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Full Length Research Paper

Evaluation of eco-environmental vulnerability in Efon-Alaye using remote sensing and GIS techniques

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This study evaluates the environmental vulnerability of Efon-Alaye located in Ekiti State, Nigeria, which is a typical mountainous region with steep slope and an upland ecosystem. An Integrated Remote Sensing and Geographical Information System approach was used to analyse the environmental vulnerability of the region. Satellite data of the study area for two periods 1986 and 2002 were used for the analysis. Spatial multi-criteria evaluation operation was used to generate the vulnerability map of the study area. Indicators used were land-use, vegetation map (NDVI) and slope map generated from digital elevation model. The vulnerability distribution was classified into five levels: potential, slight, moderate, high and extreme. The results show that the environmental vulnerability in the study is at potential level and the driving force of this change is attributed mainly to the cultural activities of the inhabitants of the study area. The result of this study has also shown that using Integrating remote sensing, geographical information system and spatial multi-criteria evaluation model to evaluate environmental vulnerability in mountainous regions will assist decision makers in environmental management.

Key words: Environmental vulnerability, spatial multi-criteria evaluation model, GIS, remote sensing, vegetation, land-use.

INTRODUCTION

The environment is threatened by the frequencies of natural disasters and anthropogenic factors confronting it. And different methods have been used to study these changes on the environment. Models have been developed for assessment, evaluation, monitoring and prediction of some major factors that contribute to these changes. Advances in technology based on monitoring, change detections have made it very easy to have an over view of what is being studied. Most of the environmental problems are spatial phenomenon. Since time is also important, it is a spatial-temporal phenomenon. Making this possible is geo-referenced satellite data and GIS. Satellite data provides the user with a good synoptic view of her area of study. Such data can be applied in forecasting the overall agricultural production of a large area, identify areas in which structures have been built illegally and other mistakes by urban planners and policy makers.

The concept of sustainable land management calls for integrated technology, policies and activities aimed at integrating socio-economic principles with environmental concerns, so as to simultaneously enhance productivity, attain security, prevent further degradation of natural resources and gain viable economical returns acceptable to the society (Rajendra et al., 1999). This is against the back drop that the environmental quality is deteriorating day by day. Rapid urbanization brings with it many problems as it places huge demands on land water, health, etc. (Asadis et al., 2007).

Soil erosion is an important aspect of environmental change. Soil erosion destroys the soil and its biological resources. It is also dangerous for living environment as it increases cost of production, triggers pollution and enhances ill health. The evaluation of land-use sustainability serves as a benchmark that would indicate the current level of sustainability and guide land-use management and developmental options. The ecosystem of Efon-Alaye is threatened by soil erosion. This is as a

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Table 1. Data characteristics.

Data type	Sensor	Date of acquisition/ production	Spatial resolution/ scale	Source	Band	Path/row
Landsat image	TM	Dec. 17th , 1986	30 m	GLCF,USGS	NIR, RED and Green (4,3,2)	P190 r55
Landsat image	ETM+	Jan. 3rd , 2002	30 m	GLCF,USGS	NIR, RED and Green (4,3,2)	P190 r55
Administrative and local government map of Ekiti State		2000	1: 160,000	NCRS		

result of the following:

i) The cultural activities of the indigenes have mounted pressure on the soil and has resulted in the losing of the surface soil.
ii) Geologically, the type of rock associated with the terrain is called quarzites. These are easily fractured once they are pressurized.
iii) The topography of the area has a steep slope and the indigenes build on the slope.

In a recent study by Ainong (2005) remote sensing and gis technologies together with numerical modelling techniques developed using spatial principal componet analysis (SPCA), the eco-environmental vulnerability in the upper reaches of Minjiang River China was evaluated.In the same context, remote sensing and GIS application with spatial multi criteria evaluation (SMCE) an application in Ilwis 3.3 environment was used to come up with classified vulnerable areas as relates to their vulnerability index.

Aim and objectives

The major objective of this study is to evaluate the eco-environmental vulnerability in a typical hilly region (Efon-Alaye) characterized by a steep slope while the specific objectives for the study are:

i) To create a digital elevation data from the digital elevation model (DEM), using the SRTM from the radar terrain model satellite.
ii) To develop the spatio-temporal land cover change of the area.
iii) Using SMCE application to develop an environmental vulnerability map index and the computed result classified.
iv) To determine the percentage vulnerability change relative to years under consideration.

Study area

The study area is located Ekiti State Nigeria, with spatial extent between 7°42'31.71"N to 7°42'31.71"N latitude and 4°52'30.41"E to 4°57'21.18"E, with elevation of about 536 m above sea level. Efon-Alaye is characterized by a hilly terrain. It is also a typical mountainous region with upland ecosystem. The inhabitants are mainly concentrated in the valley area.

DATA AND METHODOLOGY

Data collection

Satellite image data for this study was downloaded from Global Land Cover Facility (GLCF) on the internet. and other sources as shown in Table 1.

SRTM (Shuttle Radar Terrain Model) was downloaded from GLCF on the internet, with path and row (p190r55). This data was used to develop the Digital Elevation Model for the study area.

Methodology

The processing and analysis of the data was done using the following digital image-processing software packages: Ilwis 3.3 and Global Mapper v8.03. This same procedure was also employed by Adinna et al. (2009) in analysing urban heat island situation in Enugu urban.

Generation of land use/ land cover map

False colour composite, combining the near infrared, red and green bands of the satellite data were generated; for vegetation recognition because chlorophyll in plants reflects very well to near infrared than the visible. A classification scheme was developed for the study area (Figure 1).

A brief reconnaissance survey was carried out to obtain information on the elevation of the place and to verify the training sites (classification categories) as regards the pixel signature, plotting the ground control points obtained using a global positioning system. The classification method used was supervised and maximum likelihood operation was used to determine the land use/ land cover classification for both periods (Figure 2 and Table 2).

Generation of vegetation map (NDVI)

NDVI is an acronym for normalized difference vegetation index. This is the ratio of red and near infrared bands of a sensor system. Mathematically:

$$NDVI = \frac{NIR4 - RED_3}{NIR_4 + RED_3}$$

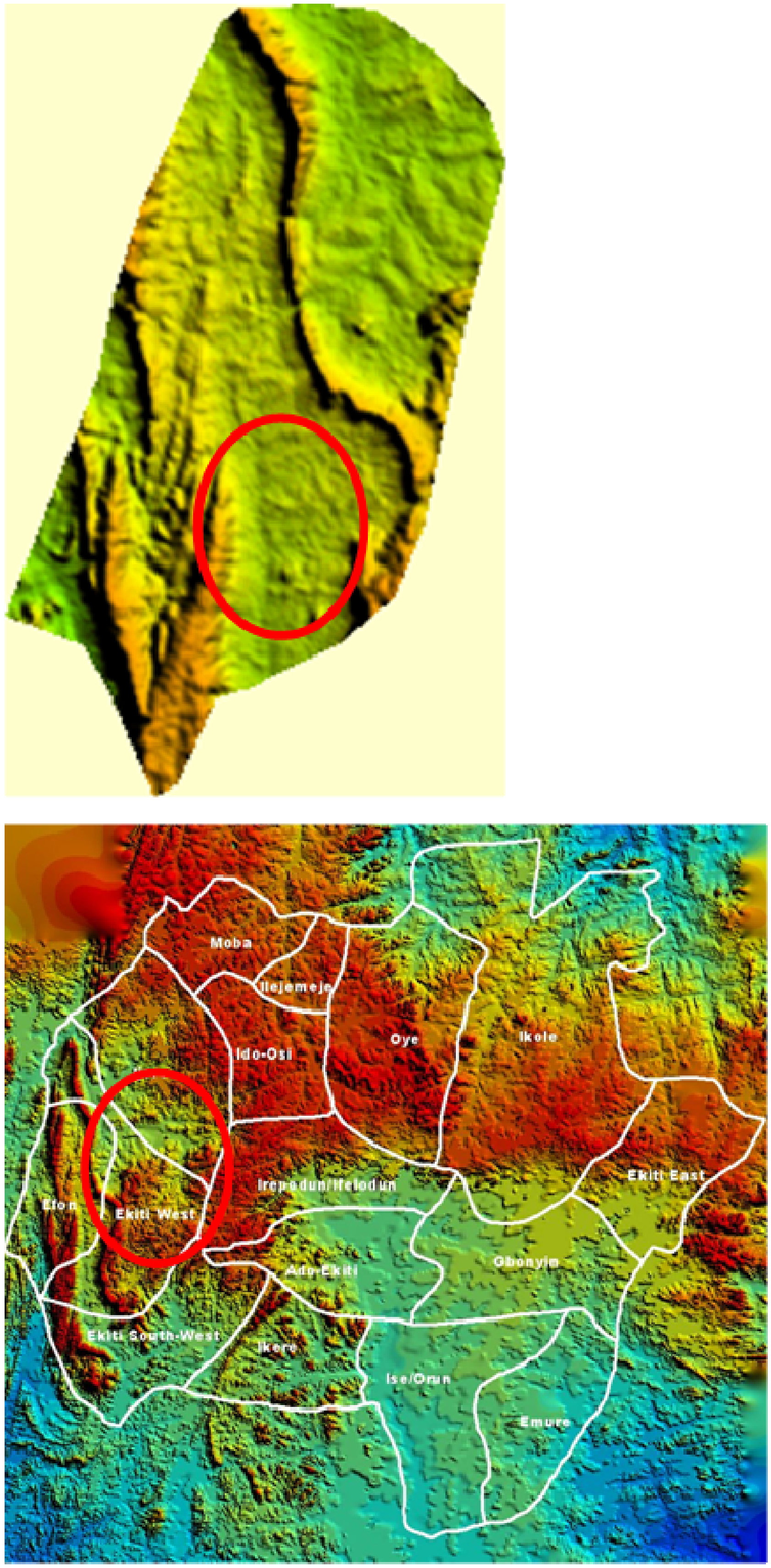


Figure 1. Location map of Efon-Alaye (Study area).

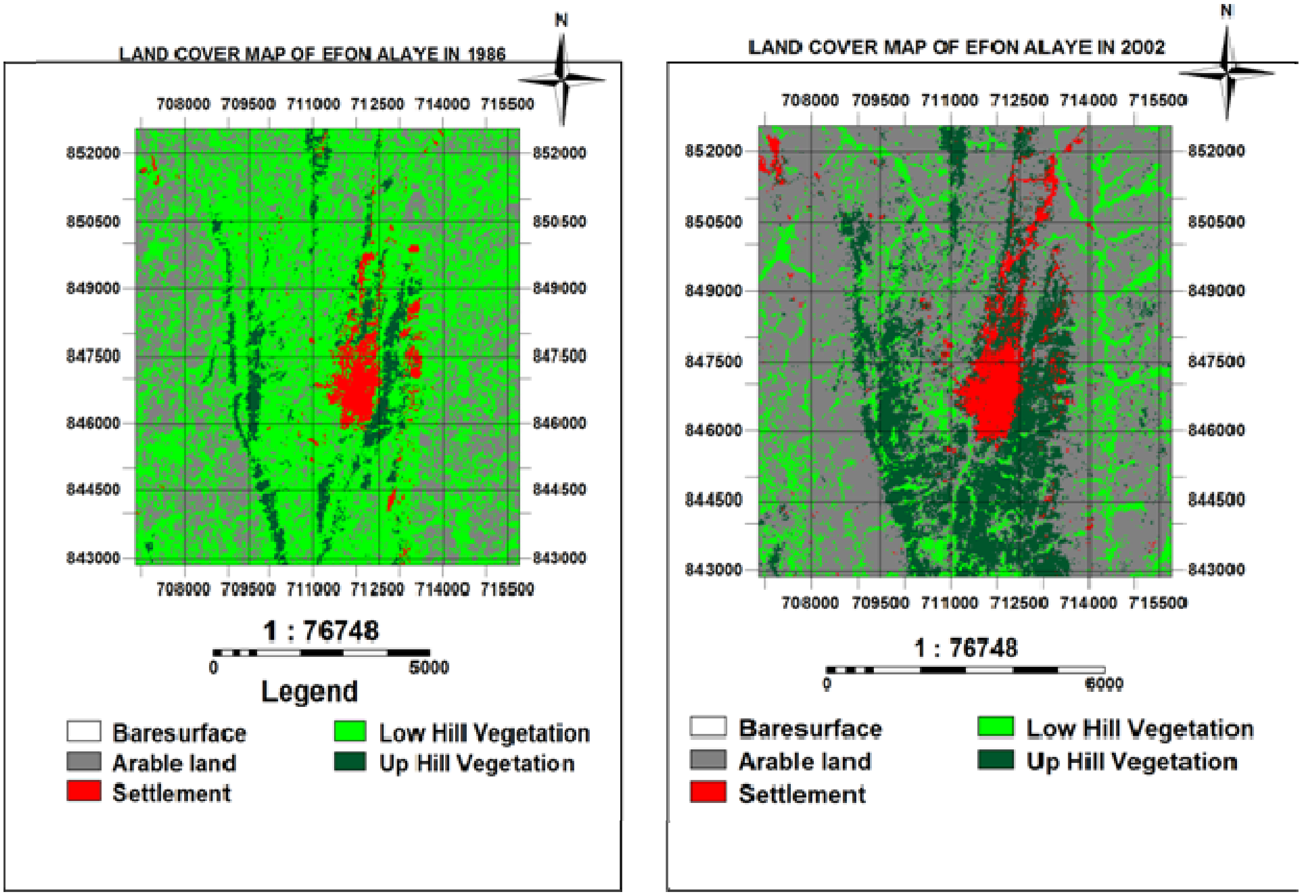


Figure 2. Land use/ Land cover classification of the study area in 1986 and 2002.

Table 1. Land use/land cover classification categories.

Classification	Colour
Arable land	Blue
Bare surface	Yellow
Low Hill vegetation	Magenta
Settlement	Red
Up hill vegetation	Cyan

NDVI is a good indicator of the ability for vegetation to absorb photosynthetically active radiation and has been widely used by researchers to estimate green biomass (Adeyewa, 2007; Rosental et al., 1985; Tucker et al., 1985; Prince, 1991). NDVI values range from -1.0 to 1.0. Non - vegetative features such as bare surface, built-up area and water body are classified when the values are less than zero between 0 and - 1. Also when the value is greater than zero, it points out that there is vegetation cover.

Generation of slope map

The SRTM of the study area was downloaded from the internet, from which the DEM was obtained and the slope map was generated from the DEM (Digital Elevation Model) (Figure 5). The DEM shows the elevation of the study area in heights.

RESULTS AND DISSCUSSIONS

Data analysis

This study adopted Remote Sensing (RS) and Geographical Information System (GIS) technologies. For the evaluation of eco-environmental, a special application in Ilwis 3.3 known as Spatial Multi-Criteria Evaluation (SMCE) was used to develop the classified level results.
In the SMCE module implementation in Ilwis, this process was greatly facilitated through the development of the

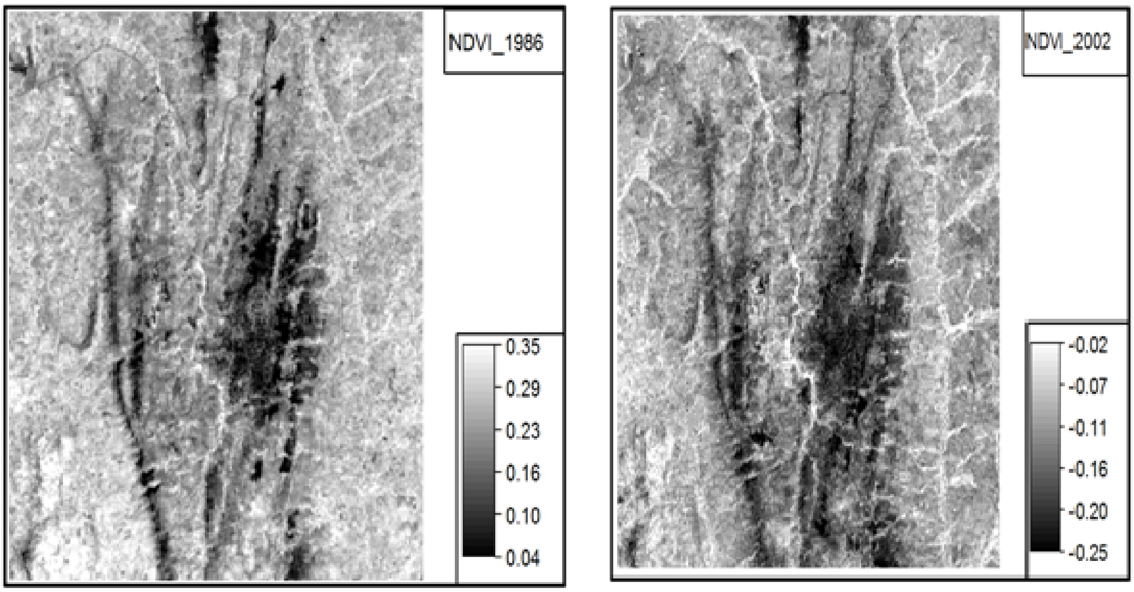
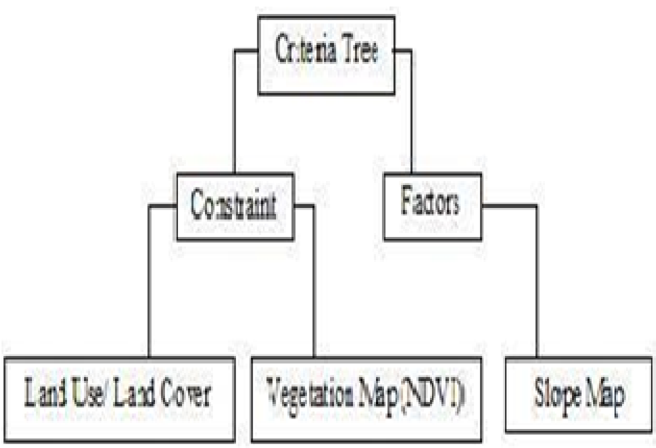


Figure 3. Image representation of Vegetation Map (NDVI) of 1986 and 2002.

criteria tree structure. The leaves of the tree are indicators that are represented by separate maps. The related map was eventually assigned to each leaf in the tree.



Standardization

For analysis, the values and classes of all maps were converted into a common scale, having the same geo-reference which is called Utility. Utility is a measure of appreciation of decision maker with respect to a particular criterion and relates to its value/ worth (measures in a scale of 0 to 1). The transformation is commonly referred to as standardization.

Different standardization is applied for different types of maps:

a) For “value maps”, standardization is done by choosing the proper transformation function from a set of linear and non-linear functions. The outcome of the function is always a value between 0 and 1. The function is chosen in such a way that pixels in the map that are highly suitable for achieving the objective result in high standardized values and unsuitable pixels receive low values. ILWIS’ SMCE module provides a number of linear and nonlinear functions. Possible standardization methods for value maps in the developed SMCE module are for example “Maximum”, “Interval” and “Goal”. Together with the “cost/benefit” property of the criterion, this information is sufficient for applying the selected standardization method in the correct way.

b) For “classified maps”, standardization is done by matching a value between 0 and 1 to each class in the map. This can be done directly, but also by pair wise comparing or rank ordering the classes. And this was applied here.

Figure 3 shows the vegetation map (NDVI) of both years. In 1986 the legend depicts that the study area had some level of vegetation cover than what it is seen in 2002. Figure 4 shows the NDVI histogram trend of the study area. Its shows that vegetation reflectance is quit high in 1986 reaching about 0.35 positively than that of 2002 where we have the value at about - 0.25 which show non-vegetative features.

Weighing

The next step in SMCE is the identification of the relative importance of each indicator, or the weights. ILWIS’

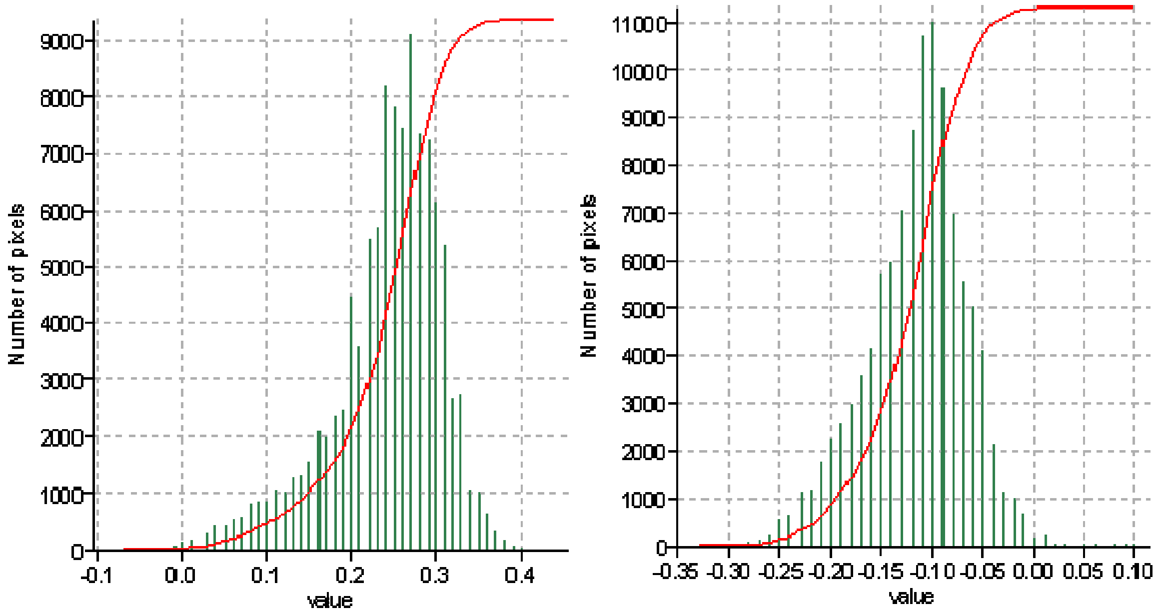


Figure 4. Graphical representation of NDVI trend for 1986 and 2002 respectively.

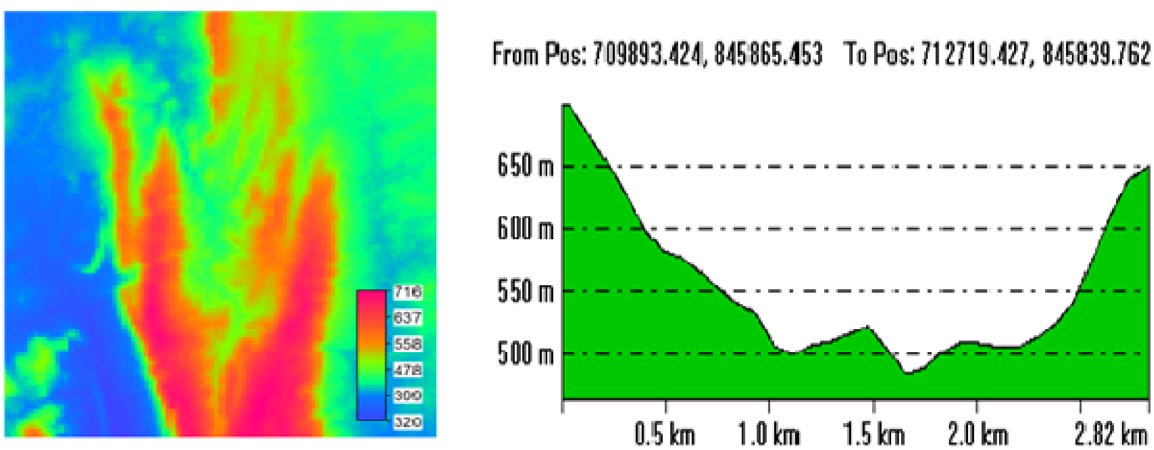


Figure 5. (a) Digital elevation model of Efon-Alaye (b) Cross-section of elevation in meters.

Table 2. The result of eco-environmental vulnerability classification in Efon-Alaye.

Evaluation level	Number	Index classification	Feature description
Potentially vulnerable	I	0.0 - 0.2	Stable ecosystem, relatively low altitude, settlement
Slightly vulnerable	II	0.2 - 0.4	Relatively stable ecosystem and low altitude
Moderate vulnerable	III	0.4 - 0.6	Relatively unstable ecosystem, sparse vegetation distribution
Highly vulnerable	IV	0.6 - 0.8	Unstable ecosystem, vegetation distribution, relative high altitude
Extremely vulnerable	V	0.8 - 1.0	Extremely unstable ecosystem, high altitude, vegetation distribution

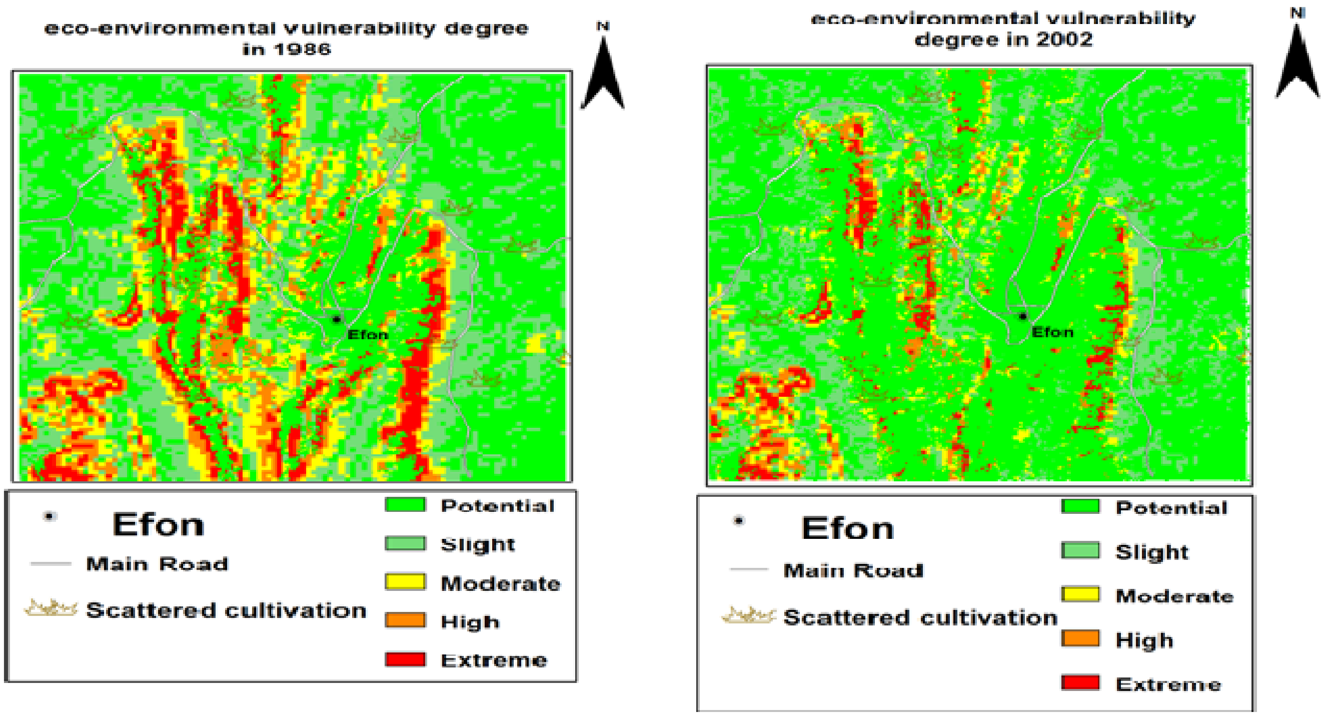


Figure 6. Distribution of eco-environmental in study area, showing the eco-environment vulnerability level in 1986 and 2002, respectively, as well as a general change trend since the green region standing for "potential" is expanding gradually from 1986 to 2002.

SMCE module provides support for a number of techniques (direct, pair wise comparison and rank ordering) that allows elicitation of weights in a user-friendly fashion, at any level and for every group in the criteria tree. The criteria tree designed in the first step enables giving weights to a few factors at a time, as the branches of one group only are compared to each other. Starting e.g. with the group “Soil”, the factors “Thickness”, “Texture” and “Permeability” are compared to each other and a weight is assigned to them. Factors are always weighed, but for constraints there is no weight involved, because they simply mask out the areas which are not interesting.

Environmental vulnerability map of Efon-Alaye

Environmental vulnerability map is classified into five levels defined as potentially vulnerable, slightly vulnerable, quite vulnerable, highly vulnerable and extremely vulnerable levels with each level characterized by a typical feature description shown in the Table 3.

Table 3 shows the characteristics of each of the classified levels. Levels I-II is relatively at low altitude, levels III - V are relatively at high altitude which is upland. The classification index for each level was automatically generated by the software used with the input of the indicators used that is the land-use/land-cover map, vegetation map and slope map. The Classification of the evaluation level into 5 levels was verified by ground trotting.

Figure 6 shows the graphical distribution of the eco-environmental vulnerability degree of 2002 relative to 1986. The figure depicts that eco-environmental degree was at level I in 2002which has a wide spread and can be attributed to the socio-economic activities of the people of the area.

Figures 7(a) and (b) shows the vulnerability percentage for both years. Where level I was at 47% in 1986 and 70% in 2002. The percentage difference, increase or decrease is shown in Figure 7 (d). Level I increased by 23% and levels II, III, IV and V decreased by - 9, - 5, - 5 and - 4% respectively. More activities has moved upland which has effect on levels II, III, IV and V, such as vegetation loss, which then can allow for easy runoff of water from rain, down the slope to the lowland. The spread of level I to other levels shows how the people of the area have moved their activities to the other levels-thus, making part of other levels potentially vulnerable to any environmental hazard.

Figure 7(c) shows the different levels area cover extent in m^2. Level I increased in area cover in 2002 relative to 1986 and for the other levels II, III, IV and V decreased in

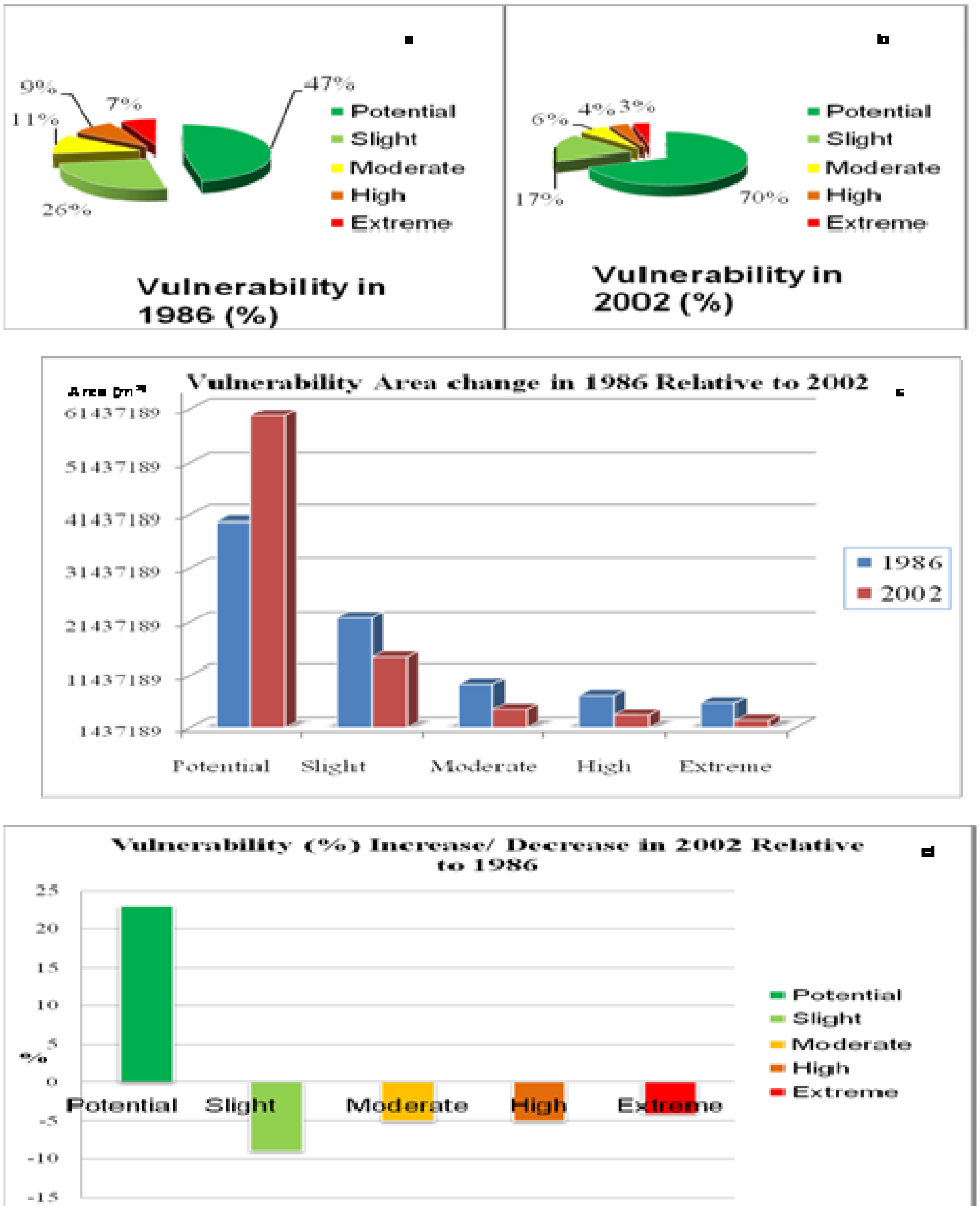


Figure 7. (a) - (d) Change of eco-environmental vulnerability between 1986 and 2002.

area cover in 2002 relative to 1986. With respect to the increase of level I in 2002, it shows that there was an increase in land-use in the area.

Evaluation of results

In general, potential vulnerability level occupies the largest area, accounting for 70% in 2002 relative to 1986 (47%). It shows that there was an increase in population/ cultural activities at low level; the area is potentially vulnerable to the environmental hazard.

The study area is characterized by a typical middle and high mountainous regions. Mountain spread, slope direction and degree and changing climate cause great difference in human activities in the area.

Analysis of eco-environmental vulnerability change driving forces

The eco-environmental vulnerability showed a significant change during the study period. In the past years, comparatively stable eco-factors, such as land-forms, water-heat condition and vegetation have very limited influence on eco-environmental vulnerability changes in this area. However, the driving forces for the change are mainly related to the impact of socio-economic, resulting in increasing pressure of human activities on land which lead to rapid change of land-use. Thus, the coverage of land is cutting down and environmental hazards are intensified, resulting in a further degradation of the environment.

Recommendations

The following recommendations are made to upgrade the methodology described in this study:

1. Proper environmental management evaluation using GIS will assist decision makers to know the level of damage or pressure on socio- economic activity has on the environment.
2. Vulnerability management is emerging as a critical part of any sustainable development strategy. Therefore, for the goal of sustainable development to be realized, we must manage our vulnerabilities by engaging in aggressive environmental research.
3. More studies can be carried out in the study area by integrating different fields such as geology, soil science, etc which can test for the soil compaction, soil water retention capacity, permeability, etc.
4. For sustainable development with respect to the results from this study, the inhabitants should be regularly informed on the dangers of planting or building on slopes.
5. Integrated satellite technology data when available, will produce better results in studying environmental vulnerabilities for the location studied.

Conclusion

Space technologies, such as remote sensing (RS), geographical information system (GIS) and numerical modelling techniques have been developed as powerful tools for ecological environmental assessment (Krivstoc, 2004; MacMillan et al., 2004; Store and Jokimaki, 2003). Combination of these technologies cannot only supply a platform to support multi-level and hierarchical integrated analysis on resource and environment, but also integrate the obtained information in a comparative theoretical ecosystem analysis.

The study area which is a typical mountainous region characterized by a steep slope, has over the years been over populated leading to increase in various socio-economic activities in the area with the use of the land.

The Land-use/ Land-cover classification in this study has validated the fact that the land has been under pressure resulting from the increase in population from 1986 to 2002. The classification scheme shows that Built-up area has increased and from the calculation of NDVI, it shows that there is reduction in vegetation in 2002 relative to 2006.

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