e-ISSN:2706-6800

Research Open Access

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Transitional dynamics of paramo grassland ecosystem and the primary activities through neural networks in an Andean lake complex, Sangay National Park

Dinámica de transición del ecosistema herbazal de páramo frente actividades primarias mediante el uso de redes neuronales en un complejo Lacustre Andino, Parque Nacional Sangay

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Abstract

The present study shows the change in three decades, where gains and losses of cover of the páramo ecosystem were analyzed in the Ozogoche lake complex; whose surface area is 9397.97 ha, an altitudinal range from 3792 to 4096 m.a.s.l., average temperature from 4 to 12°C and precipitation 1000-1200 mm. A Land Use Change Modeler (LCM) was used for land cover change; six categories were established, forest (B), páramo (Pr), crops (C), pasture (Ps), water bodies (A) and forest plantations (Pf); during the period 1991-2001, Pr showed gains of 503 ha and losses of 305 ha, a net change of 808.8 ha; the forest category (B), suffered a loss of 41 ha and a gain of 19 ha with a net change of 60 ha, this value shows a moderate and slow change trend; category changes for the decade from 2001 to 2011, show a change for (B) with loss of 30 ha and gain of 13.92 ha, a net change of 43.92 ha; the Pr category shows losses of 2201.2 ha and gain of 1334.8 ha, a total change of 3536 ha, the change between categories in this time is systematic, but it is much more marked in terms of loss of fragile ecosystems; the trend of páramo 0.94 shows the probability of displacement to other categories, mainly to pasture, crops and forest plantations.

http://centrosuragraria.com/index.php/revista, Published by: Edwards Deming Institute, Quito - Ecuador, July - September vol. 1. Num. 14. 2022,

Received January 01, 2022
Approved: June 28, 2022

Key words: Conservation, land management, páramo, resilience, land use.

Resumen

El presente estudio muestra el cambio en tres décadas, donde se analizaron ganancias y pérdidas de cobertura del ecosistema páramo en el complejo lacustre Ozogoche; cuya superficie es 9397.97 ha, un rango altitudinal de 3792 a 4096 m.s.n.m, temperatura promedio de 4 a 12°C y precipitación 1000-1200 mm. Para el cambio de cobertura vegetal se empleó un Modelador de cambio de Uso del Suelo (LCM, Land Change Modeler); Se establecieron seis categorías, bosque (B), páramo (Pr), cultivos (C), pastos (Ps), cuerpos de agua (A) y plantaciones forestales (Pf); durante el período 1991-2001, el Pr mostró ganancias 503 ha y pérdidas de 305 ha, un cambio neto de 808.8 ha; la categoría bosque (B), sufrió una pérdida de 41 ha y una ganancia de 19 ha con un cambio neto de 60 ha, este valor muestra una tendencia de cambio moderada y lenta; los cambios de categoría para la década del 2001 hasta el 2011, muestran un cambio para (B) con pérdida de 30 ha y ganancia de 13.92 ha, un cambio neto de 43.92 ha; la categoría de Pr muestra pérdidas 2201.2 ha y ganancia de 1334.8 ha, un cambio total de 3536 ha, el cambio entre categorías en este tiempo es sistemático, pero es mucho más marcado en función a pérdida de ecosistemas frágiles; la tendencia de páramo 0,94 muestra la probabilidad de desplazamiento a otras categorías, principalmente a pasto, cultivos y plantaciones forestales.

Palabras clave: Conservación, ordenamiento territorial, páramo, resiliencia, usos de suelo.

Introduction

The páramos are semi-humid and cold ecosystems located on the Andes Mountains, above the upper limit of the forest, characterized by having a vegetation of low vegetation and a low humidity. (Mena, Medina, & Hofstede, 2001)In biological terms, the páramos constitute an important part of the extraordinary ecological diversity of a relatively small country like Ecuador, but with an environmental and biological variety greater than that of countries with much larger areas. (Mittermeier, Myers, Thomsen, Da Fonseca, & Olivieri, 1998). The diversity of these ecosystems is attributed to the adaptation of species in adverse ecosystems that have interacted over time. (Azócar, 1981).

In Ecuador, the páramo covers about 1 250 000 ha, approximately 6% of the national territory and contains almost 30% of Ecuador's vascular plant species. (Medina & Mena, 2001)This demonstrates the presence of this ecosystem and the importance of diversity in these ecosystems. (Magurran, 1988)This kind of information will serve as a starting point for the monitoring of climate change, and thus be able to define how the flora behaves in the face of this type of variation. (Rodríguez, Armando, Guido, Guillermo, & Enrique, 2016)..

The degradation of the ecosystems that constitute the páramo zones, determine the need to broaden the perception of their current and future conditions, in order to propose the precepts for the definition of a management plan for environmental planning and zoning of the territory in accordance with the potential of the ecosystems found in these zones. (Alvizu, 2004).

The present study aims to determine the current state of the páramo ecosystems using a Land Use Change Modeler (LCM) that is incorporated in the Geographic Information System (GIS), IDRISI developed by Clark Labs, which is based on a network-based GIS. (Eastman, 2012)The LCM is based on artificial neural networks to obtain information in a systematic and continuous way from large extensions of land impossible to cover with any other kind of methodology. (Paegelow & Olmedo, Spatio-temporal simulation models and remote sensing, the segmentation method for chronological land use mapping, 2010)..

The community of Ozogoche is of great importance because it is formed mostly by a paramo ecosystem, which is under anthropic threat, that is why it is important to carry out this type of study to help determine the floristic composition and serve as a basis for projects that help protect the resources available and in turn become a source of economic income for the local inhabitants.

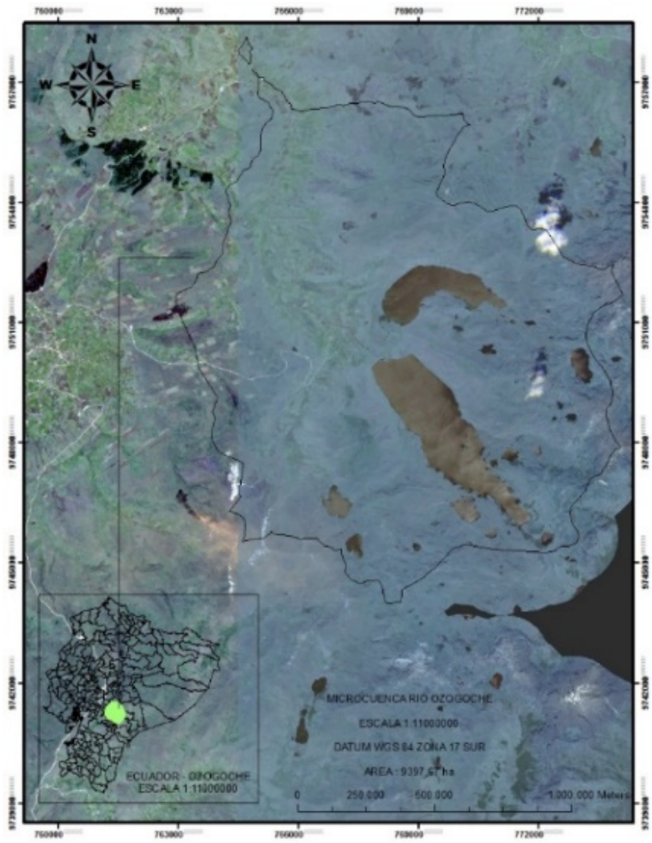
The stratification was carried out based on the land use classes present in the study area, considering the size of the micro-watershed where three strata were differentiated (MAE Continental Ecological Classification 2012). The study area that encompasses the Ozogoche River micro-watershed has an area of 9397.97 ha, these results are of utmost importance for the care and preservation of ecosystems vulnerable to climate change.

The information generated in this type of studies is of vital importance in the management of these ecosystems, making it possible to locate the areas with the greatest degree of affectation over time and to identify the possible causes that generate it. (Wilson & Weng, 2011)These aspects will eventually serve as input in the development of management plans and conservation policies aimed at the protection and sustainable management of these sensitive areas. (Izco, 2007).

Materials and methods

The research was carried out in an area corresponding to the upper micro-watershed of the Ozogoche River, where two communities, Ozogoche Alto and Bajo, are located, with an area of 9397.97 ha and an altitudinal range between 3792 - 4096 meters above sea level. The data obtained from the yearbooks of the meteorological station (M396 INHAMI 2012) show an average temperature of 8ºC, with ranges of (4 - 12) °C; a precipitation of 1077 with ranges of (1000 - 1200) mm. The soils are sandy loam of great depth, (50-100) cm; with high organic matter content. In the upper micro-basin there is a lake complex made up of thirty main lagoons. At the local, national and regional levels, this area is considered of the utmost importance because of the environmental services it provides to the surrounding communities, including water supply for human consumption, irrigation and hydroelectric plants.

Figure 1. Study area Upper Ozogoche micro-watershed



Our analysis was focused, under a double stratification sampling design, in the first part the strata were selected considering the land uses of the study area, classifying in quadrants of (1*1) km; the second part consisted in estimating the weight in proportion of the strata (%), where plots were implemented for each stratum, for which equations were used, modified from forest inventories. (Fonseca, Alice, & & Rey, 2009)..

$$n = \frac{t^2 * CV^2}{E_{\%}^{\ 2}}$$

Base cartographic inputs were used, generated by the Instituto Geográfico Militar (IGM) at a scale of 1:50,000 (Beltrán et al. 2009). In addition, Rapid Eye and Landsat 8 images provided by the Ministry of Environment of Ecuador (MAE) were used, with a resolution of 5 meters and 30 meters respectively.

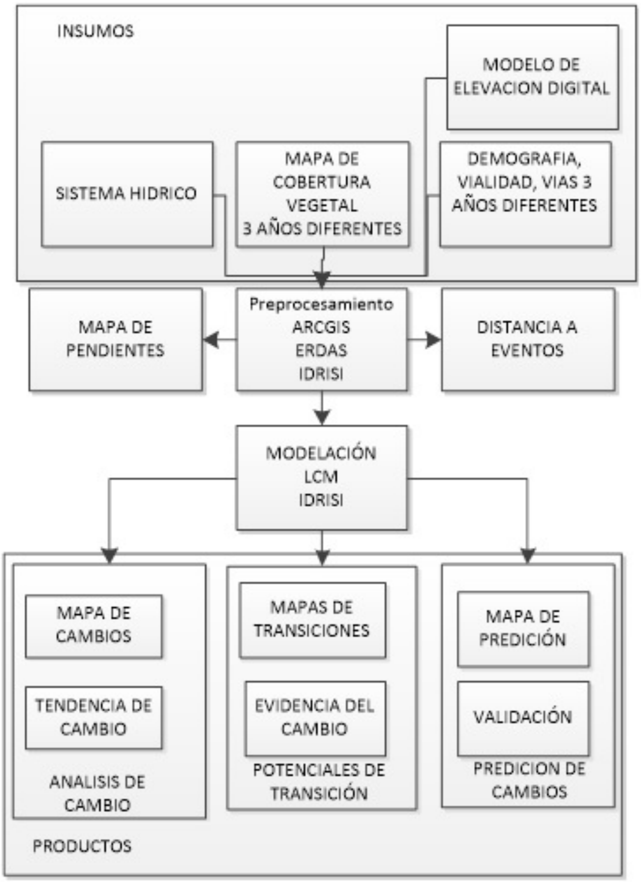
The supervised classification was performed with the Maximum Likelihood method, which uses numerical manipulation of the images, which can be interpreted and classify the digital numbers that represent each pixel and convert them to a language that can manipulate and work in different enhancements, with this method to achieve a different mapping. (Aguayo, Pauchard, Azócar, & Parra, 2009)..

This procedure allowed the creation of a database for the years (1991-2001-2011), with numerical and geographic data that were visually evaluated through coloration scales of vegetation masses. The changes in vegetation cover and the gain or loss of páramo area as a consequence of a natural or anthropogenic phenomenon were evaluated. (Ruiz, Savé, & Herrera, 2013)..

For the land cover change study, a Land Use Change Modeler (LCM, Land Change Modeler) that is embedded in the Geographic Information System (GIS), called IDRISI developed by Clark Labs, was used. The Land Use and Land Cover Change Modeling (LUCC) (Mas, Kolb, Paegelow, Camacho Olmedo, & Houet, 2014) using past and current land cover information, provides information for environmental and land use planning. (Wilson & Weng, 2011).

In the following flowchart we can observe the inputs that must be prepared for the input to the model, various geographic information systems such as ERDAS, ARCGIS, IDRISI, can be used for the correct input to the model. Other "raster" data useful in modeling are obtained from these data. All the layers are necessary for the LCM in IDRISI with which the respective outputs of the subprocesses and the products of the modeler are obtained.

Figure 2. Soil Change Modeler Flowchart



Source: Authors,2022

Vegetation cover changes in the area were included to manage different scenarios. This allowed predicting impacts derived from anthropogenic intervention. The LCM is based on neural networks, the maps of transitions generated by this modeler have presented optimal levels of accuracy. (Oñate & Bosque, 2010). The comparison between the maps of potential change generation with observed deforestation (LUCC Land Use and Cover Change), using the method of weights in categories of 0-1, which allows to identify the transition potential and the data entropy. (Pérez & F, 2012).

In order to use this methodology, it was necessary to take into account 4 important factors. (Sohl & Claggett, 2013).:

- Document the source code of the model.
- Have reference scenarios to frame uncertainties.
- Improve methods for the propagation of key processes in land use and change.
- Adopt scientifically rigorous measures for uncertainty quantification and model validation.

The LUCC model used input values as if they were only one (global input), these values are represented as weights of the input values, these are not restricted but change as the influence they have on the input values was evaluated, i.e. the input variables (output) of roads, slope, settlements and uses, are evaluated and distributed according to their influence within a system, to obtain the Skill measure, and interact with the hidden layers to have accuracy rates according to the certainty values in order to establish the ideal characteristics of the change and the prediction model generated by it. (Pineda Jaimes, Bosque Sendra, Gómez Delgado, & Plata Rocha, 2009)..

Input function of LUCC neural networks.

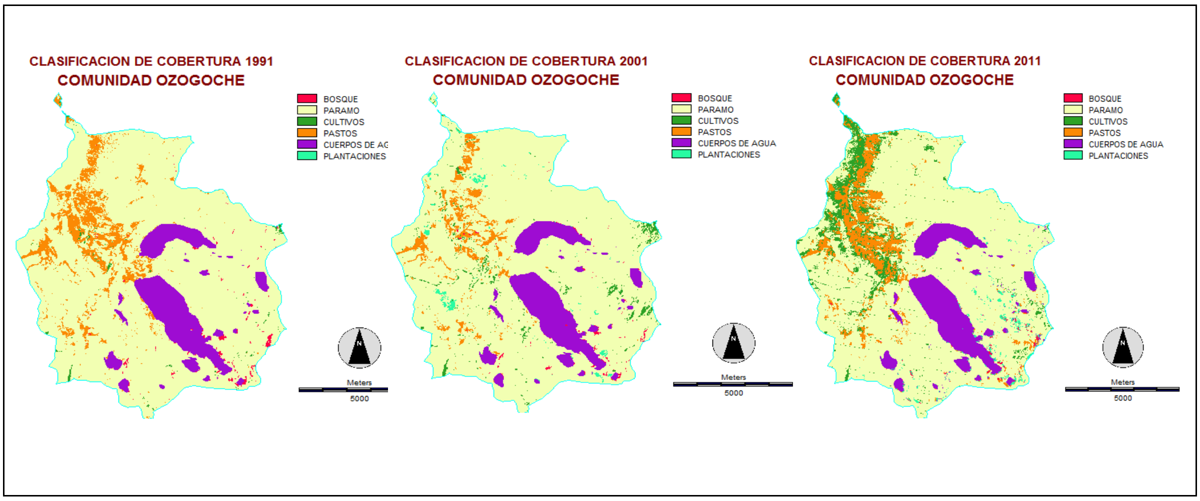
$$imput_i = (in_{il} * w_{il}) * (in_{i2} * w_{i2}) * \dots (in_{in} * w_{in})$$

There are different types of vegetation cover classification, but no thresholds of data accuracy have been determined. The present study determines the influence of variables on change trends and the measures that should be considered when evaluating a cover.

Result

For a long time methodologies have been created to make the modeler work correctly, the primary information "INPUT", must be evaluated so that it complies with the logical characteristics, to establish interactions with the neural networks, which show variations of temporality according to reality, formats, spatial consistency in its extension, reference systems, pixel resolution, limit values to zero (0), area and categories must be evaluated before implementing these models. (Liu & Deng, 2010). The (Figure 03) shows the Ozogoche micro-watershed (9397.97 ha), which has the nearby communities of Ozogoche Alto and Bajo, a 12 km (91) third order road. In addition to 10% of it are water bodies (about 27 perennials), among the main ones are the Cubillín and Magtallán lagoons. It has an altitudinal range between 3792-4096 meters.

Figure 3. Land use 1991/2001/201



Source: Authors,2022

The maximum likelihood supervised classification is established with an algorithm that categorizes by segmenting areas defined by points in space (north and east coordinates), called training areas, (Paegelow & Olmedo, Spatio-temporal simulation models and remote sensing, the segmentation method for chronological land use mapping, 2010).The classification established six categories, forest, moorland, crops, pasture, water body, plantations; being the moorland ecosystem of greater surface occupying 78.69% in relation to the total; followed by water bodies (water/lake), with an average value in the three time periods with a value of 10.36%; pastures with an average of 6.75 and the other uses that together add up to 4.21% of the total surface.

Table 1. *Land Use Categories 1991-2001-2011*

Category	Legend	1991 has	2001 ha	2011 ha
1	Forest (B)	65.84	43.23	26.66
	Paramo (Pr)	7544.80	7742.7 9	6876.3 4
	Crops (C)	42.51	177.54	630.44
	Pastures (Ps)	767.27	390.93	743.85
5	Water/lake (A)	966.52	961.20	989.48
	Forest	0.090	71.16	127.36

	plantations (Pf)	

Source: Authors,2022

The change of category in high Andean zones has become alarming in recent years. Lack of training, inadequate management of soil resources, lack of land management policies and inadequate training have become a trigger for the increase of the agricultural frontier. Access to mechanization is one of the most important factors of change. (Paruelo, Guerschman, & Verón, 2005).In our study we were able to determine the changes detected by the maximum likelihood algorithm during three decades (1991-2001-2011).

Table 2. *Changes in land use categories 1991-2001-2011*

Category	Legend	1991 has	%	2001 ha	%	2011 ha	%
1	B	65.84	0.70	43.23	0.46	26.66	0.28
	Pr	7544.8	80.37	7742.79	82.49	6876.34	73.2
	C	42.51	0.45	177.54	1.89	630.44	6.71
	Ps	767.27	8.17	390.93	4.16	743.85	7.92
5	A	966.52	10.30	961.20	10.24	989.48	10.53
	Pf	0.09	0.001	71.16	0.76	127.36	1.36

Source: Authors,2022

During the first decade, it is clear to observe the change that arises in the grass stratum, which our classification also shows fragmented wetland areas due to its coloration in the combination of bands at the time of classification, with a value corresponding to 4% of the area corresponding to its category, while the transition of the other categories is constant in its proportionality, excluding exotic forest plantations that had an exponential increase at a rate of 1:8 times its initial area.

For the decade of 2011, different behaviors were observed in the transition of the categories, the most relevant change was observed in the moorland category, with a value of 9.79%, which shows a marked decrease in terms of area; in contrast, the cultivation category increased by 4.82%, showing a strong anthropic intervention.

Profit and loss

Several LUCC models have been developed, so it is difficult to compare which one gives an accurate representation; there are a number of land use modeling tools and techniques, the most widely used models is the integrated modeling technique in IDRISI. The Land Use Change Modeler (LCM) and Markov chains. (Mishra, Rai, & & & Mohan, 2014).. But LCM is widely used modeling tool. Land Change Modeler that performs the comparison of trend and land use changes as a function of change factors, roads, settlements, the LCM module works on neural networks and evaluates levels of accuracy, but this is highly dependent on the influencing variables, land use changes were evaluated by gains and losses by different classes.

During the 1991-2001 period, the páramo showed a gain of 503 hectares and a loss of 305 hectares, with a net change of 808 hectares; a fragile ecosystem such as the Andean brow forest suffered a loss of 41 ha and a gain of 19 ha with a total net change of 60 ha; the pasture category suffered a loss of 461 ha and a gain of 85 ha, with a net change of 546 ha; this loss will be analyzed in the transitions submodel; the páramo category was also representative in terms of its area since it suffered a gain of 71 ha, with a similar value of total net change. The total net change in all categories shows a moderate and slow change trend in relation to the area.

Category changes for the decade from 2001 to 2011, showed a representative change for forest with a loss of 30 ha and a gain of 13.92 ha, with a net change of 43.92 ha; the paramo category had a notable loss 2201.2 ha and a gain of 1334.8 ha, with a total net change of 3536 ha; the crop category had a gain of 526.59 and a loss of 73.8 ha, with a total net change of 600.39 ha; the pasture category suffered a loss of 432.3 ha and a gain of 79.71 with a net change of 512.01 ha; the forest plantation category suffered a loss of 56.14 ha and a loss of 2.1 ha, with a total net change of 58.24 ha; the change between categories in this time period is more systematic, but is much more marked in terms of the loss of fragile ecosystems analyzed in previous chapters.

Table 3. Profit *and loss 1991-2001-2011*

Category	Legend		1991-2001 Losses	Earnings	2001	2001-2011 Losses	Earnings	2011
1	B	0.70	-41		0.46	-30.0	13.92	0.28
	Pr	80.37	-305	503	82.49	-2201.2	1334.8	73.20
	C	0.45	-22		1.89	-73.8	526.59	6.71

	Ps	8.1 7	- 461	4.16	-432.3	79.71	7.92
5	A	10. 30	-17	10.2 4	-59.4	63.79	10.53
	Pf	0.0 0	0	0.76	2.1	56.14	1.36

Source: Authors,2022

Annual Percentage Rate of Change

The values of change are reflected with two positive trends (+) that show that the final area is greater than the initial area, represented by the annual or total variation in a given time, while the negative sign (-) shows that the final area is less than the initial area, the calculated value should be considered according to the total area of the study area and the vulnerable ecosystems that may exist in it; Generally, anthropic activities cause severe changes in the natural ecosystems; the opening of roads and population centers are the causes of changes in the categories; the main effects are the loss of ecosystem goods and services in the micro-watershed.

Table 4. *Annual rate of change 1991-2011*

Category	Legend	Changes (ha) 1991/2001	Changes (ha) 2001/2011	Annual rate of change (ha/year)
1	B	-22.61	-16.57	-1.96
	Pr	197.99	-866.45	-33.42
	C	135.03	452.90	29.40
	Ps	-376.34	352.92	-1.17
5	A	-5.32	28.28	1.15
	Pf	71.07	56.20	6.36

Source: Authors,2022

The trend showed a variation in two decades, manifesting the high values in the decade 2011-2017, in the páramo ecosystem with a loss of 866.45 ha, with an average annual value of 33.42 ha/year; while anthropogenic changes show a high growth, showing a value of 452.90 ha for the crop category, with an average annual gain of 29.40 ha; the smallest changes but corresponding to sensitive ecosystems are given by the loss of forest at a ratio of 22.61 ha in the decade 1991-2001, with an annual rate of 1.96 ha/year.

Transition and persistence, have a structure so that the multilayer perceptron neural network (MLP), which is one of the most widely used Artificial Neural Networks (ANN). The training of multilayer perceptron neural networks is based on Backpropagation (BP) which is a supervised training algorithm. It is a common method of training Artificial Neural Networks. Starting from a desired output, the network interacts with various inputs. An (MLP) is an automated process, which maps input data sets to an output set. An MLP consists of multiple layers of nodes in a directed graph, with each layer being fully connected to the next. The perceptron is an algorithm for supervised classification of an input into one of several possible outputs. MLP performs classification of remotely sensed images through multilayer perceptron neural network classifier using back propagation. (Matich Damian, 2001)..

Table 5. *Analysis of variables according to the transition and persistence submodel*

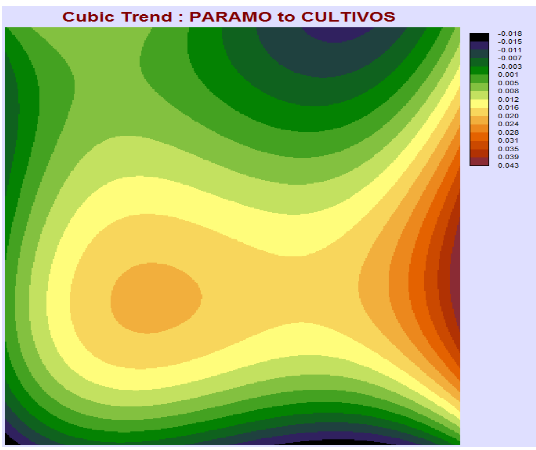
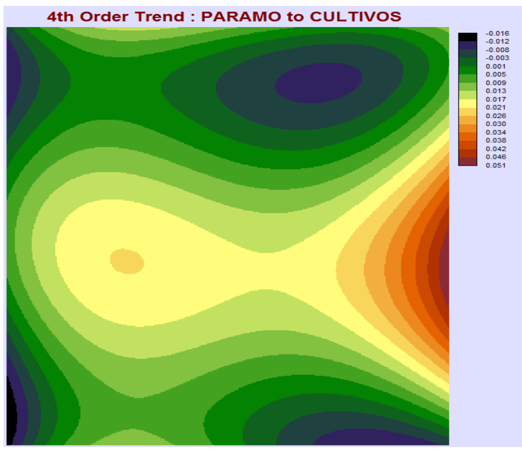
Input Files	Forcing a Single Independent Variable to be Constant			Model Skill Breakdown by Transition & Persistence	
Variable	Accuracy (%)	Skill measure	Influence order	Class	Skill measure
DEM	75.80	0.71		T Paramo to Pastures	0.200
DEM	59.19	0.51		T Bosque to Páramo	0.887
Changes (91/01)	48.91	0.39	1 (Last influential)	T Crops to Páramo	0.998
Changes (01/11)	27.42	0.13	1 (Last influential)	T Paramo to Crops* T	0.889
Villages 2001	81.35	0.78	6 (most influential)*	T Pastures to Páramo	0.200
Villages 2011	46.13	0.35		T Pastures to Crops	0.703
Class 91	81.18	0.77		P Páramo	0.887
Class 01	72.90	0.67		P Forest	0.857
Rivers	81.21	0.77	5	P Crops	0.200
Rivers	79.68	0.76	5	P Páramo	0.502
2001	81.09	0.77		P Pastures	0.499
Roads 2011	80.32	0.76	6 (Most influential)*	P Pastures	0.741

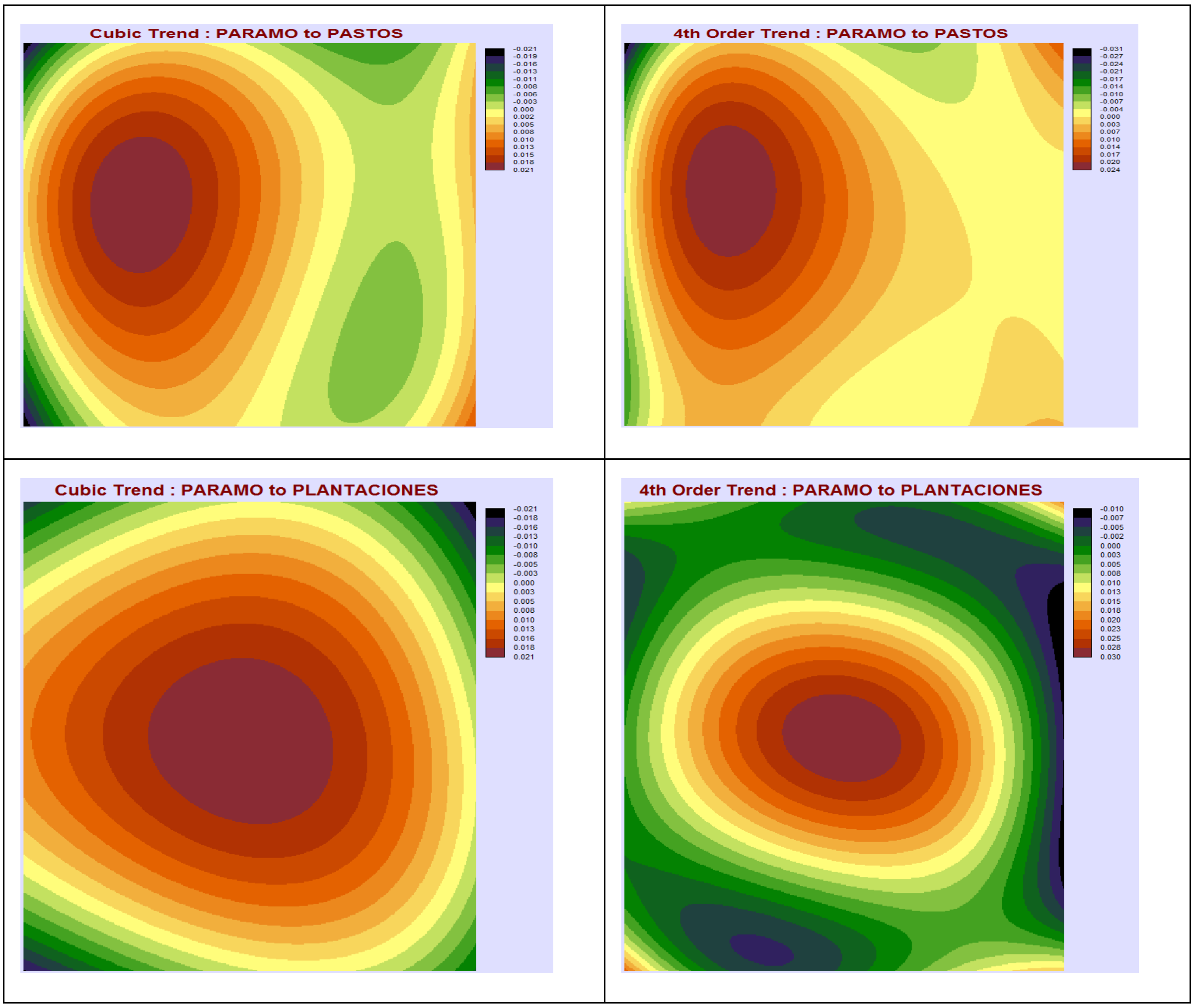
Analysis 1991/2001 Bold, 2001/2011 italic; *significance

The analysis of the transition (T) and persistence (P) submodel is based on the study of the crossed matrix of the weights of the neurons of the hidden layer and the neurons of the output layer, six variables that LUCC considers influential in the process of change were used, for the 91/01 change; a precision of 81.18% was determined, with an ability measure of 77.42; the order of influence to the change was established for the populated variable, this is due to the fact that the settlements at the beginning of the 90's, increased due to the opening of the facility of rural land acquisition in the projects of IERAC (Ecuadorian Institute of Agrarian Reform and Colonization), which resulted in the displacement towards the moorlands, contingency projects like FACE (Forest Absorbing Carbon Dioxide), implemented extensive areas with forest plantations as a measure of "reforestation" in areas that have no forestry aptitude. The changes occurred in the decade 2001/2011; determined a total precision of 80.32%, with a measure of ability of 0.76; the variable that has influenced in greater proportion was that of roads, the opening of new roads is a factor in the change of coverage, the settlements have access to the mechanization of the soil, the agricultural frontier increases systematically and in all uses; for the analysis of change tests were performed ignoring areas of transition between 0.1:0.1:1:1 ha and 1:1:1:13 ha; among which it is evident that there is a relationship to change by ignoring changes of less than 14 hectares, thus reducing from 22 to 6 transitions.

From the previous analysis, we can see the tendency of change to know which area generates the greatest change in coverage, and it is directly related to the introduction of roads, communities and influence of the geomorphology by the fluvial network, the changes in volume of the water bodies are negligible, around the Cubillín and Magtayan lagoon, but the tendency of all the variables have direct influence towards the zones that have been analyzed whose described indexes show a high floristic diversity, with emphasis on the paramo ecosystems.

Figure 4. Trends in change 1991-2011

1991-2001	2001-2011
	



Source: Authors,2022

The IDRISIS module implements Markov chains (MARKOV) and simulates the prediction of the state of a system at a given time from two preceding states. This means that the modeling does not take into account explanatory and descriptive variables, but is based exclusively on the analysis of the internal dynamics of the system, which, in our case, corresponds to the evolution of land use. It is a discrete procedure in discrete time, where the value at time t1 depends on the values at times t0 and t1 (second order Markovian chain). The algorithm compares two chronologically successive land cover maps, and estimates and configures a transition probability matrix. The prediction is materialized in a series of land cover maps (one for each category) for a future time, where the digital level of each pixel expresses the probability of belonging to the category under analysis. (Paegelow, Camacho

Olmedo, & Menor Toribio, Markov chains, multi-criteria evaluation and multi-objective evaluation for prospective landscape modeling, 2003)..

Table 6. *MARKOV Chain Analysis*

	Probability of changing to:					
CUT's	**B**	**Pr**	**C**	**Ps**	**A**	**Pf**
Forest	**0.4077**	0.5198	0.0068	0.0178	0.026	0.0219
Paramo	0.0017	**0.9492**	0.0198	0.0105	0.0012	0.0176
Crops	0.0127	0.3835	**0.4746**	0.1292	0	0
Pastures	0.0029	0.5664	0.0254	**0.4046**	0.0004	0.0004
Water Bodies	0.0065	0.0139	0.0007	0	**0.9763**	0.0026
Forest plantations	0.2	0.2	0.2	0.2	0.2	**0.001**

Source: Authors,2022

The MARKOV matrix shows the probability that an entire category changes or remains in its category, analyzing the directionality of change in previous analyses, the trend of moorland was observed with a 0.94 probability of change in other categories, thus showing us the transition submodels, which show that the trend of change towards other categories, mainly pasture and crops; the change generated on the basis of stochastic processes occurs in greater proportion in the categories of forest, pasture and crops, due to their dynamics in the analysis and the interaction generated in the changes in land use; Water bodies have a tendency of permanence according to the area; forest plantations will not suffer alterations according to their cutting season; this category has a particularity because when they reach their season they are extracted and the changes they can generate are not foreseeable, since they can be replaced by agricultural zones and in some cases they can be considered zones of assisted natural regeneration.

Conclusions

A supervised classification was established with the Maximum Likelihood algorithm, establishing 6 categories, forest (B), paramo (Pr), crops (C), pastures (Ps), water bodies (A) and forest plantations (Pf); the largest area corresponds to the Pr category, while the BPf categories occupy a smaller area. During the period 1991-2001, the páramo showed a gain of 503 ha and a loss of 305 ha, with a net change of 808 ha.8 ha; a fragile ecosystem such as the Andean brow forest (B), suffered a loss of 41 ha and a gain of 19 ha with a total net change of 60 ha; the Ps category suffered a loss of 461 ha and a gain of 85 ha, with a net change of 546 ha; the Pr category was also representative in terms of its area since it suffered a gain of 71 ha, with a similar value of total net change. The total net change in all categories shows a moderate and slow trend of change in relation to area.

Category changes for the decade from 2001 to 2011, show a representative change for B with a loss of 30 ha and a gain of 13.92 ha, with a net change of 43.92 ha; the Pr category has a notable loss 2201.2 ha and a gain of 1334.8 ha, with a total net change of 3536 ha; the crop category has a gain of 526.59 and a loss of 73.8 ha, with a total net change of 600.39 ha; the Ps category suffered a loss of 432.3 ha and a gain of 79.71 with a net change of 512.01 ha; the Pf category suffered a loss of 56.14 ha and a loss of 2.1 ha, with a total net change of 58.24 ha; the change between categories in this time span is more systematic, but is much more marked in terms of loss of fragile ecosystems.

The analysis of the transition and persistence submodel is based on the study of the crossed matrix of the weights of the neurons of the hidden layer and the neurons of the output layer, using six variables that LUCC considers influential in the process of change, for the 91/01 change; a precision of 81.18% was determined, with an ability measure of 77.42; the order of influence to the change was established for the population variable, this is due to the fact that the settlements at the beginning of the 90's, increased due to the opening of the facility of rural land acquisition in the IERAC (Ecuadorian Institute of Agrarian Reform and Colonization) projects, which resulted in the displacement towards the moorlands, contingency projects such as FACE (Forest Absorbing Carbon Dioxide), implemented extensive areas with forest plantations as a measure of "reforestation" in areas that do not have forest aptitude. The probability that an entire category will change or remain the same is the result of analyzing the directionality of change; the trend of moorland 0.94 shows the probability of displacement to other categories; the transition submodels show that the trend of change towards other categories, mainly to pasture and crops; the change generated on the basis of stochastic processes occurs in greater proportion in the categories of forest, pasture and crops, due to their dynamics in the analysis and the interaction generated in the changes in land use; Water bodies have a tendency of permanence according to the area; forest plantations will not suffer alterations according to their cutting season; this category has a particularity because when they reach their season they are extracted and the changes they can generate are not foreseeable, since they can be replaced by agricultural zones and in some cases they can be considered zones of assisted natural regeneration.

They express the synthesis of the main result obtained by the research process or study carried out, they are a consequence of the same and therefore the conclusions are directly related to the stated objective.

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