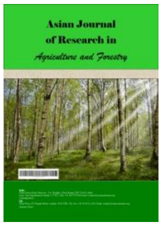

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Comparison of Logistic Regression and Geomod Approaches to Forest Change Modeling in the Period of 1988 – 2025

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Spatial modelling of land use change is a technique for understanding changes in terms of the location and amount. In this study, logistic regression and Geomod approaches were used for modelling forest change in Gorgan area in Northern Iran in the time period of 1988-2007. To do this, at first, remotely sensed imagery data of the years 1988, 1998 and 2007 were used to produce land use maps. Land use maps accuracy assessments were achieved using Error matrix method and then the maps were used to implement change detection process in two time periods of 1988-1998 and 1998-2007. Results indicated a reduction in forest areas during the mentioned time period. Next, the independent variables were extracted in order to land use change modeling. The Results of the models implementation showed the ability of both models for forest change modeling in this region. Also, the models were used to predict the future condition of forest area in the years

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2016 and 2025. The results revealed that the forest area would be associated with a reduction in the future. Comparison of the results of the models using kappa indices showed the successful implementation of both models for forest change modelling in this region. The results of this research reveal the need for appropriate applications of the proper plans to control land use change in order to preserve the environment and ecological balance of the area. Therefore, careful planning can reduce the land use change and its impacts in the future in this region.

Keywords: Land use change modeling; logistic regression; geomod approach; Gorgan area; Iran.

1. INTRODUCTION

Land use change is an important research subject in global environmental change and sustainable development [1]. Land use and land cover change due to human activities in a time sequence [2]. Human activities are altering the land at unprecedented rates, magnitudes and spatial scales [3]. Land use change can be characterized by a complex interaction of behavioural and structural factors associated with demand, technological capacity and social relations, which affect demand and environmental capacity as well as the nature of the environment in question. It has effects on aquatic ecosystems and biodiversity [4] and loss of habitat [5]. Floods and air pollution in large cities, as well as deforestation, urban growth, soil erosion and desertification, are all consequences of mismanaged planning without considering environmental impacts. Presently unplanned changes in land use have become a major problem. Most of the Land use changes occur without clear and logical planning, paying no attention to their environmental impacts [2]. Forest cover is an important natural resource which should be conserved on a priority basis for sustainable environmental management. Depletion of forest affects many ecological, social and economic consequences including the extinction of biotic communities leading to loss of biodiversity, soil erosion, global warming and loss in income to forest dwellers [6]. Environmental management and land use planning, therefore, need information about the dynamics of land use. Models can help to understand these dynamics and projects near future land use trajectories in order to target management decisions [7]. Then, land use and land cover change modeling have become an extremely common tool to understand and extrapolate land use change [8,5] and myriad different modeling techniques are now available [5]. Modeling land use change has attracted considerable attention because it could explain the mechanisms and causes of land use change, and help governments formulate relevant policies [1]. Land use change models are usually used to illustrate land use change and its relationship with driving forces. Even so, it is complicated to assess driving forces of land use change [9]. Spatially explicit modeling of Land use changes is an important technique for describing processes of change in quantitative terms and for testing our understanding of these processes [10]. Spatially-explicit models of land-use and land-cover change (LUCC) typically begin with a digital map of initial time and then simulate transitions in order to produce a prediction map for a subsequent time [11]. In this study, logistic regression model and Geomod approach were used to model forest change of Gorgan area in Northern Iran in the period of 1988-2025. These models are described as follows:

1.1 Logistic Regression

In the application of logistic regression, each “observation” is a grid cell. The dependent variable is a binary presence or absence event, where 1 = forest loss and 0 = other. The logistic function gives the probability of forest loss as a function of the explanatory variables [12]. Logistic regression is a statistical method to evaluate the relationship between a set of independent variables and a categorical binomial dependent variable. In logistic regression, the dependent variable must be binary in nature and can only take two values (0 and 1). As such, to test and describe the possible relationship between one or more continuous independent variables and the binary dependent variable, logistic regression is used with the assumption that the probability that the dependent variable takes the value of 1, follows the logistic curve and its value can be estimated with the following formula:

$$P(y = 1 | X) = \exp(SBX) / 1+\exp(SBX) \quad (1)$$

Where P is the probability of the dependent variable being 1, X is the independent variable and B is the estimated parameter. To line arise the above model and to remove the 0/1 boundaries for the original dependent variable, the following transformation are usually applied:

$$P' = \log_e (P/ (1+P)) \quad (2)$$

This transformation is referred to as the logit or logistic regression transformation. By performing the logit transformation on both sides of the above logit regression model, we obtain the standard linear regression model:

$$\log_e (P/(1+P)= b^0 + b^1 * x^1 + b^2 * x^3 + \ldots + b^k * x^k + \text{error term} \quad (3)$$

Logit transformation of the dichotomous data ensures that the dependent variable is continuous and the predicted probability is continuous within the range of 0-1. A logistic regression achieved on pixels of an image as above produces a layer containing real scores from zero to 1. In order to produce the final simulated map showing the changed areas, the modelled layer is ranked in ascending order and exactly the same number of pixels detected as a change in the real change map is selected from those having the highest scores [13]. Model validation was carried out by the Relative Operating Characteristic (ROC) and Pseudo-r^2. The ROC compares binary data over the whole range of predicted probabilities. It aggregates into a single index of agreement, the ability of the model to predict the probability of forest distribution at various locations on the landscape. That is, the ROC is a measure of the ability of the model to correctly specify a location [14]. This model has been used in many studies to model land use/cover change. Many researchers were used this model to model land use/cover change such as Schneider & Pontius [3] Pontius and Schneider [15], Mahiny & Turner [13] and Peterson, et al. [16].

1.2 Geomod

Geomod is a more recent and simpler model and was originally designed to simulate the loss of tropical forests and to estimate the resulting carbon dioxide emissions. This model uses the quantities specified by the user (instead of a transition matrix) and a suitability map to simulate the change of a single category using a linear relationship between beginnings and ending time amounts [17]. GEOMOD, a spatially explicit land use change model, identifies through a rigorous calibration/validation process those spatially distributed biophysical, and/or socio-economic variables that explain past and current development patterns, and projects them into the future assuming business as usual. It can be used to analyze any kind of LULC conversion, for example, forest to pasture or pasture to suburban residential development, if such changes can be detected through remote sensing [18]. The model predicts the location of land use change. The rate of change is derived by comparing the area of forest found in a map of land use at one point in time to that found in another map of the same area at a different point in time. A future rate of change can also be estimated from predicted population growth or economic activity, or a combination of the two [19]. Geomod uses spatially distributed data to simulate landscape dynamics in a geographical information system (GIS). There are two components to this model: the rate of land-use change and where the change will occur. To derive the rate of land-use change, an extrapolation of past rates is generally used, based on interpreted satellite imagery for two or more points in time for the area under study. To simulate where deforestation will occur, the model uses numerous spatial data layers of biophysical and socioeconomic factors (e.g., elevation, slope, soils, and distance from rivers, roads and already established settlements) to explain the pattern of deforestation. The Geomod model has an internal validation procedure—the kappa index for location, an index that measures the improvement by the model over what just a random selection would achieve [20,21,22]. Potential advantages of GEOMOD include its capability of spatial resolution at any scale for which data are available because it is raster-based (and thus gives deforestation estimates for any pixel or geographic scale requested within the analytic domain, for an entire region). Additionally, incorporation of the kappa for-location index allows evaluation of model performance versus chance [21,22]. Geomod is designed to predict a one-way change over time from exactly one category to exactly one other category [23,17] and it can evaluate the change in two land-use types at a time [24]. This model only needs one time moment to make an estimation based on expected time quantities, a suitability map and, optionally, a contiguity rule [17]. Geomod approach was used for modeling degraded forest area in many areas such as I Massachusetts (Schneider & Pontius, 2001), Costa Rica [25], India [26], Brazil [22] and Chile [27].

The study aims to use logistic regression and Geomod approaches for modelling forest change in Gorgan area in Northern Iran in the time period of 1988-2007. Therefore, land use change modeling was complemented using logistic regression modeling and Geomod techniques. After that, the results of the models were compared. In these models, changes in a forest area in the period of 1988 - 1998 and 1998-2007 and then future conditions modelling of forest area was predicted using these models for the years of 2016 and 2025. Modeling land use change makes it possible to control the land use change.

2. MATERIALS AND METHODS

2.1 The Study Area

The study area is located in Gorgan Area in Golestan province in Northern Iran (Fig.1). This area is Approximately 123265 ha and is located in the 54°12′ to 54°58′ longitude and 36°32′ to 37°02′ latitude. The region has mainly two parts; one part is flat (North of the region) and the other is mountainous (South of the region). The forest area of this region includes mountainous parts and contains forest areas of Tuskestan, Shastkalateh, Mohammadabad and Ziarat. The aim of choosing this region to study was the drastic land use changes especially in forest areas and the rapid rate of their changes in the last years. Also, some parts of the region are important for tourism which has brought about extensive construction and land use changes in this area. These factors have been influential in choosing this area for study.

2.2 Data

Nowadays, human activities have a great impact on spatial land cover patterns [28]; therefore the combination of human factors with biophysical factors is important in order to extract the patterns of land use changes. Accordingly, the socio-economic variables and biophysical variables were used to land use change modeling in the desired period. This study was conducted in the period of 1988 to 2025. Remote sensing data were used for the years of 1988, 1998 and 2007 to prepare land use maps. Then, change detection and modeling processes were performed in the two periods of 1988-1998 and 1998-2007. The results of the models were compared using Kappa indices. After that, the future condition of forest area was predicted using these models for the years of 2016 and 2025. Table 1 shows the characteristics of the image used in this study. Also, Digital Elevation Model (DEM), slope, aspect, distance to the main road, distance to the main river and distance to the village were extracted from the Map of Geographical organization by the scale of 1/25000.

2.3 Image Classification and Change Detection

The images were studied in terms of geometric and radiometric properties and then each image was classified into six categories using maximum likelihood classifier algorithm. Then, the accuracy assessment was performed using Error matrix method. The forest change detection was performed using Post-classification comparison method. Land use maps for 1988, 1998 and 2007 were prepared. Thus, change detection was performed in the two periods of 1988-1998 and 1998-2007.

2.4 Preparing Driving Forces Maps

Digital Elevation Model (DEM), slope, aspect, distance to the main road, distance to the main river and distance to the village were extracted from the Map of Geographical organization by scale of 1/25000. Land use maps were used to prepare some driver forces consisting of distance to agricultural lands, distance to range, distance to the forest edge and X, Y Location. Also, the satellite images were used to prepare NDVI and Fragmentation indices. These layers were prepared in the Idrisi kilimanjaro software. After that, autocorrelation between driving forces was investigated using Principle Component Analysis (PCA) and the covariance between them was calculated. Autocorrelation between the independent variables was determined by Calculating covariance between variables. The results indicated that the autocorrelation between these variables was low. Table 2 showed the variables were used to forest change modelling in this area.

Table 1. Satellite data used in the study

Path / Row	Acquisition data	Platform	Sensor
162/35	1988-09-05	Landsat	TM
163/34	1998-06-12	Landsat	TM
72/44	2007-10-15	IRS	LissIII

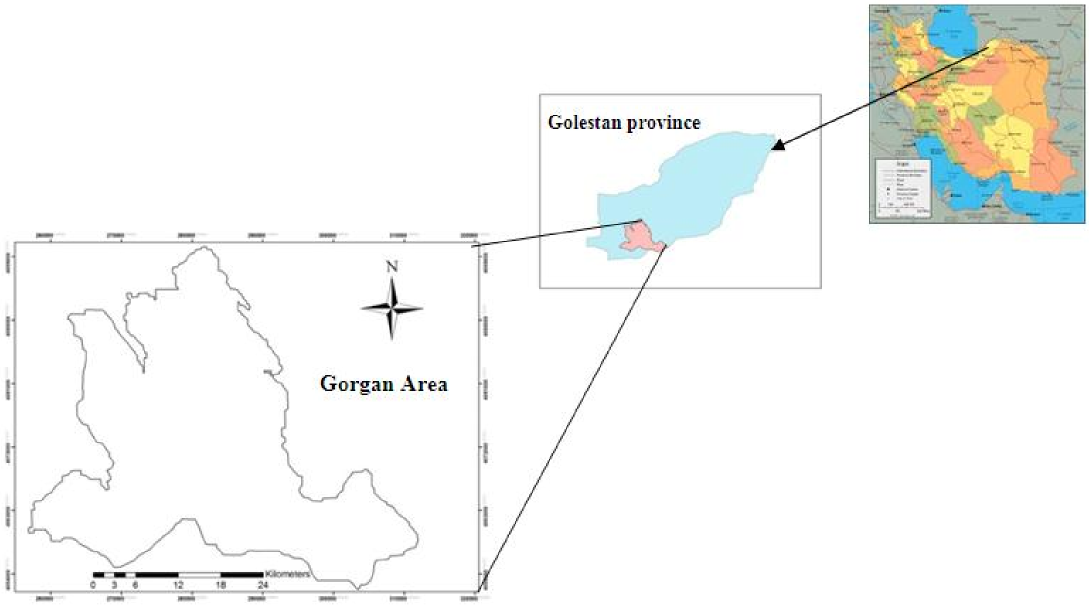

Fig. 1. The case study area

(Source : Googole images.,https://www.google.co.in/search?biw=1352&bih=619&tbm=isch&sa=1&ei=rghHXMWAL82m9QOx0Y7QCA&q=Gorgan+Area+in+Golestan+province+&oq=Gorgan+Area+in+Golestan+province+&gs_l=img.3...17046.17396..18254...0.0..0.184.184.0j1......0....1j2..gws-wiz-img.....0.00fiWgV0mWo)

2.5 Logistic Regression Model

After preparing variables for modelling process, Contract operation was achieved to autocorrelation effects reduce on modelling results using Idrisi Kilimanjaro software. Then, Logistic Regression model was performed for forest change modelling in the specified time period in the study area. Accuracy of models is an important issue in land use/land covers change studies. In this study, ROC index and Pseudo-R^2 were used to investigate the accuracy of the logistic regression model. The calculation of these indices was achieved by Idrisi kilimanjaro software when the model has been run. ROC is a quantitative index that is used for validation of land use/land cover change models [15]. This index is in the range of 0-1 and its value indicates the model's ability to correctly identify the location [14]. High values of ROC showed that the model has been implemented have had a good ability in land use changes modeling. Fig. 2 shows the steps to perform logistic regression model.

Table 2. The list of independent variables

Independent variable	Meaning	Nature of variable
X_1	Slope	continuous
X_2	Aspect	continuous
X_3	Elevation	continuous
X_4	Distances to main roads	continuous
X_5	Distances to agricultural lands	continuous
X_6	Distances to range	continuous
X_7	Distances to forest edge	continuous
X_8	NDVI	continuous
X_9	Fragmentation	continuous
X_{10}	X Location	continuous
X_{11}	Y Location	continuous

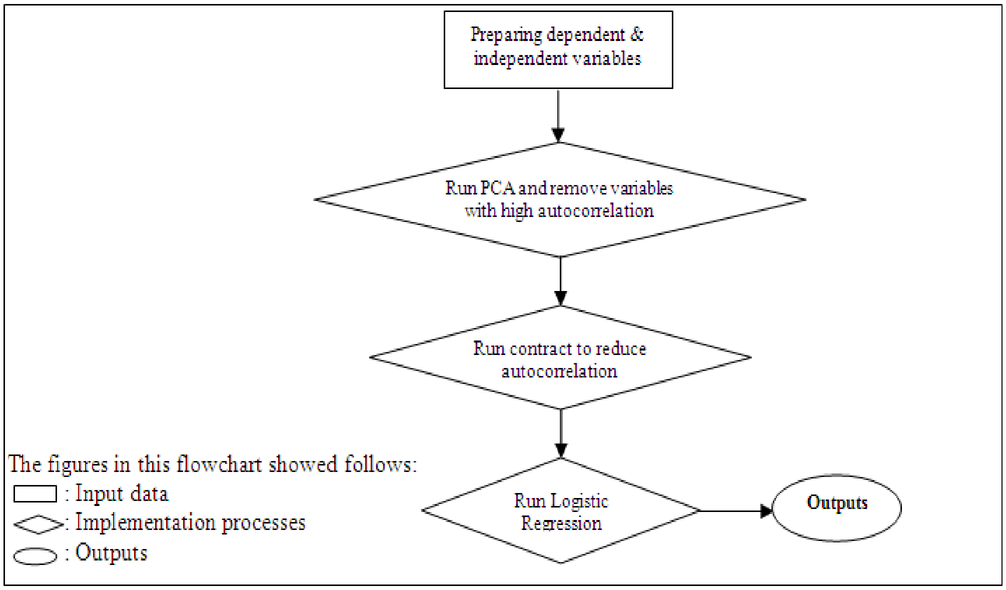

Fig. 2. The steps of logistic regression implementation

2.6 Geomod

Forest change modeling was implemented in two time periods of 1988-1998 and 1998-2007 in the region. At first, the probability map or suitability map must be prepared to run Geomod. This map shows the probability of change for each pixel according to the independent variables and high values in this map show the locations with higher potential for change. Suitability map can be developed using logistic regression and Multi-Criteria Evaluation (MCE) methods. In this study, logistic regression was used to prepare this map. GEOMOD has an internal validation method that helps to validate the model. Also, Results of land use change models are often assessed by comparing simulation results with actual land use data. For this, the Kappa coefficient of the agreement is a common algorithm for map comparison [29]. The validation was performed using the Validate module and the result of the model was evaluated using the kappa indices. This index has a range between 0 and 1 and high values of this index shows high accuracy of results. Fig. 3 shows how to implement GEOMOD.

2.7 Comparison of the Results of Two Land-Use Change Models

The best measure to compare different types of land use models is the ability of the models to land use change modelling and this criterion will be evaluated using the validation process. So, after that GEOMOD and logistic regression models were run, the modeled maps were validated using a similar method in order to evaluate the ability of two models for forest change modeling in this region. In this study, kappa indices were used to compare the results of two models.

2.8 Prediction of Future Conditions

After running the models in the specified time periods, the results were evaluated. Then, the models were run to predict future conditions. In this study, future conditions were predicted in the periods of 2007-2016 and 2007-2025.

3. RESULTS

In this study, forest change modeling was implemented using Geomod and logistic regression models in Gorgan area in the period of 1988-2025. The results of models were compared using Kappa indices. Next, the future condition of forest areas was determined for the years 2016 and 2025. To perform this procedure, at first, needed to prepare multi-temporal land use maps for the desired period. These maps were produced using remote sensing data. Then, the forest change detection process was performed using post-classification comparison method. After that, forest change modelling process was implemented using the mentioned methods. The results of this study are as follows:

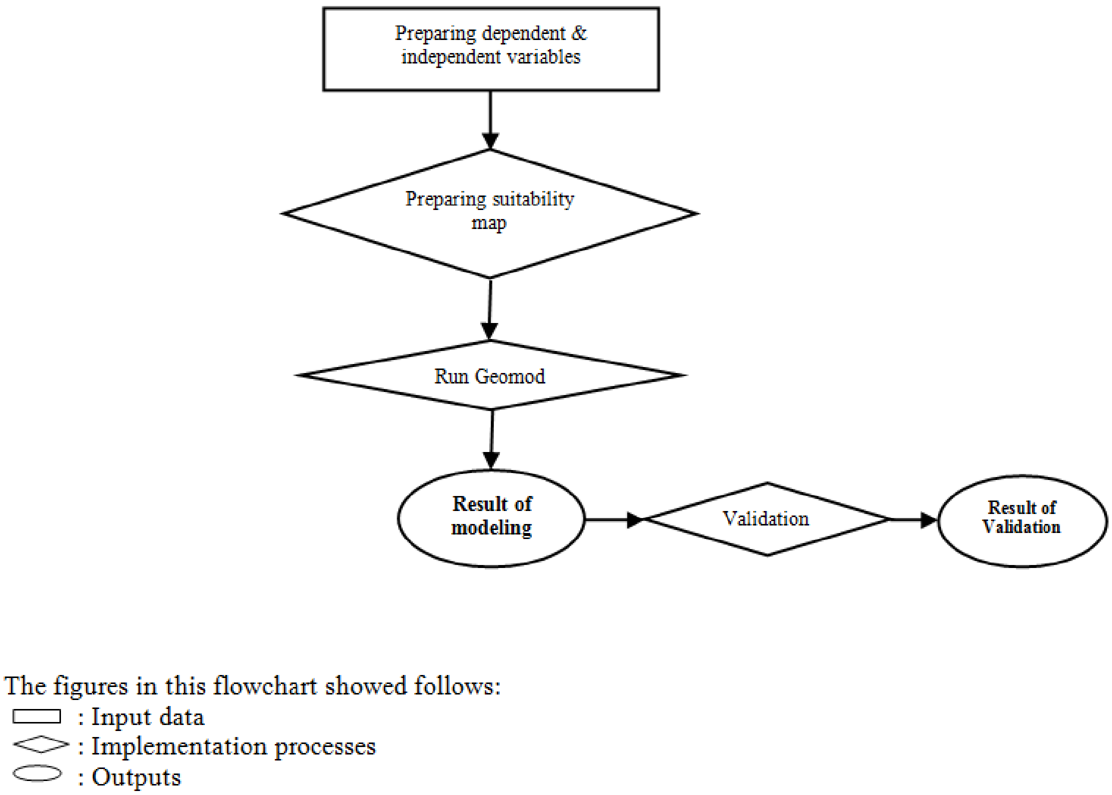

Fig. 3. The steps of geomod implementation

3.1 Accuracy Assessment of Image Classification

Ground Control Points method was used for accuracy assessment of the classified images. In this method, the classified images were compared with an image containing ground control points. This procedure was performed for each land use maps and Kappa values and overall accuracy was obtained (Table 3). The rate of kappa index and overall accuracy is in the range of 0-1. If these indices are closer to 1, the maps will have higher accuracy.

3.2 Change Detection Process

After preparing land use maps and evaluating their accuracy, the change detection process was achieved using Post-Classification Comparison method. This process was performed in 1988-1998 and 1998-2007 periods separately and forest changes studied in both periods (Table 4). The results show that the significant changes in forest areas have been established in these periods.

The results of forest change detection show that forest area in this region has a decreasing trend in the time period. According to the results, approximately 453 ha of forest area was decreased in the period of 1988-1998 and approximately 894.5 ha have been reduced at the period of 1998-2007. In most cases, the main reason for these changes was changing the forest areas into agricultural lands and also into residential areas. Given these results, it is clear that forest destruction has been rising in this region during the mentioned time period. For example, Fig. 4 shows the results of change detection in the period of 1998-2007.

Table 3. The result of the accuracy assessment of classification images

Land use maps	Kappa index	Overall accuracy
Land use map 1988	0.9140	0.9360
Land use map 1998	0.9602	0.9714
Land use map 2007	0.9304	0.9470

Table 4. The results of the change detection process

Land use type	Area in 1988 (ha)	Area in 1998 (ha)	Increase rate of area (ha)	Area in 2007 (ha)	Increase rate of area (ha)
Forest	49885.6	49833.5	453	48539	894.5

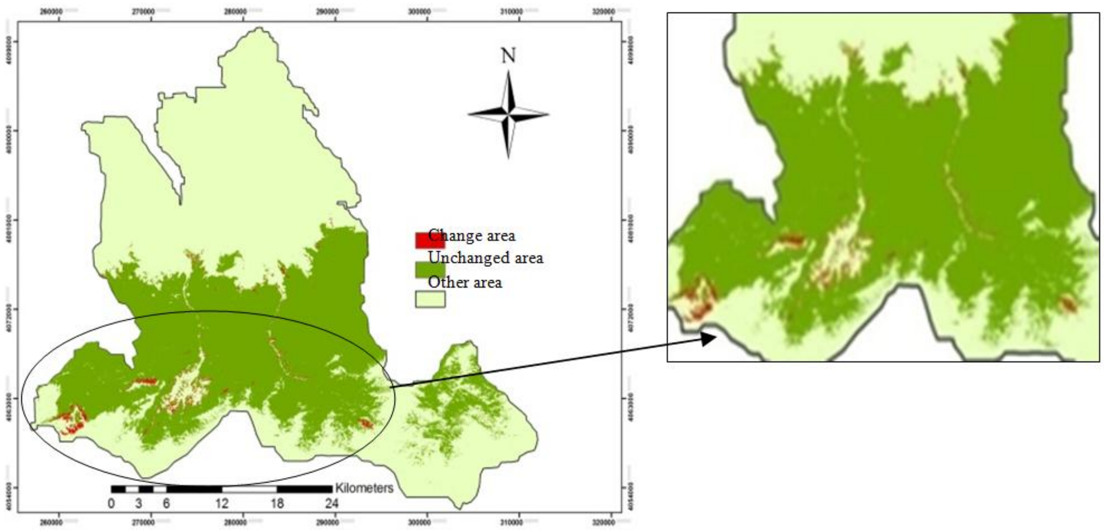

Fig. 4. Change detection map of forest area in 1998-2007

3.3 The Results of Modeling

3.3.1 Logistic regression

Forest areas showed decreasing trends in the region during the study time period. So the logistic regression model was implemented in both time periods for forest degradation. The logistic regression model with the independent variables for forest degradation in period of 1988-1998 and 1998-2007 leads to equations that follows (Table 5):

In these equations X_1 to X_{11} are independent variables containing slope, aspect, elevation, distance to villages, distance to agriculture, distance to the range, distance to forests edge, NDVI, Fragmentation, X Location and Y Location.

Table 6 shows Pseudo-R^2 and ROC values for the model that are suitable values. These amounts confirmed the capability of the logistic regression model for forest degradation modelling in this region. Figs. 5 and 6 show the prediction map of forest degradation derived from logistic regression model in the periods of 1998-1988 and 1998-2007, respectively.

3.3.2 Geomod

Geomod approach has been implemented in the periods of 1988-1998 and 1998-2007 using suitability maps that were produced using Logistic Regression method. Figs. 7 and 8 show the forest change modelling maps using Geomod approach in the periods of 1988-1998 and 1998 - 2007 in the study area, respectively.

Table 5. Equations derived from the logistic regression model in periods 1988-1998 and 1998-2007

1988-1998	$\text{Logit (Y)} = 1095.29 - o.00648\ X_1\ o.00033\ X_2 + 0.02241X_3 + 0.00513\ X_4 – 0.00151\ X_5 + 0.00096\ X_6 – 0.01011\ X_7 – 6.19455\ X_8 + 1.50815\ X_9 – 0.000009\ X_{10} + 0.00026\ X_{11}$
1998-2007	$\text{Logit (Y)} = 139.81 + 0.00035\ X_1 + 0.0004\ X_2 + 0.0002\ X_3 – 0.00722\ X_4 – 0.0008\ X_5 – 0.0041\ X_6 – 0.00552\ X_7 + 4.36\ X_8 + 0.05864\ X_9 – 0.000071\ X_{10} – 0.000031\ X_{11}$

Table 6. Pseudo-R^2 and the ROC values derived from the model

Time period	ROC	Pseudo-R^2
1988-1998	0.9217	0.2892
1998-2007	0.9113	0.2767

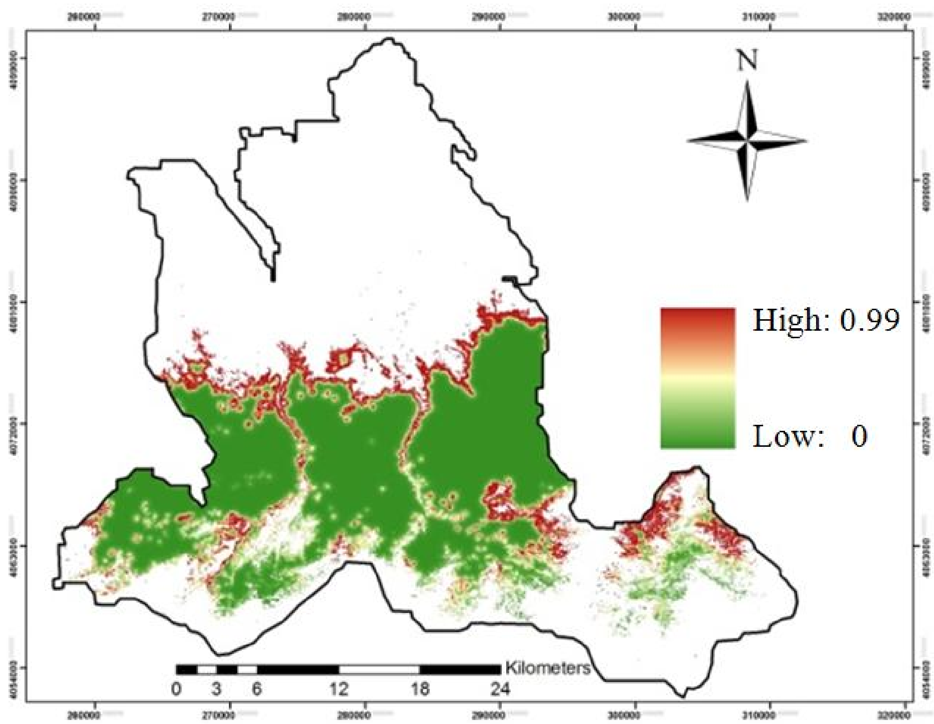

Fig. 5. Forest degradation prediction map in 1988-1998

Table 7. Kappa values derived from modelled maps validation

Time period	Kappa indices		
	$Kappa_{standard}$	$Kappa_{Location}$	$Kappa_{No}$
1988-1998	0.9962	0.9962	0.9968
1998-2007	0.9923	0.9924	0.9937

The validation process was achieved by calculating the kappa values (Table 7). High amounts of these indices confirmed the ability of Geomod for forest change modelling in this region. Landis and Koch (1977) quoted Zhou, et al. (2009) were ranked Kappa index in 4 categories: K values > 0.8 (i.e., > 80 %) represent strong agreement or accuracy between the modeled and the ground reference map (reality map), K values between 0.6 and 0.8 (i.e., 60% and 80%) represent high agreement, K values between 0.4 and 0.6 (i.e., 40% and 60%) represent moderate agreement and K values < 0.4 (i.e., < 40) represent poor agreement. Then, According to this classification, accuracy of Kappa obtained strong agreement that confirmed the high capability of Geomod to forest change modeling in this region.

3.4 Comparison of Logistic Regression Model and Geomod Approaches to Forest Change Modeling in Northern Iran within the Period of 1988 – 2025

In this study, the validation process was achieved using the calculation of Kappa indices for evaluating the results of two models consisting of logistic regression and Geomod. This process was implemented using the VALIDATE module in Idrisi Kilimanjaro software and the rate of kappa standard, Kappa location and K_{No} were calculated (Table 8). Comparison of model results using kappa indices showed the successful implementation of both models to forest change modelling in this region.

3.5 Prediction of Future Conditions of Forest Areas

Prediction probability map of forest areas in the time period of 1998-2007 was used to predict future conditions in this region. The results indicated that the forest area has a reducing the trend in this region in the time period. According to the results of change detection, forest areas in the period of 1998-2007 show a decrease of about 894 ha. So, it is expected to have a reduction of about 15520 pixels in the period of 2007-2016 and about 31040 pixels in the period of 2007-2025 in a forest area in this region. This number was ranked and detached from the prediction probability map of 1998-2007 years which were extracted separately for the periods of 2007-2016 and 2007-2025 and used to run the logistic regression model. Also, Geomod approach using suitability map was implemented for forest degradation in the period of 1998-2007 and also using the number of pixels that were reduced during this period. Fig. 9 shows the prediction map of future conditions of forest areas in the period of 2007-2025 by Geomod model. Fig. 10 indicates the prediction probability map of forest areas by the logistic regression model in the period of 2007 -2025. The locations with high values in this map show the areas that have a high probability to change in this time period.

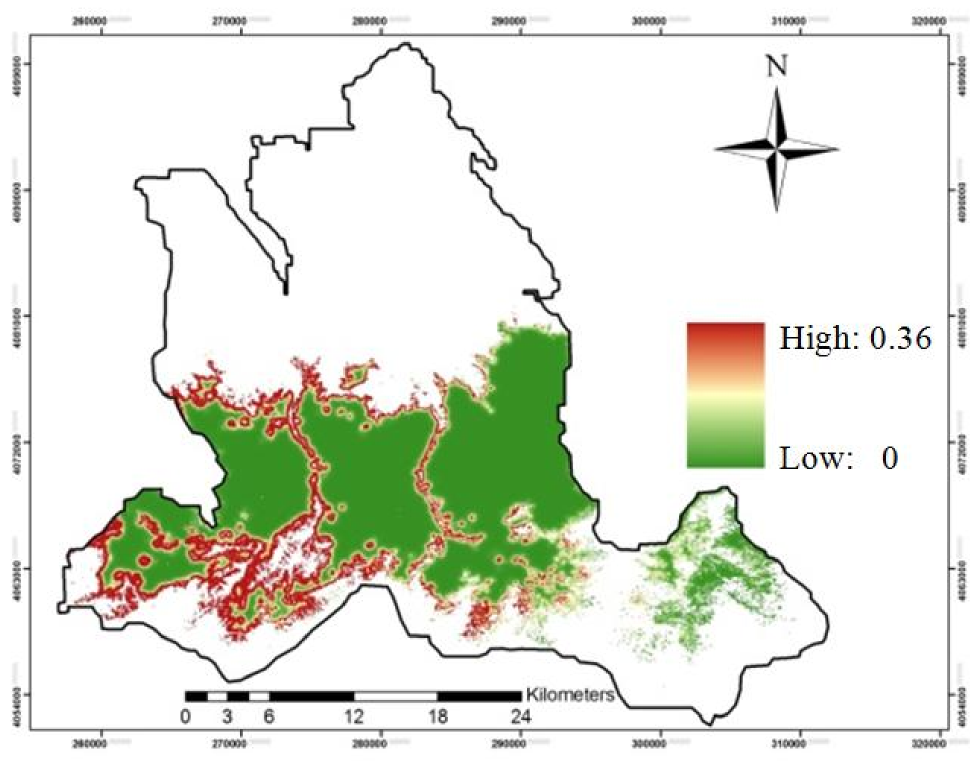

Fig. 6. Forest degradation prediction map in 1998-2007

Table 8. Result of models validation

Time period	Land type	Logistic regression			Geomod		
		$K_{Standard}$	$K_{Location}$	K_{No}	$K_{Standard}$	$K_{Location}$	K_{No}
1988-1998	forest	0.9927	0.9949	0.9961	0.9962	0.9962	0.9968
1998-2007	forest	0.9847	0.9866	0.9921	0.9923	0.9924	0.9937

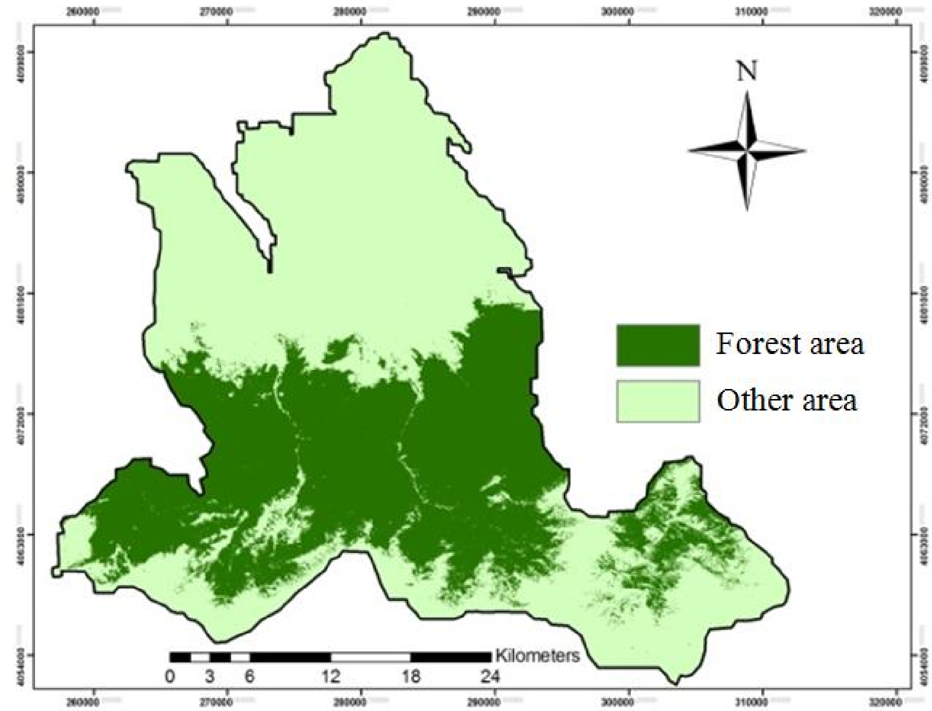

Fig. 7. Forest degradation modeled map in 1988-1998

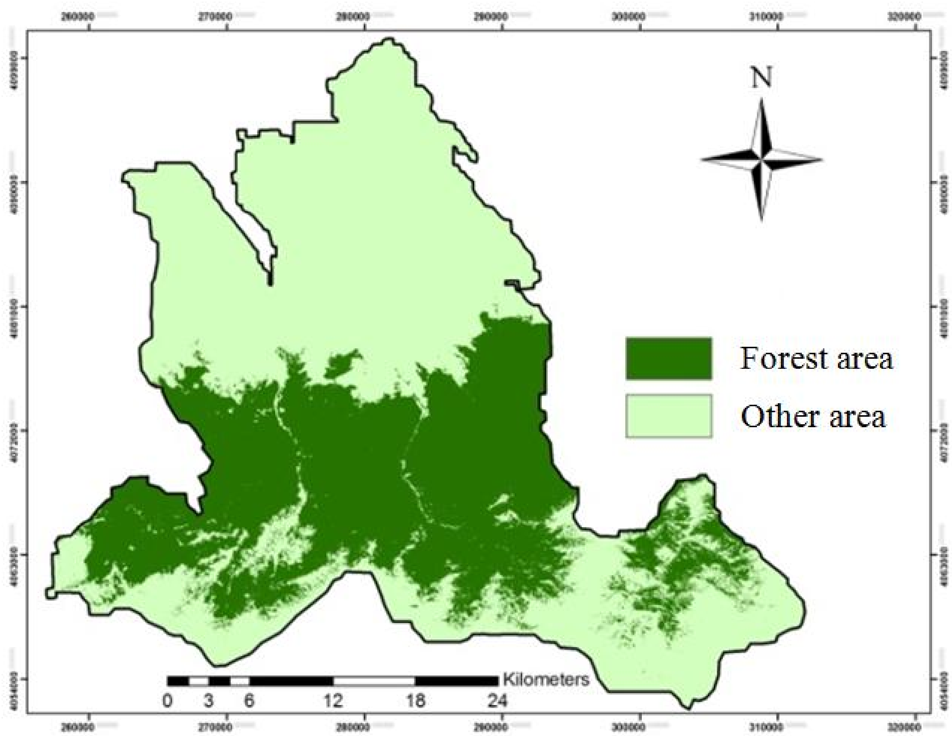

Fig. 8. Forest degradation modeled map in 1998-2007

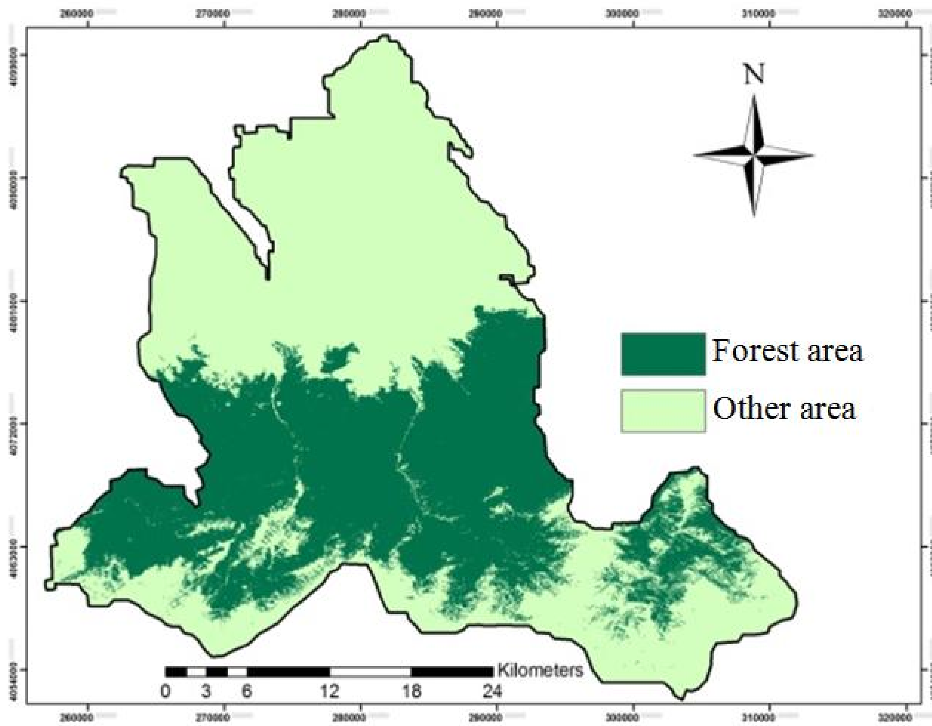

Fig. 9. Prediction map of the future condition in the period of 2007-2025 by geomod model

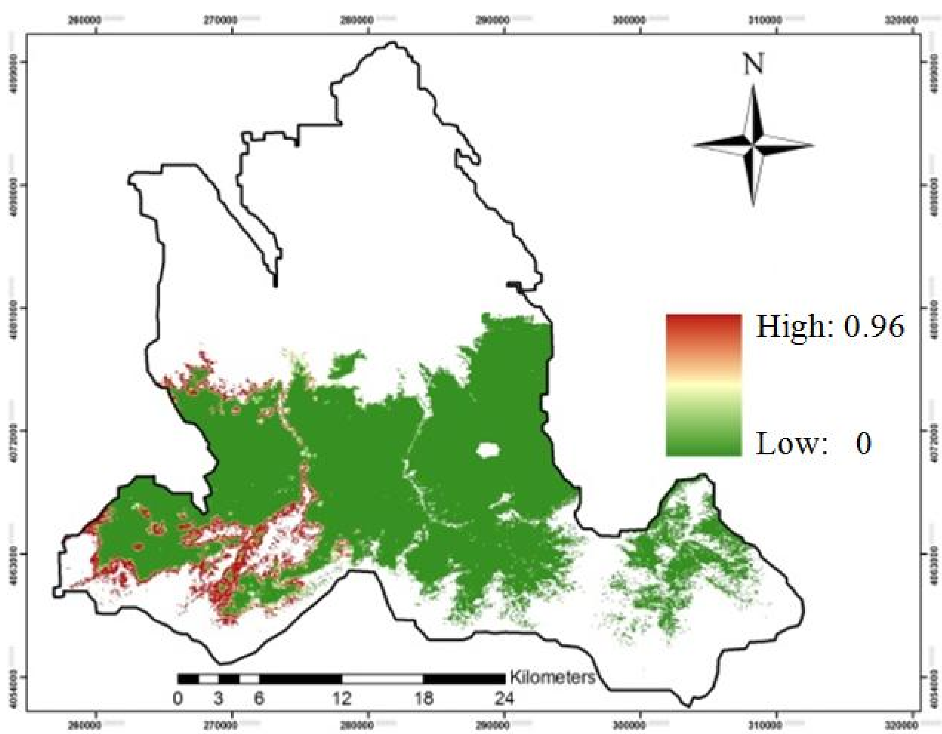

Fig. 10. Prediction probability map by logistic regression model by in the period of 2007 -2025

The results show that forest areas had been seriously damaged. Then, officials intervention is required to prevent further destruction of forest areas in this region. Without any controlling activities land use change process, extreme changes in the near future will appear in this region. Therefore, management and conservation activities such as determining agricultural areas boundary and preventing their development, buying and converting agricultural areas into land use such as conservation and also preventing rural development and preventing uncontrolled access to forest areas were recommended.

4. DISCUSSION

In this study logistic regression model and Geomod were used to forest changes modeling in Gorgan area in northern Iran in the period of 1988-2025. Then, the result of models was compared using Kappa indices. After that, the future condition of forest areas was determined for the years 2016 and 2025. The results of forest change detection showed that this area was decreased approximately 453 ha in the period of 1988-1998 and approximately 894.5 ha was reduced in the 1998-2007 period. This subject indicates that deforestation rate is growing along this period in the region. If this trend continues in the future, forest degradation with high rate will see in this region. Otherwise, without any appropriate management practices and by increasing deforestation, this valuable asset will be significantly reduced in a short time. Therefore, appropriate practices are required to prevent it. These activities can be contain determining agricultural areas boundary and preventing their development, buying and converting agricultural areas into land uses such as conservation and also preventing rural development and preventing uncontrolled access to forest areas were recommended. Forest change modelling was performed using a logistic regression model and the Geomod approach. The results of the logistic regression model by taking more than 0.27 and 0.91 for Pseudo-R^2 and ROC, respectively, are in agreement with the actual forest destruction and shows the high ability of logistic regression model for modelling forest reduction in this region. Results of logistic regression modelling show that "distance to forest edge" has an important role in forest reduction and the areas closer to the border of the forest has more probability for deforestation. Also, Geomod approach was implemented for forest change modelling in the period of 1988-1998 and 1998-2007. At first, the suitability map was prepared using logistic regression method for running Geomod. This method was used in many studies to prepare suitability maps such as Schneider and Pontios [3], Verburg, et al. [7], Williams, et al. [30] and Ellis and Porter-Bolland [31]. In the present study, the results of Geomod indicated the capability of model for forest change modelling in this region. Validation results by kappa values with more than 0.99 can confirm the ability of model to achieve forest change modelling in this area. Results of two models for forest change modelling were compared using Kappa indices. Vliet [29] confirmed that Kappa indices are proper criteria to validate the modelled maps. Validation results showed the ability of two models for forest change modelling in the region. Then, the future condition of forest areas was predicted using these models. The results of future condition prediction of forest areas showed forest areas have declined during the years of 2016 to 2025. It seems that the development of socio-economic activities is the main reason for deforestation in this region. In fact, land use change caused by human activities is an important reason to have forest degradation in this region. This shows that necessary administrative measures need in order to prevent forest destruction in the mentioned areas. Otherwise, without any appropriate management practices and by increasing deforestation, this valuable asset will be significantly reduced in a short time. Then, mentioned suggestions confirmed to implement in order to prevent forest areas and to control land use changes.

5. CONCLUSION

Land use change Modeling is an effective way to get information on how land use change has occurred and what variables have influenced it over time. Nowadays, different models have been developed for land use change modeling, such as logistic regression, Markov, neural networks and Geomod. In this study, logistic regression model and Geomod were used for forest change modelling in the period of 1988-2025 in Gorgan area in Northern Iran. Multi-temporal remotely sensed data for the years of 1988, 1998 and 2007 were used to prepare land use maps. Accuracy assessment of land use maps was investigated using Error matrix by calculating kappa values. Then, these maps were used to change detection process in two time periods of 1988-1998 and 1998-2007. The results of changes detection process in both periods showed a decrease in forest areas. In most cases, the main reason for these changes was changing the forest areas into agricultural lands and also into residential areas. Then, the forest change modelling was performed by the mentioned methods. After that, the Validation method by calculating Kappa indices was used for comparison of the results of both models. The future condition of forest areas was predicted using these models. If this reduction trend continues in the future, forest degradation will see in this region. Otherwise, without any appropriate management practices and by having a deforestation rate, this valuable asset will be significantly reduced in a short time. Therefore appropriate practices are required to prevent it. To do this, the practices such as determining agricultural areas boundary and preventing their development, buying and converting agricultural areas into land uses such as conservation and also preventing rural development and preventing uncontrolled access to forest areas were recommended.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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