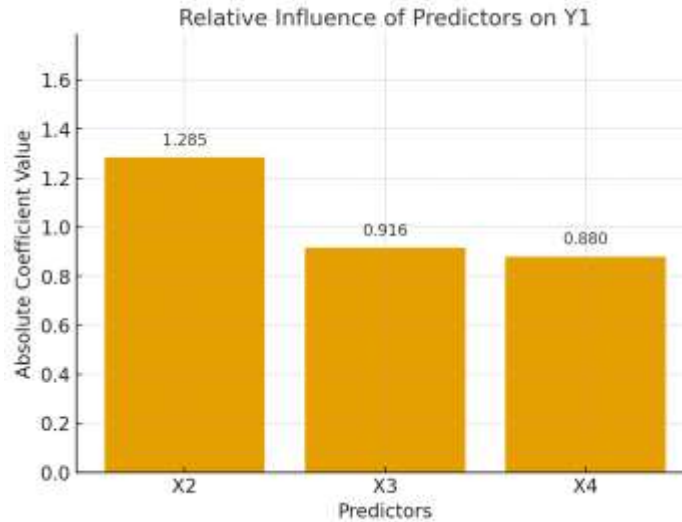


Figure (2) shows influence of the independent on the dependent based on the coefficients: X_2 is (largest by X_3 and then X_4 , and the differences between them are close.

the strength of the three selected variables (X_2, X_3, X_4) variable Y_1 , and regression the most influential coefficient), followed

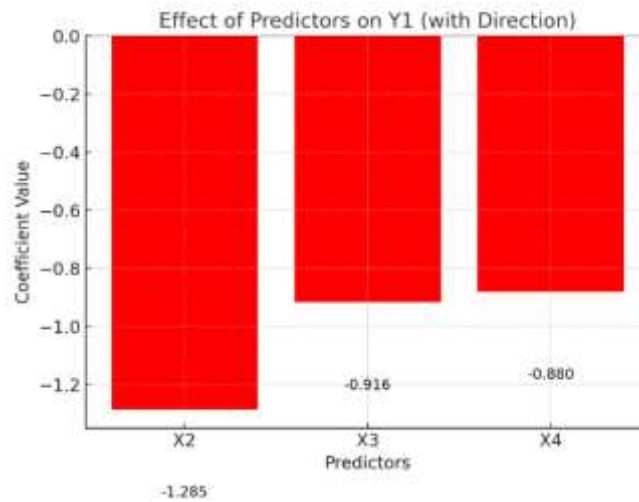


Figure: (3) shows independent on Y_1 : All coefficients are meaning that

the effect of the variables $X_2, X_3,$ and X_4 negative (in red), increasing these

variables leads to a decrease in the value of Y_1 , X_2 has the strongest effect (-1.285), followed by X_3 (-0.916), and then X_4 (-0.880). The black horizontal line represents zero, and all the bars below it confirms the negative direction of the relationship.

5. Discussions

The results interpretation of the stepwise multiple regression analysis, as shown in the Tables 1, 2 and 3 Figures 2 and 3, showed a high ability to explain the changes in the dependent variable representing the reduction in forest landscape coverage area (Y_1). From the final model three main variables were retained: (X_2) which is shifting cultivation, (X_3) represent forest fires, and (X_4) is barren land expansion. Variables X_1 and X_6 were excluded due to lack of statistical significance. This efficiency reflection of the stepwise multiple regression in constructing a purposeful model that focuses on influential variables while avoiding the inclusion of irrelevant values. The model showed high statistical significance of ($F = 14.98$, $p = 0.0004$) and explained approximately 72.55% of the total variance through Y_1 ($R^2 = 67.70\%$). The models also maintained good explanatory power after the correction for the number of variables (adjusted $R^2 = 0.6656$). The relatively high expected R^2 (55.39%) and the standard error of the estimate ($S = 5.83$) further support the model's stability and predictive power. The estimated regression equation is as follows:

$$Y_1 = 65.65 - 1.285 X_2 - 0.916 X_3 - 0.880 X_4$$

Statistically the models indicate a significant negative effect across all retained variables ($p < 0.05$). The study results suggest that increasing the values of these variables lead to a consistent decrease in the dependent variable which is forest landscape coverage area. Furthermore, the variance inflation coefficient (VIF) values close to one indicate an absence of multicollinearity, thus

supporting the reliability of the coefficients and the accuracy of the inferred conclusions. While at the individual effects, shifting cultivation (X_2) was shown to have the greatest impact on forest landscape coverage area reduction, with the highest regression coefficient ($\beta = -1.285$, $p = 0.0001$). This showed that a one-unit increase in this variable would reduce Y_1 by approximately 1.29 units, when assuming all other factors remain constant. The reflect of the role of shifting cultivation in weakening forests capacity for natural regeneration and reducing their ecological structure through recurring forest fires and forest harvesting patterns. The study findings align with those of [24], who identified shifting cultivation as one of the most significant drivers of deforestation globally. This study adds an empirical dimension at the local level, illustrating the continued impact of shifting cultivation, despite additional stressors, such as forest fires and land degradation. The study results intersect with the proposals of [25] and [16], who linked agricultural patterns to forest fires, biomass loss, and carbon emissions. In addition, this study indicates the direct structural impact of shifting cultivation on forest landscape coverage area, adding an environmental dimension to complement the prevalent climatic dimension in previous studies.

Regarding forest fires, we observed that the independent variable (X_3) had a statistically significant negative impact ($\beta = -0.916$, $p = 0.005$). These results suggest that forest fires are not only a consequence of forest degradation, but also a direct cause of forest landscape coverage area loss in the study area. This finding aligns with [2] who

classified forest fires as a significant global factor contributing to forest landscape cover loss, particularly in areas where they coincide with shifting cultivation. This study provides quantitative evidence of the local-level impact of forest fires, thereby supporting large-scale global studies. Furthermore, [26] results support this interpretation, observing that forest fires are the fastest growing and most rapid driver of global forest landscape coverage area loss, particularly in tropical regions. Although the previous studies have attributed the escalation to the interaction between human practices and climate change, these results demonstrate that forest fires have significant explanatory power even without of direct climate factors. This confirms the role of forest management in amplifying the local impact of forest fires.

The increasing of barren lands (X_4) statistically observed a negative significant effect on Y_1 ($\beta = -0.880$, $p = 0.001$). This increase an important analytical question: Is barren land merely a consequence of deforestation, or is it an independent causal factor that accelerates ongoing degradation? The finding of this study suggest that the increasing of barren land areas does not represent the final stage of degradation, but rather accelerates the loss of forest landscape coverage area, as demonstrated by the risk factor. These results align with [27], who considered the transformation of forests into barren lands an advanced, nearly irreversible stage of ecosystem degradation, often fueled by recurring forest fires and poor land use. Furthermore, [25] support the interpretation of this study by linking biomass loss and soil degradation to the impediment of tree coverage area restoration, thus transforming degraded land into a sustainable base for deforestation. Unlike many studies that treated barren land as a dependent variable, this study's inclusion of barren land as an

independent variable enhances the depth of the statistical model used.

The analysis of the three independent factors showed that forest fires, shifting cultivation, and increases in barren lands do not act in isolation manner. Rather, they constitute an interactive system comprising climatic and human interaction factors. While many global studies confirmed the observed role of forest fires ([2]; [26]), the results of this study emphasize that forest fires have an amplified impact when combined with unsustainable shifting cultivation patterns and pre-existing land degradation. Similarly, while [24] analyses showed the dominance of shifting cultivation as a primary driver of deforestation, this study illustrates that shifting cultivation maintains an independent and measurable impact even in the presence of other pressures. Barren lands, on the other hand, have a cumulative long-term effect on these interactions, a dimension not reflected in global models. The scientific value of this study lies in its quantitative ability to differentiate the roles of various human interaction factors rather than merely providing a general description. The results demonstrate that forest fires and shifting cultivation practices are immediate drivers of forest landscape loss and structural factors that shape the long-term trajectory of forest landscape coverage area, especially when interacting with land degradation. This study confirms that there is a need for integrated forest management policies that go beyond immediate, sector-specific responses and depend on comprehensive approaches that address forest fires, unsustainable agricultural practices, and the rehabilitation of degraded lands simultaneously.

6. Conclusion

The findings of the stepwise multiple regression analysis definitively show that

shifting cultivation (X₁), forest fires (X₂), and the expansion of barren lands (X₃) are the primary factors contributing to the reduction in forest landscape coverage (Y) in the Zawita study area of the Duhok district. Furthermore, the expected coefficient of determination (R²) showed suitable predictive power, which lead to enhance the model's potential application in future of forest landscape management and environmental policy planning.

This study emphasizes the importance of involving programs for rehabilitating degraded lands in long-term forest landscape management strategies. From a wider perspective, the findings of this study confirm the importance of basing forest policy priorities on quantitative evidence and the necessity of adopting and implementing integrated approaches that include sustainable land use planning, forest fire risk management, and the development of environmentally friendly agricultural policies locally. These approaches are fundamental for preserving forest landscape coverage area and ensuring the area's long-term sustainability. The results emphasize that shifting cultivation, forest fires, and barren lands are key factors in the reduction of forest landscape coverage area in Zawita Forest in the Duhok district. This finding is aligned with the recent global trends of accelerating rates and their effects on forest landscape cover loss in recent years but offers specific insights for our region. Shifting cultivation reflects changes in land-use patterns in barren areas. These patterns interact with a variety of agricultural practices, contributing to ongoing forest landscape coverage loss. The increase in barren lands reflects the continuous pressure on the land resulting from deforestation and soil degradation. These findings underscore the urgent need for sustainable land use

planning, effective forest fire risk management, and environmentally friendly agricultural policies to preserve and sustainably maintain the forest landscape coverage area in the study area district.

These results indicate the necessity of reviewing current forest policies and promoting sustainable land use practices to reduce the pressure on forest resources. Furthermore, forest fires were identified as an independent and significant impact on forest landscape reduction, aligning with recent global trends showing an increase in forest fire frequency and their growing role in forest landscape coverage area loss. The study results indicate that forest fires in the study area are not random occurrences, but rather major factors interacting with other human practices, particularly shifting cultivation, to cause long-term forest landscape coverage loss.

The increase in barren lands reflects cumulative environmental pressures resulting from deforestation and soil degradation. Studies have shown that barren lands are not only a result of a loss in forest landscape area, but also a factor that contributes to continued degradation and limited opportunities for forest restoration.

Depending on the finding of this study, for the next contribution in this aspect we suggest new investigation, such as using higher-resolution imagery, incorporating socioeconomic surveys to understand the drivers of shifting cultivation, or using predictive modeling (like the ARIMA model mentioned in the intro) to forecast future landscape changes under different policy scenarios.

7. References

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