Original Article

Comparing Spatial Determinants of Forest Landscape Degradation based on Experts' Perceptions and GIS Analysis: The Case of Kilimanjaro World Heritage Site, Tanzania

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The awareness of spatial determinants of forest degradation is crucial to adequately equip human capacity and inform decision-makers when implementing institutional instruments, including the World Heritage Convention (WHC) and other strategic policies for forest protection. Therefore, the study aimed to investigate and contrast experts' perceptions and Geographic Information Systems (GIS) outcomes on spatial determinants of forest landscape degradation in the Kilimanjaro World Heritage Site (WHS), Tanzania, to create awareness and support strategic policies for forest landscape protection and natural heritage sustainability. In doing so, Matrix questionnaire was designed to generate data and deployed a descriptive analysis of response to summarise the questionnaires' data characteristics. The findings were used to contrast the GIS outcomes on spatial determinants of forest degradation. The key findings showed that most experts perceived distances to tourist routes, campsites, picnics, historical sites, and degrees of slope as positively associated with forest degradation but with contradicted opinions on the level of elevation. Also, key findings showed contradictions between the GIS outcome and experts' perceptions of the degrees of slope. However, the findings on distances to campsites, tourist routes, and picnics showed that experts' opinions are in line with the GIS outcomes as both indicated positive associations. The awareness provided in this study is crucial for experts and other decision-makers in implementing WHC and other strategic policies for forest protection in the Kilimanjaro WHS and other natural WHS found in the Global South in general and Sub-Saharan Africa in particular.

INTRODUCTION

In the Global South, tropical forest degradation poses challenges to forest protection and hinders the effective implementation of institutional instruments such as the World Heritage Convention (WHC) and other strategic policies for improving the sustainability of forests as a natural heritage (Lu et al., 2020; Sandström et al., 2020; Sahide et al., 2020; Allan et al., 2017; Hua, 2007; URT, 1998a; URT, 1998b; URT, 1997; Enoguanbhor et al., 2023a). Forest sustainability, in this context, can be seen as a situation that allows the use of forest resources by current and future generations without degrading the forest ecosystems or reducing the services/benefits provided by the forest as a natural heritage.

The Kilimanjaro World Heritage Site (WHS), Tanzania, is a National Park, relatively located in northeast Tanzania and was inscribed under criteria vii as a natural WHS in 1987 due to the outstanding universal value of the mountain as one of the world's largest volcanoes (UNESCO, 2021; IUCN, 2020). The montane forest, which is the primary forest that serves as the buffer zone, is another outstanding universal value and integrity feature of the site that was included to the site in 2005 to protect the forest from degradation due to human activities (UNESCO, 2021; IUCN, 2020). In the Kilimanjaro WHS, anthropogenic factors such as tourism activities, agricultural activities, wildfire, insufficient land availability in local communities, poverty in local communities, illegal logging, charcoal production, Bees keeping and honey harvesting, as well as natural factors such as topography are generally associated to forest degradation (IUCN, 2020; Enoguanbhor et al., 2022a; Enoguanbhor et al., 2023b). Such determinants/drivers may pose threats to the protection of the montane forest that serves not just only as a buffer zone of the WHS but also a habitat for various wildlife species (UNESCO, 2021; IUCN, 2020).

To support the effective implementation of WHC and other strategic policies for forest protection in general and those in WHS in particular, spatial determinants, which are the anthropogenic and natural proximate causes that contribute to the explanation of the geographical location of land and environmental change, are crucial to be captured, understood, and addressed (Meyfroidt, 2016; Abiodun et al., 2017; Adedire et al., 2016). A previous study conducted by Enoguanbhor et al. (2022a) deployed Geographic Information systems (GIS) to capture spatial determinants of forest degradation in the Kilimanjaro WHS, including topographic elevation and slope as natural factors and tourism activities (tourist routes, campsites, picnics, historical sites, and attraction area) as anthropogenic factors but the level of awareness among experts is unknown. Experts' awareness of spatial determinants of forest degradation is crucial to adequately equip human capacity and inform decision-makers when implementing WHC and other strategic policies for forest protection. In the Kilimanjaro WHS and other WHS in Sub-Saharan Africa, no previous study was conducted by contrasting experts' perceptions and GIS outcomes on spatial determinants of forest degradation.

Our current study, therefore, aims to investigate and contrast experts' perceptions and GIS outcomes on spatial determinants of forest landscape degradation to create awareness and support strategic policies for forest landscape protection and natural heritage sustainability. The study focuses on two objectives including;

- To analyse spatial determinants of forest landscape degradation based on experts' surveys

- To contrast experts' perceptions and GIS outcomes on spatial determinants of forest landscape degradation.

MATERIALS AND METHODS

Expert surveys was conducted using questionnaires from 21 February to 8 April 2022. A matrix questionnaire was designed (Babbie, 2013; Secor, 2010), guided by the current study objectives and spatial determinant variables captured by Enoguanbhor et al. (2022a). The variables included level of elevation, degrees of slope, distance to tourist routes, distance to campsites, distance to picnics, distance to historical sites, and distance to attraction areas. Questionnaires were distributed to experts purposively selected for the study. The study defined various government departments associated with forest protection to select experts. The departments included the Tanzania Forest Service (TFS), the United Nations Educational, Scientific and Cultural Organization (UNESCO), Sokoine University of Agriculture Training Forest (SUATF), and Kilimanjaro National Park (KINAPA). As a result, 46 questionnaires were distributed to experts out of which 26 were retrieved.

The study utilised descriptive statistics for data analysis by summarising dataset characteristics through the calculations of the response frequencies of each variable (Bryman, 2016; Maxwell, 2013; Secor, 2010; Enoguanbhor et al., 2021). The response frequencies of each variable was utilised to identify experts' perceptions of positive, negative, or unknown associations of spatial determinants of forest degradation. On the other hand, the study contrasted the experts' perceptions and GIS outcomes on spatial determinants of forest degradation using the calculated highest frequencies from experts' perceptions and coefficients of the multiple linear regression from GIS results as positive or negative associations. The positive association indicates that such identified variables contribute to forest degradation, and the negative association indicates that such variables do not contribute to forest degradation. The GIS outcomes on spatial determinants of forest degradation were analysed by Enoguanbhor et al. (2022a) using Euclidean distance measurement and linear regression modelling (Yenisetty & Bahadure, 2021; Fotang et al., 2021; Visser & Jones III, 2010; Fotang et al., 2021; Enoguanbhor et al., 2022b). The GIS data was generated through a supervised classification of remotely sensed satellite images from Landsat 7 for 2020 using the maximum likelihood algorithm (Vijayalakshmi et al., 2021; Campbell & Wynne, 2011; Enoguanbhor et al., 2019; Lu et al., 2011; Tso & Mather, 2009; USGS, 2021; Enoguanbhor, 2021). The final contraction was based on where the highest frequency of the experts' perceptions coincides with or contradicts the coefficient of the GIS outcomes positively or negatively (Enoguanbhor, et al., 2023c).

RESULTS

The results in showed spatial determinants of forest landscape degradation based on experts' perceptions. Regarding the level of elevation, experts gave contradicting opinions on positive and negative associations with forest degradation. While 42.3% of experts agreed that the level of elevation is positively associated with forest degradation, 42.3% agreed with a negative association, and 15.4% of experts do not know the association. Regarding degrees of slope, 50.0% of experts perceived a positive association, 34.6% agreed with a negative association, and 15.4% were not sure of the association. Distance to tourist routes as a human (tourism) determinant was perceived as a positive association with forest degradation, as 61.5% of experts agreed to this fact. While 23.1% agreed with a negative association, 15.4% of experts are not sure of the

association. Regarding distance to campsites, most experts (69.2%) perceived such tourism activities as having a positive association with forest degradation. While 15.4% of experts opined that the association is negative, the remaining 15.4% are not sure of the association. Most experts (73.1%, 57.7%, and 69.2%) believe that distances to picnics, historical sites, and attraction areas, respectively, are positively associated with forest degradation. Others (11.5%, 19.2%, and 11.5%) perceived negative associations for distances to picnics, historical sites, and attraction areas, respectively. While 15.4%, 23.1%, and 15.4% of experts are not sure of how distances to picnics, historical sites, and attraction areas, respectively are associated with forest degradation in the Kilimanjaro WHS.

Table 1 and *Figure 1* show the results and spatial patterns of the GIS multiple linear regression for spatial determinants of forest landscape degradation in the Kilimanjaro WHS extracted from Enoguanbhor et al. (2022a). While distances to tourist routes, campsites, picnics, and the level of elevation are positively associated with forest degradation, the degree of slope is negatively associated. Distances to the historical site and attraction area were not calculated at this level due to the problem of multicollinearity as indicated on the initial VIF (Variance Inflation Factor) 18.106 and 22.116 values, respectively, which are above 10 values. The final VIF shows that the calculated values are free from such a problem of multicollinearity, considering their values are less than 10.
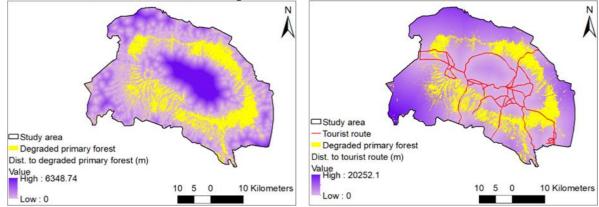
Table 1: Spatial determinants of the degraded primary forest of the Kilimanjaro WHS

	Independent variables	Multiple linear regression				
		Coef.	P-value	Std. error	Initial VIF	Final VIF
1	Dist. to tourist routes	0.007	0.151	0.005	6.818	5.955
2	Dist. to campsites	0.154	0.000***	0.005	6.171	5.339
3	Dist. to picnics	0.002	0.684	0.004	3.765	3.457
4	Dist. to the historical site	-	-	-	18.106	-
5	Dist. to attraction area	-	-	-	22.116	-
6	Level of elevation	1.109	0.000***	0.013	3.260	1.972
7	Degrees of slope	-0.182	0.000***	0.012	1.130	1.122

Residual standard error = 796.1 on 9994 degrees of freedom (multiple linear regression)
Multiple R-squared = 0.414, Adjusted R-squared = 0.4139 (multiple linear regression)
*Over all P-value = 0.000*** (multiple linear regression)*

Source: Extracted from Enoguanbhor et al. (2022a).

Figure 2: Maps showing Euclidean distance to the degraded primary forest and the spatial relationship with Euclidean distances to tourist routes, campsites, picnics, the historical site, the attraction area, and elevation, and slope

Source: Enoguanbhor et al. (2022a)

We contrasted experts' perceptions and GIS outcomes on spatial determinants of forest landscape degradation (Table 2). Regarding elevation, both GIS outcome and experts' perceptions coincide on positive association but contradict on negative association. The degrees of slope showed that both GIS outcome and experts'
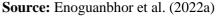
perception contradict as the highest frequency of experts' opinions is positive and the coefficient of GIS outcome is negative. Distances to campsites, tourist routes, and picnics showed that both GIS outcome and experts' perceptions coincide as such variables indicated positive associations.

Table 2: Contrasted Experts' perceptions and GIS outcomes on spatial determinants of forest degradation in the Kilimanjaro WHS

	Spatial determinants	Coincide	Contradict
1	Dist. to tourist routes	Yes	No
2	Dist. to campsites	Yes	No
3	Dist. to picnics	Yes	No
4	Dist. to the historical site	-	-
5	Dist. to attraction area	-	-
6	Level of elevation	Yes	Yes
7	Degrees of slope	No	Yes

DISCUSSIONS

Our current study investigated and contrasted experts' perceptions and GIS outcomes on spatial determinants of forest landscape degradation to create awareness and support strategic policies for forest landscape protection and natural heritage sustainability.

Our findings showed spatial determinants of forest landscape degradation based on experts' perceptions. Most experts opined that distances to tourist routes, campsites, picnics, historical sites, and degrees of slope are positively associated with forest degradation but with contradictions on elevation as 42.3% perceived positive and negative associations. These findings indicate that the closer the tourism activities and the lower the degrees of slope, the higher the likelihood of forest degradation. The findings on tourist routes, campsites, picnics, and historical sites support those of Pongpattananurak (2018), who reported that tourism activities have an impact on forest degradation in the overlapping area between the Thai Samakkhi and Thap Lan National Park sub-district of Thailand. The findings on the degrees of slope and the positive perception of elevation support the reports by Freitas et al. (2010) and Htun et al. (2013) that a low level of elevation and degrees of slope are associated with forest degradation in the Plateau of Ibiuna, near Sao Paulo, Brazil, and the Popa Mountain Park, Central Myanmar, respectively. However, the negative perception of elevation does not support those previous studies.

The contrasted experts' perceptions and GIS outcomes on spatial determinants of forest landscape degradation showed that (for elevation), both GIS outcome and experts' perception coincide a positive association but contradict a negative association. This indicates the number of experts who are not aware of the case in the Kilimanjaro WHS is large, considering the additional experts who chose unknown associations to those who perceived negative associations. The degrees of slope showed that both GIS outcome and experts' perception contradict as the highest frequency of experts' opinions is positive and the coefficient of the GIS outcome is negative. Also, this shows a lack of awareness of the situation in the Kilimanjaro WHS. Our findings on the distances to campsites, tourist routes, and picnics showed that both GIS outcomes and experts' perceptions coincide, as both indicated positive associations. This indicates that the majority of experts are aware of the situation in the Kilimanjaro WHS.

Implications of the Findings

An important implication of our study can be deduced from awareness creation, especially on spatial determinants that showed experts' opinions contradict the GIS findings for Kilimanjaro WHS. For example, the contradicting perceptions of the experts with GIS on topographic elevation and degrees of slope are crucial for experts to be aware of when identifying, explaining, and resolving various natural proximate causes of forest degradation. The positive implication of our study can also be deduced from experts' perceptions that coincide with the GIS findings. For example, the findings on distances to tourist routes, campsites, and picnics associated with forest degradation showed that many experts are aware of the situation in the Kilimanjaro WHS. Additionally,

other experts who did not contradict GIS findings on the level of elevation and degrees of slope show that there are experts with a high level of awareness about such spatial determinants. The awareness provided in this study is crucial for experts and other decision-makers in implementing WHC and other strategic policies for forest protection. This will help to identify and put under control the natural and anthropogenic proximate causes of forest degradation in the Kilimanjaro WHS and other natural WHS found in the Global South in general and Sub-Saharan Africa in particular. Our study, therefore, contributes to World Heritage Studies and Management for improving the sustainability of forests as a natural heritage.

CONCLUSIONS

The study investigated and contrasted experts' perceptions and GIS outcomes on spatial determinants of forest landscape degradation to create awareness and support strategic policies for forest landscape protection and natural heritage sustainability. Our findings showed that experts perceived distances to tourist routes, campsites, picnics, historical sites, and degrees of slope as positively associated with forest degradation but with contradictions among the experts on the level of elevation. Also, findings showed that both GIS outcome and experts' perception of the level of elevation coincide with a positive association but contradict a negative association with forest degradation. Additionally, the degrees of slope showed a contradiction between GIS outcomes and experts' perceptions, as the highest frequency of experts' opinions is positive, and the coefficient of the GIS outcome is negative. Furthermore, distances to campsites, tourist routes, and picnics showed that both GIS outcomes and experts' perceptions coincide as both indicated positive associations of such variables to forest degradation.

The awareness provided in this study is crucial for experts and other decision-makers in implementing WHC and other strategic policies for forest protection. This will help to identify and put under control the natural and anthropogenic

proximate causes of forest degradation in the Kilimanjaro WHS and other natural WHS found in the Global South in general and Sub-Saharan Africa in particular. Future research should expand the knowledge on geographical locational explanations of forest degradation by integrating other variables, including illegal logging, agricultural activities, charcoal kilns, forest villages, and other natural and anthropogenic proximate causes of forest degradation.

Limitations and Recommendations

The limitations of our study can be linked to time constraints during the field research due to the government bureaucracy for research permit approval. Also, some experts were not available as respondents to questionnaires. The opinions of those experts that were not available could not be incorporated into the study. However, the 26 questionnaires retrieved from experts were sufficient, considering we did not deploy inferential statistics on experts' questionnaires.

Based on the findings of the current study study, the following are recommended. First, the opinions of experts should always be integrated into similar research and contrasted with other tools, such as GIS, to create awareness about the knowledge gap. Bridging the knowledge gap is crucial for experts and decision-makers to improve forest landscape protection and natural heritage sustainability. Second, the opinions of local residents, including those involved in forestry, agricultural, and charcoal activities should be incorporated into future research. Finally, future research should also incorporate other spatial variables such as illegal logging, agricultural activities, charcoal kilns, forest villages, and other natural and anthropogenic proximate causes of forest degradation to expand the knowledge on geographical locational explanations of forest degradation.

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the promotion of young female researchers - completion of a doctorate".

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