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ANALYSIS OF THE CAUSATIVE FACTORS BEHIND CHANGES TO FOREST COVER IN THE STATE OF MEXICO FROM 1993 TO 2000

Noel Bonfilio Pineda Jaimes[1], Joaquín Bosque Sendra[2], Montserrat Gómez Delgado[3] and Roberto Franco Plata[4]
[1,4] Faculty of Geography. Autonomous University of the State of Mexico
[2,3] Department of Geography. University of Alcalá

I. INTRODUCTION

Any analysis of changes to land use and occupation in a given region implies an attempt to understand the interaction between diverse socioeconomic and biophysical factors. In the case of forest cover, whether tropical or temperate, changes may be due to a variety of causes and factors (Lambin, 1997; Bocco *et al*. 2001). The strongest and most frequent effects of such changes in a region concern climate, hydrology, soil quality, food shortages, risk of illness and loss of biodiversity (Chhabra *et al*. 2006).

Numerous empirical techniques currently exist for exploring, explaining and predicting changes to land use and occupation, such as exploratory data analysis, regression analysis, Bayesian statistics and artificial neural networks (Lesschen *et al*. 2005). In the case of deforestation processes, these techniques are generally used to model and quantify the magnitude of relationships between causative factors and loss of forest cover.

In recent years, deforestation and changes to forest ecosystems have been a source of concern in numerous regions of Mexico, and consequently, various sectors in the country have become involved in assessment and analysis of the phenomenon. Some of these have recognised the enormous complexity involved in studying the causes and origins of these processes (Merino and Segura, 2002). The State of Mexico is not exempt from this problem, and thus the primary aim of this study was to understand and relate the causes and factors leading to loss of forest cover in the study area between 1993 and 2000. To this end, the following specific objectives were set: (1) to estimate and fit a multiple linear regression model (MLR) for each type of forest cover, (2) to estimate and fit a logistic regression model (LR) for each type of forest cover, and (3) to analyse the results obtained with these regression models, in order to compare two different spatial observation units.

II. METHODOLOGY

1. Material

Two digital forest cover maps at a scale of 1:250 000 and provided by the Mexican National Institute of Ecology (INE) were used as the reference baseline for this study. The cartographic basis comprised a 1993 map, designated series II, produced by the Mexican National Institute of Statistics and Geography (INEGI), and another map from 2000 corresponding to the Mexican National Forest Inventory of 2000 (IFN2000) produced by the INE in conjunction with the Institute of Geography (IG) at the National Autonomous University of Mexico (UNAM).

The advantages of these maps compared with the cartography used by Pineda *et al*. (2009) included better geometric and thematic quality, both as regards the series II map and IFN2000 coverage, and the compatibility strategy employed when compiling each data base so that they were statistically and cartographically comparable (Velázquez *et al*. 2002). However, one disadvantage was that the period studied in the present research was shorter.

2. Methods

Two of the analytical methods most commonly used for this type of study were applied. Firstly, taking the municipality as the spatial observation unit, multiple linear regression was employed using municipal socioeconomic and biophysical information as independent variables. Secondly, taking the pixel as the spatial observation unit, the influence of certain factors which lead to loss of forest cover was analysed. Logistic regression models were estimated according to a series of socioeconomic and biophysical factors.

In order to identify the main factors which had most impact on the process of forest and jungle loss in the study area, municipal statistical data were compiled, separating the information into two spatial units: municipal level and pixel level. On the basis of the information obtained, various potential variables were selected corresponding to factors related to loss of forest cover. A Pearson's correlation analysis was conducted in order to measure the intensity of the association between the explanatory variables. Those variables which did not correlate with each other and which presented greatest explanatory power were selected. Lastly, in order to validate the goodness-of-fit of the models, ROC statistics were used.

IV. RESULTS

Considering the first three most influential coefficients in all the MLR models, it was concluded that the biophysical variables exercised most influence on deforestation processes, followed by land tenure and availability of credit and subsidies. This demonstrates that some of the variables were associated with factors related to agricultural expansion and with political and institutional factors. The first case was considered a direct and immediate cause

of deforestation, whilst the second represented an indirect, or secondary, cause. Biophysical variables were considered factors which exercised a mixed influence on the process, sometimes directly and sometimes indirectly.

As they corresponded to pixel level measurements, the results obtained from the LR model were more consistent as regards the proximity variables and once again, this group was associated with factors related to agricultural expansion and political and institutional factors, together with variables related to expansion of infrastructures.

If the results obtained from both the methods employed in this study are analysed from the perspective of type or group of variables, it can be seen that no clear pattern of variables which influence the deforestation process emerged which was significant in both models. However, if the results are analysed from the perspective of causative factors of change, it can be observed that agricultural expansion and political and institutional factors emerged as significant variables in both of the regression models employed. As regards the type of causes which have an impact in both models, it would appear that direct causes have greater impact according to the LR model, possibly due to the type of unit analysed, whilst according to the MLR model, mixed causes have greater impact.

V. DISCUSSION AND CONCLUSIONS

1. Discussion

Two spatial observation units and two different statistical techniques were employed, yielding quantitative results which measured the positive and/or negative impact of the variables used on four types of forest cover. Multiple linear regression was used for a municipal level analysis of the variables which had most influence on deforestation processes, whilst pixel level logistic regression contributed to improved understanding of the probable impact of explanatory variables on loss of forest cover.

Nevertheless, the goodness of both the statistical methods applied presented disadvantages which should be considered. It will be necessary to explore mechanisms for overcoming problems such as loss of information due to data aggregation, spatial autocorrelation, re-expression of statistical variables, or the non-normal distribution of data in some models, for example. In addition, it should be borne in mind that the assumptions of MLR and LR methods do not include a consideration of spatial behaviour in geographical data. Lastly, one of the disadvantages of using LR is the high spatial autocorrelation presented by data aggregated at municipal level.

2. Conclusions

This study presents elements which help to explain the extent to which the factors employed are related to or responsible for deforestation processes in the State of Mexico. The results show that the joint application of statistical methods and GIS technology constitutes a powerful tool for geographical analysis. These methods could serve as the methodological basis for future forestry planning procedures within the municipality and in other regions of the country. The statistical analysis proposed in the present study has provided quantitative

results which will help to improve understanding of the causes and mechanisms of change to forest cover.

The results of this research show that in some regions of the state of Mexico, social organisation has certain implications for loss of forest and jungle cover, although further research will be necessary in order to confirm this finding.