Dinámica espacio-temporal de la cobertura y uso del suelo en una cuenca hídrica

Dynamic spatio-temporal coverage and land use in a water basin

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Resumen

Este trabajo contribuye al conocimiento del cambio de cobertura y uso del suelo, su dinámica y proyección en una cuenca. Para ello se utilizó una combinación de herramientas de percepción remota, sistemas de información geográfica y técnicas de análisis de dinámica de cambio (tasa de cambio, procesos de transición, índice de permanencia y escenarios tendenciales).

Los resultados y su análisis sugieren que la dinámica espacio temporal de la cobertura y uso del suelo en la cuenca del río Mololoa en Nayarit, México, puede definirse en cuatro procesos: degradación antrópica/deforestación, revegetación, conversión y permanencia, con tasa de cambio anual (TCA) de -1.4 % para rasgos naturales y 0.9 % para rasgos antrópicos; disminución de 4162 ha de vegetación secundaria; porcentaje de permanencia arriba de 90 para las diferentes coberturas, excepto vegetación secundaria (56 %). Se concluye que la cuenca del río Mololoa presenta un proceso acelerado de transformación de la cobertura vegetal a usos del suelo antrópicos, que pone en riesgo los servicios ecosistémicos y, por lo tanto, la capacidad de abastecimiento.

Palabras clave: paisaje, cambio de cobertura, uso del suelo, dinámica espacial, cuenca, SIG.

Abstract

This work contributes to the knowledge of the change in coverage and use of soil, its dynamics and projection in a basin. It was a combination of tools from remote sensing, geographic information systems and analysis techniques of dynamics of change (rate of change, processes of transition, rate of permanence and trend scenarios).

Results and their analysis suggest that the dynamic space temporary coverage and land use in the basin of the Mololoa River in Nayarit, Mexico, can be defined in four processes: anthropogenic degradation / deforestation, revegetation, conversion and permanence, with Rate of Annual Change (TCA) - 1.4% for natural features and 0.9% for anthropic features; decrease of 4162 has secondary vegetation; percentage of staying above 90 for the different coverages, except secondary vegetation (56%). It is concluded that the Mololoa River basin presents an accelerated process of transformation of vegetative cover to anthropogenic land uses, which puts at risk the services ecosystem and, therefore, the ability to supply.

Key words: landscape, coverage, soil, spatial dynamics, watershed, GIS.

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Introduction

Changes in coverage and land use have been recognized for more than two decades as a major cause of changes in the global environment (Chen and Yang, 2008), with implications to practically all scales (Garcia and Mas, 2008; Rosete et al., 2009). At the regional level causes changes in water cycles, changes in temperature and precipitation regimes, favoring thus the global warming, the decrease in carbon dioxide sequestration and the loss of habitats and biodiversity. Locally, they induce the deterioration and degradation of soils, microclimate changes and modifications in basin-wide water cycles (Masis and Vargas, 2014).

In Mexico, this problem has been increasing in recent decades; 52 million hectares of forests and jungles that was in the year 2000, presented a 631 thousand average deforestation rate ha/year (FAO, 2005) (Velázquez et al., 2002); considered one of the extreme ranges reported for Mexico by the Ministry of the environment and natural resources (SEMARNAT) in 2006 (316-800 thousand ha/year).

The decrease of vegetal cover has implications affecting the availability and quality of the environmental goods and services that offer. Among others, affects the infiltration of rain water, as well as the recharge of the water layers and balance in the water cycle (Mendoza et al., 2010) and, as a result, social security related to access to this vital resource (Gómez et al., 2014), which may lead to water depletion (Loya-Carrillo et to the., 2013). The processes of change of land use and coverage have become a central theme within the current environmental research because of its importance in the areas social, academic, and Government (Garcia and more, 2008). Their analysis allows us to understand the mechanisms of deterioration (Hernández - Gómez and Valdez-Reyna, 2012) and is a useful guide for decision-making on the use of the territory (Chen and Yang, 2008), particularly basin as the basic territorial unit for the management of water resources (Cotler and Caire, 2009).

The basin of the Mololoa River in Nayarit, Mexico, has been a source of goods and services for the inhabitants of the 34 towns settled in the place, which represent more than 50% of the total population of the State. This relationship with nature has been carried out without any planning that takes into account environmental criteria, resulting in accelerated deterioration of natural resources and promoting a low standard of living.

The present work aims to generate knowledge of baseline for the integration of instruments of management-planning of the territory and natural resources and thus contribute to decision-making planned in the sector. This evaluates the dynamic spatial and temporal coverage and land-use in the basin of the Mololoa River in Nayarit, Mexico, between the years 2000-2011 and its tendency to 2021.

Methodology

A survey covering land use was performed with images Landsat TM remote sensing dated February 2000 and February 2011, obtained from the server United States Geological Survey. The images were georreferidas using coordinates in the Universal Transverse Mercator map projection (UTM) (Zone 13 North) for integration within the Geographic Information System (GIS) environment.

the level of detail of the survey, which corresponds to the recognition (Table 1), which is aimed at studying the lessons of the second hierarchical level of the cover classification and land use according to the system of the Center for Research and Development was determined Geographic information (CIAF) (Melo and Camacho, 2005).

For the analysis of each of the covers and land uses in the period 2000-2011, the methodology of supervised classification maximum likelihood was used; in that the data follow a normal distribution function to assign the probability that a pixel belongs to each class. The pixel is thus assigned to the class most likely belong (Eastman, 2012).

Picture 1. *Cover Classification and Land Use under CIAF System*

Nivel 1 Exploratorio Gran Grupo	Nivel 2 Reconocimiento Grupo
Rasgos Naturales	Vegetación Natural Vegetación Secundaria
Rasgos Antrópicos	Cultivos Asentamientos e Infraestructura Tierras sin vegetación aparente

Training camps were selected by visual analysis using the compounds false RGB (red, green, blue) 321, true color RGB 432 protruding vegetation and RGB 542 to distinguish soils and urban areas (Melo and Camacho, 2005), with the support of digital orthophotos of the area under study and field data.

the equation proposed by the Food and Agriculture Organization (FAO) in 1996 (Ruiz et al., 2013), was used in the analysis and quantification of changes in coverage and land use and to calculate the annual change (TCA):

$$Tasa = \left[\frac{S_2}{S_1}\right]^{1/n} - 1$$

Where: S2 = superficie fecha 2, S1 = superficie en la fecha 1, n = es el número de años entre las dos fechas, multiplicado por 100 para expresarlo como porcentaje.

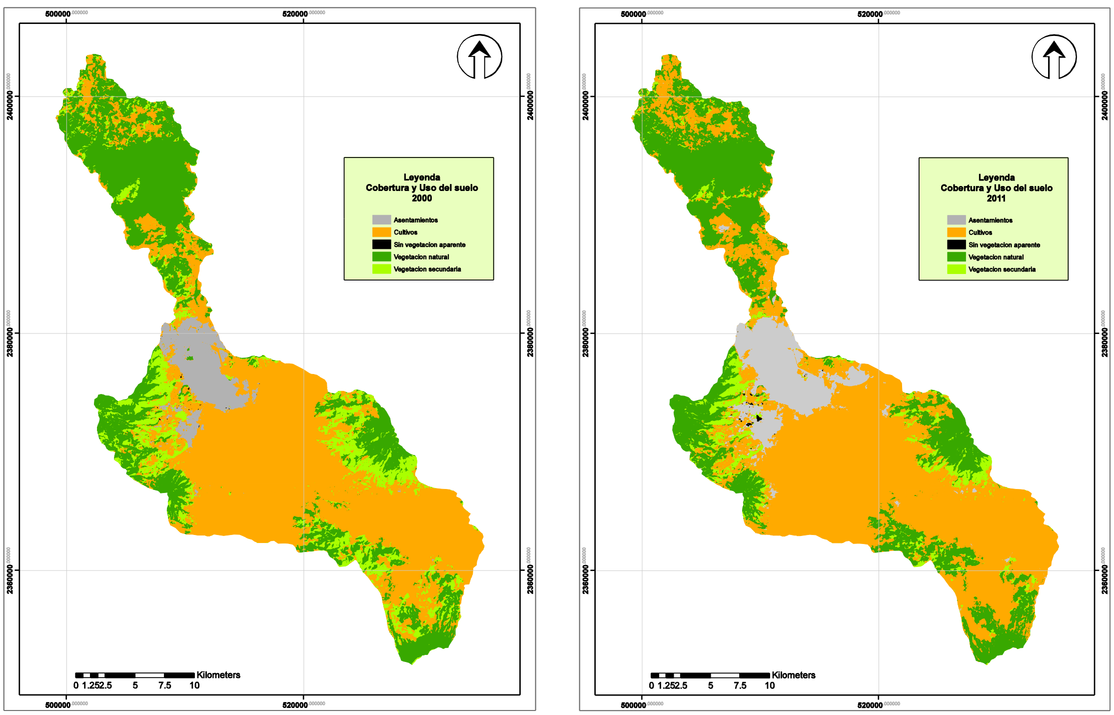
The dynamics of changes in coverage and land use is determined from the Evaluation Model Change Land Use (LCM: Land Change Modeler for Ecological Sustainability) integrated into the GIS, thereby changing trends were evaluated (Eastman, 2012) and the map of the transitional areas of coverage of 2000- 2011 and the tables of loss, gain and retention rates (Braimoh, 2006) was obtained. To generate a projection 20, the method of Markov chains, which assumes that the land use is a stochastic process where the change of different categories of land use depends on the state immediately before the change (Balzter, 2000 was used).

Results

Exchange rate

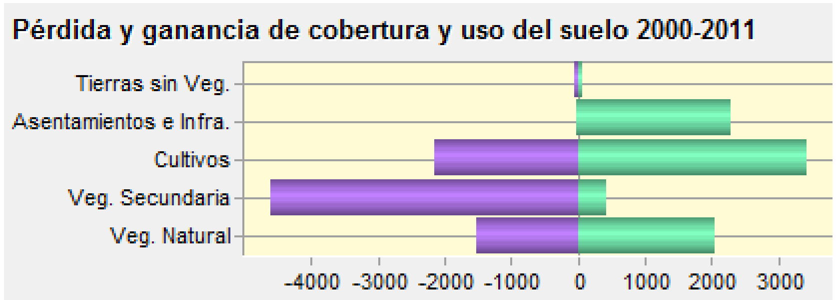
The analysis of the coverage surveys and land use shows that the natural features of vegetation accounted for 2000, 44.3% of the total area of the basin; while anthropogenic features, 55.7%. By 2011, these percentages changed to decrease to 37.9% natural features and man-made features to increase 62.1% (Figure 1, Table 2).

Figure 1. Coverage and land use for the year 2000 y 2011



A Large group level an annual rate of change (TCA) to natural features of 1.4%, with secondary vegetation is the most impacted (-4.6% TCA) with a net negative change of 4,162 ha was obtained (see Figure 1 and tables 2 and 3).

Grafica 1. *Loss and gain of Coverage and Land Use 2000-2011*



Picture 2. *Cover and land use annual rate of change (TCA) in the period 2000-2011*

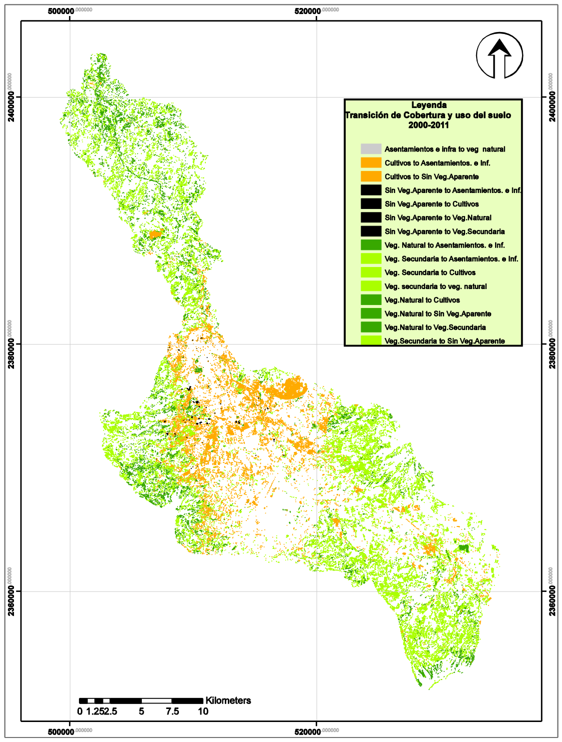
GRAN GRUPO	GRUPO	Superficie (ha) 2000	Porcentaje de Superficie %	Superficie (ha) 2011	Porcentaje de Superficie %	TCA
Rasgos Naturales	Vegetación Natural	15 017	26.3	15 550	27.3	0.3
	Vegetación Secundaria	10 215	17.9	6054	10.6	-4.6
	Subtotal	25 233	44.3	21 604	37.9	-1.4
Rasgos Antrópicos	Cultivos	28 107	49.3	29 372	51.6	0.4
	Asentamientos e Infraestructura	3574	6.2	5898	10.3	4.6
	Tierras sin Vegetación	46	0.1	86	0.1	5.8
	Subtotal	31 728	55.7	35 356	62.1	0.9
	TOTAL	56 960	100	56 960	100	

Picture 3. *Loss and gain of Coverage and Land Use 2000- 2011*

Coberturas y Uso del Suelo	Pérdida hectáreas	Ganancia hectáreas	Cambio neto hectáreas
Vegetación Natural	-1 511	2 044	533
Vegetación Secundaria	-4 596	434	-4 162
Cultivos	-2 155	3 420	1 265
Asentamientos e Infraestructura	0	2324	2324
Tierras sin Vegetación	39	79	40

The results on the retention rate to 91% yield of 56% natural vegetation and secondary vegetation are hedges that do not present any kind of transformation in the analysis period. From the above it follows that the secondary vegetation was most impacted by changes in land use in the period 2000 to 2011 (see Figure 2 and Table 4).

Figure 2. *Coverage Gap and Land Use 2000-2011*



Picture 4. *Permanence of Coverage and Land Use 2000-2011*

Cobertura vegetal y uso del suelo	Hectáreas	Porcentaje de superficie de permanencia %
Vegetación Natural	13 725.8	91
Vegetación Secundaria	5 685.6	56
Cultivos	26 200.6	93
Asentamientos e Infraestructura	3 583.9	100
Sin Vegetación Aparente	7.4	16

With respect to the coverage of settlements and infrastructure, retention is 100%, a group that in 2011 has increased 2324 to 2000. existing Meanwhile, the cultures were maintained in 96% and in areas without vegetation apparent only 7.4 ha are permanent, that is, the gain of 40 ha in 2011 took place mainly on land cover, changing to mine stone material (see tables 3 and 4).

Transition cover change and land use

The results indicate that the dynamics of change is greater on plant hedges (natural and secondary), which change to other land uses (crops, settlement and infrastructure and mining) (Table 5).

Picture 5. *Transition Coverage and land use 2000-2011*

Cobertura y Uso del Suelo 2000	**Cobertura y Uso del Suelo** 2011	**Hectáreas**
Vegetación Secundaria	Vegetación Natural	2 044
Vegetación Natural	Vegetación Secundaria	433
Vegetación Natural	Cultivos	1 060
Vegetación Secundaria	Cultivos	2 335
Tierras sin Vegetación	Cultivos	25
Vegetación Natural	Asentamientos e Infraestructura	17
Vegetación Secundaria	Asentamientos e Infraestructura	191
Cultivos	Asentamientos e Infraestructura	2 104
Tierras sin Vegetación	Asentamientos e Infraestructura	13
Vegetación Secundaria	Tierras sin Vegetación	27
Cultivos	Tierras sin Vegetación	51
Total		8 299

With the assessment model change in land use (LCM, for its acronym in English), the coverage gap and land use was obtained, this shows that in the period of analysis natural vegetation is replaced by secondary vegetation (433 ha), crops (1060 ha), and settlements and infrastructure (17 ha) (table 5).

Projection 2021-2041

The tendency to remain in natural hedging decreases as the years progress, ie 2021 is expected to remain 90% of the natural vegetation of 2011, but in 20 years (2041), only continue for 74% (see tables 6 and 7). This same behavior occurs in secondary vegetation but with greater impact: decreasing from 56% in 2011 to 18% in 2041; and decreasing crop of 92% in 2021 to 79% in 2041, yielding surface for settlements and infrastructure.

Picture 6. *Trends in coverage and land use for 2021 in the basin of river Mololoa*

Cadena de Markov para 2021					
	Vegetación Natural	Vegetación Secundaria	Cultivos	Asentamientos e Infraestructura	Tierras sin vegetación
Vegetación Natural	0.9	0.0	0.1	0.0	0.0
Vegetación Secundaria	0.2	0.5	0.2	0.0	0.0
Cultivos	0.0	0.0	0.9	0.1	0.0
Asentamientos e Infraestructura	0.0	0.0	0.0	1.0	0.0
Tierras sin vegetación	0.0	0.0	0.5	0.3	0.2

Picture7. Trends in coverage and land use for 2041 in the basin of river Mololoa.

Cadena de Markov para 2041					
	Vegetación Natural	Vegetación Secundaria	Cultivos	Asentamientos e Infraestructura	Tierras sin vegetación
Vegetación Natural	0.7	0.0	0.2	0.0	0.0
Vegetación Secundaria	0.3	0.2	0.4	0.1	0.0
Cultivos	0.0	0.0	0.8	0.2	0.0
Asentamientos e Infraestructura	0.0	0.0	0.0	1.0	0.0
Tierras sin vegetación	0.0	0.0	0.5	0.4	0.0

Discussion

The results show a decrease in vegetation cover and increased coverage of anthropogenic, global trend in deforestation caused by changes in agricultural and urban use (FAO, 2010). They also agree to similar work for the period 1995-2005 reported locally (Najera et al., 2010); FAO (2010) for the period 1990-2010; Céspedes Moreno-Flores and Sanchez (2010) 2000-2005, and reported by SEMARNAT (2012) for the period 2005-2010 nationwide.

The dynamic pressure on natural hedges and secondary vegetation, is explained by the index of economic pressure to deforestation (IPED) reported by the National Institute of Ecology and Climate Change (INECC, 2011); This index is based on Von Thünen type models where the motivation of changing land use is to dedicate the land for activities that generate greater income for their owners. In this regard and as the natural and existing secondary vegetation in the basin is located in areas close to agricultural and urban areas, has a very high IPED, becoming profitable by changing land use and therefore most likely to deforestation .

Meanwhile, the increase in the coverage of settlements and infrastructure is related to the population growth in the area shows an accelerating trend from 1940, which at that time had a population of 23,901 inhabitants then increased to 429 351 inhabitants in 2010. It also shows a marked migration trend of rural population to cities (Marceleño et al., 2014).

Conclusions

Spatiotemporal dynamics of coverage and land use in the basin of river Mololoa defined in four processes. anthropogenic degradation / deforestation: in 38% of the basin area in 2011, with a negative rate of 1.4% annual deforestation greater than the national average reported in 2005. The change agents are linked to this process of urbanization, building services and mining of stone material as well as the expansion of agricultural areas. Revegetation: this process is associated with conservation policies by declaring this area as a protected area and implement the program of management, to recover about 1% of the forest area in 10 years. Permanence: all (100%) of the settlements and infrastructure are constant, while 93%

of the crops remain; 91% of the natural vegetation is located in the upper reaches of the basin is continuity, while secondary vegetation persists in 56%.

Conversion between anthropic hedges (change in uses for anthropogenic soil) crops are the group that presented greater dynamism to lose and win 2155 has 3420 ha in the analysis period with a net profit of 1 265 ha.

Finally, Mololoa River Basin, where 56% of the population of the State of Nayarit sits presents an accelerated transformation of the vegetation cover uses of anthropogenic soil, endangering the ecosystem goods and services for the population process.

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