Research article

Land Use Assessment for Proposing Sustainable Development in El Jicaral, Mixteca Region, Mexico

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Abstract El Jicaral is an indigenous community of around one thousand inhabitants located in the Municipality of Coicoyán de las Flores, Mixteca Region, Mexico. This region is characterized for being one of the poorest regions in Mexico, with high levels of land degradation, deforestation and water shortages. Even though several studies have been undertaken to estimate the region's area affected by soil degradation, the findings derived from these studies cannot describe accurately the conditions in the community especially for scale differences, and hence appropriate sustainable farming practices are difficult to be proposed. For this reason, the objective of this study is to assess the present land degradation condition in the study area, using a satellite map obtained from Google Earth and through the overlaying of a mesh, for the identification and classification of several variables, namely vegetation density, slope, steepness and land use, to propose suitable farming practices for mitigating land degradation. The results showed that currently there is a severe degree of soil degradation in the community, reflected in the majority of cells of the mesh with very low and low values of vegetation density, and that most of them were also in slopes up to 16%. Also, it was observed that most of the studied area land use was dedicated for agricultural purposes, even in hillside terrains. So, it is necessary to implement farming systems taking into account this topographic factor, as well as socioeconomic and environmental ones.

Keywords land use assessment, sustainable development, Mixteca

INTRODUCTION

In the last decades, sustainable development has become a primary objective, as mentioned in the Johannesburg Declaration on Sustainable Development, adopted at the World Summit on Sustainable Development (WSSD) (United Nations, 2002). This created a continuous need for accurate information on landscape changes. With the present technologies, these changes can be observed in photographs of as practically in any places in the Earth. This is important for developing environmental management and planning strategies at different scales in terms of sustaining those resources, which provide important economical goods and services (Hammad and Tumeizi, 2012).

Such strategies for environmental management also are intended to mitigate the current situation of land degradation that could be defined as the processes derived from human activities which lead to a reduction in either the biological productivity or biodiversity, as well as in the current and/or future capacity to sustain human life (Oldeman, 1998).

In Mexico, several studies have been carried out to estimate the country's resources situation, including land degradation (Semarnat, 2008). However, the results obtained cannot be compared due to differences in methodology and scale. According to the Mexican Secretariat for Environmental Protection, Natural Resources and Fisheries (SEMARNAP in Spanish), the two most recent studies are the Assessment of soil loss due to hydric and eolic erosion in Mexico, scale 1:1,000,000 (Semarnat-UACh, 2003) and Assessment of soil degradation caused by man in Mexico, scale 1:250,000 (Semarnat-CP, 2003). However, these studies cannot describe accurately the conditions in the research site, especially for scale differences, and hence appropriate sustainable farming practices are difficult to be proposed.

STUDY SITE

For this research, the community of El Jicaral, located in the Mixteca Region was selected. Mixteca region is compounded by three states: Puebla, Guerrero and Oaxaca. The Oaxacan Mixteca (Fig. 1) is a region comprising 19,583 km^2, 8 districts, 165 municipalities, and 1,419 villages. Of its nearly 500,000 inhabitants, 68% live in rural areas and 35% belongs to one of several indigenous groups, including the Mixtecas (predominant), the Triqui, the Chochomixtecos, the Amuzgos, and the Tacuates. This region is characterized as being one of the poorest regions in Mexico, with high levels of land degradation, deforestation and water shortages (Martínez and Altieri, 2006).

El Jicaral (Fig. 2) is an indigenous community with around 1,000 inhabitants, whose spoken language is Mixteco. The main crops are rain-fed corn, chili and beans. Due to the uneven topography of the region, the upland fields are mostly situated in hillsides, being prone to land degradation processes.

Fig. 1 Mixteca Region, Mexico

Fig. 2 Land degradation in El Jicaral

OBJECTIVE

The objective of this study is to assess the present land use condition in the study area, using satellite maps obtained from Google Earth and through the overlaying of a mesh for the identification and classification of several variables, namely: vegetation density, slope and land use. In doing so, the objective is to be able to propose suitable farming practices for this community, in the hope that it could be spread throughout the region.

METHODOLOGY

Through the use of digital maps obtained from Google Earth software, a mesh was constructed above the community of El Jicaral, which is located in the coordinates 17º 07'34.56" Latitude North, and 98º11'48.9" Longitude West. Cells dimensions were 50 meters by 50 meters, covering an area of around 0.5 km^2 (Fig. 3).The digital photography used for this research was taken in November 19th 2010.

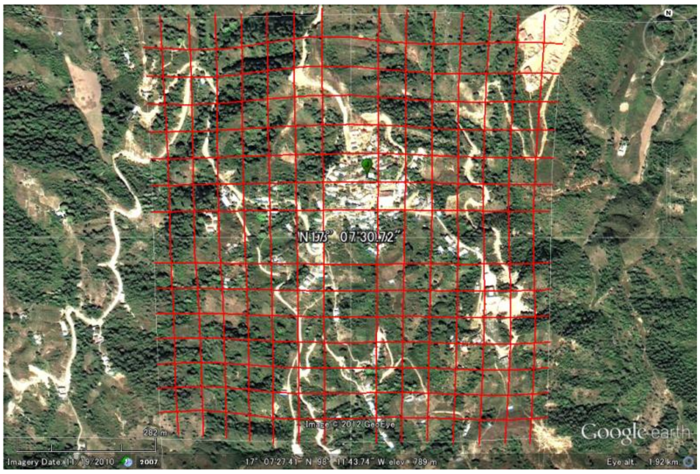

Fig. 3 Mesh projected in El Jicaral community

The Haversine formula of spherical trigonometry was used to calculate the distance between two points in the mesh using coordinates. This formula estimates the shortest distance over the earth's surface, ignoring any hills, Eq. (1).

$$harvesin\left(\frac{d}{r}\right) = haversin(\emptyset_2 - \emptyset_1) + \cos(\emptyset_1)\cos(\emptyset_2)\, harvesin(\lambda_2 - \lambda_1) \qquad (1)$$

In Eq. (1)*harvesin* is the Harvesine function, Eq. (2).

$$harvesin(\theta) = sin^2\left(\frac{\theta}{2}\right) = \frac{1-\cos(\theta)}{2} \qquad (2)$$

In Eq. (2)*d* is the distance between the two points along the sphere; *r* is the radius of the sphere, ϕ_1 and ϕ_2 are the latitude of point 1 and point 2 respectively, and λ_1 andλ_2 are longitude of point 1 and point 2, respectively.

After the mesh was projected in the study field, the elevation value of every intersection was obtained. Knowing the distance between intersections, the steepness and slope in every cell was calculated. Furthermore, with the mesh defined, vegetation density as well as land use values were assigned to every cell.

RESULTS AND DISCUSSION

Steepness and slope: Steepness (ΔL) is the difference of elevations between two points. In every cell there are four intersections, so the steepness was calculated choosing the highest value and the lowest value among these four intersection points and then making the subtraction of these two values, as shown in Fig. 4. Then with the values of steepness, and already knowing the distance between the two points chosen (Δd) the value of slope was calculated, as shown in Fig. 5.

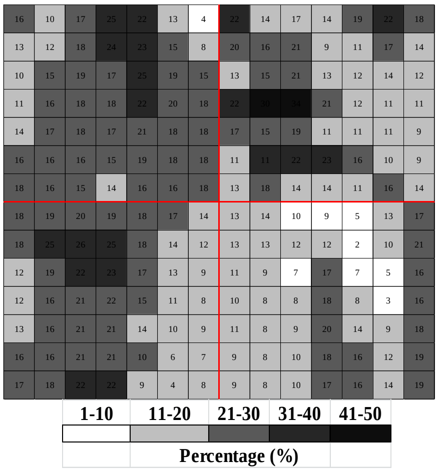

Fig. 4 Steepness values (m)

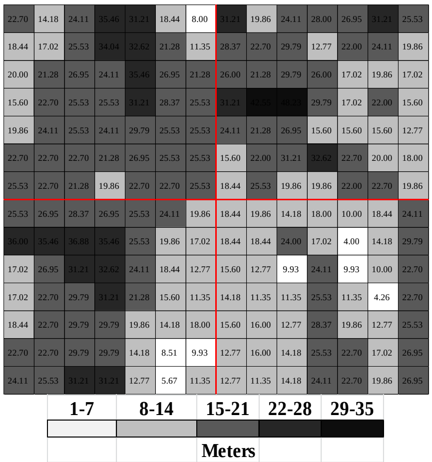

Fig. 5 Slope values (%)

The average slope value for the mesh was 21.9%. The maximum value was 48.3% and the minimum was 4%.

Vegetation density: Using the mesh projected in the research area, for every cell of 50 meters by 50 meters, a value was assigned, according to the density of vegetation observed. The values were from 1 to 5, being 1 the lowest vegetation density value and 5 the highest (Fig. 6).

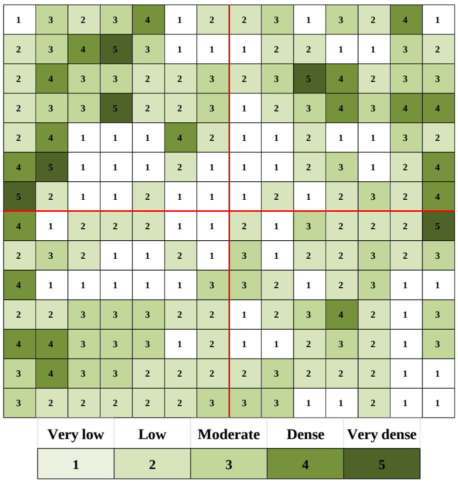

Fig. 6 Vegetation density in the study site

In the community of El Jicaral it was observed that most of the research area presented very low and low vegetation density.

Land use: The classification of land use was also carried out in the research area. As in vegetation density, values for land use were assigned to every cell according to direct observation of the digital map. The values are as follows: 1 Farmland, 2 Human settlements, 3 Water sources, 4 Forest and 5 Wasted lands (Fig. 7). Most of the area land use corresponds to farming activities, despite the steepness of the relief.

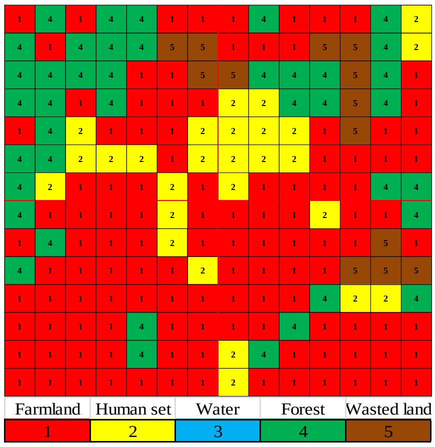

Fig. 7 Land use assessment in the research site

Land degradation: Moreover, overlapping of the Vegetation, density mesh and the Slope mesh was conducted, for determining the level of land degradation in the study site. According to Feras (2007) slopes greater than 16% are not suitable for field crops. So, taking into account this value, a mesh was projected where slopes are bigger than 16%, and where vegetation density was very low and low, as shown in Fig. 8.

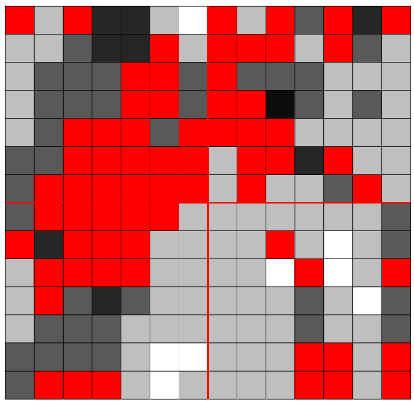

Fig. 8 Land degradation by slope and vegetation density

Cells in red indicated the areas where a high land degradation process is occurring, where slopes are bigger than 16%, vegetation density is low and agriculture is being conducted. It means that more than 35% of the study site is coming under this phenomenon.

The slope values and vegetation density variables were compared (Table 1).

Table 1 Relation between vegetation density and slope variables

Vegetation density value	Number of cells	Average slope values (%)
1	58	21.16
2	66	21.32
3	47	22.52
4	19	23.41
5	6	26.95

The highest number of cells presented a low vegetation density value, with 66 of the total of 196 cells of the study area, followed by the lowest value of vegetation density, with 58 cells. So, it could be said that there is a high level of land degradation, reflected in these data.

When comparing vegetation density mesh to land use mesh, it can also be observed that one cause that lowest vegetation density values are predominant because most of the community area is being used for conducting farming practices in hillsides.

So, as can be observed in the land degradation mesh, more than third of the research area is under a high land degradation degree. Even of this fact, still farming practices are conducting, such as maize, beans and chili cultivation as well as shepherding of goats.

CONCLUSION

Through the present analysis of the research area it can be concluded that the land degradation is serious in El Jicaral community, where the vegetation cover is low and where land use is mainly for agricultural practices in hillsides. For this reason, a suitable farming system should be proposed, for mitigating land degradation, taking into account, socioeconomic and environmental factors, such as topography, climate, production and land-owning systems, public policies and markets.

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