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Extended Abstract

Analysis of forest cover change and its influence on sustainability indicators in Ecuadorian Amazon†

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Abstract: The degradation of forest areas in the Amazon region, where many indigenous communities live, has shown a marked deterioration in recent years. The Yasuní Biosphere Reserve (YBR), placed on the Ecuadorian Amazon and settled by several indigenous groups, is considered a hotspot of natural and cultural diversity. In this study, we draw attention to the issue of forest cover management in the transition of cover zones on the YBR in the context of determining a relationship with anthropogenic activities. In our analysis, we use long-term vegetation data, from 2013 to 2020, and Landsat imagery to estimate changes in forest cover, grasslands, bare-soil and water, through a supervised classification. To determine the relationship between the Kichwa community sustainability indicator and vegetation changes, a multiple regression model was used which is based on a socio-productive survey completed by 133 Kichwa households. The results show that forest lost more than 11% of the areas between 2013 and 2020 and grasslands gained more than 10%. Annual changes in NDVI were mainly driven by land uses, economic viability and quality of life. This study is important in order to promote the continued use of green projects to address environmental change and improve the lives of indigenous communities.

Keywords: Forest cover change; Remote sensing; Sustainability; Indigenous communities.

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1. Introduction

The western Amazon, which includes territory in Bolivia, Colombia, Ecuador, Peru and western Brazil, is one of the most biodiverse areas on the planet for many taxa, including plants, insects, amphibians, birds and mammals [1]. The region contains large areas of intact tropical rainforest and has a high probability of stable climatic conditions in the face of global warming [2]. The western Amazon is also host to several indigenous ethnic groups, including some of the world's last remaining peoples living in voluntary isolation [3]. In the Ecuadorian Amazon Region (EAR) there are currently 11 officially identified nationalities, one of which is the Amazonian Kichwa, the most populous ethnic group in this region. The impacting environmental transformation in this region began in the 1970s with the intensification of oil exploitation, and thus the construction of roads, which were initially created to facilitate oil activities, but nevertheless brought about small-scale agricultural colonisation by migrant settlers, who were also pushed by government land tenure policies. These changes led to the rapid expansion of the agricultural frontier and consequent deforestation, affecting the quantity and quality of ecosystem services, which have been used ancestrally as a means of livelihood in the area [4]. Therefore, it is essential to know and understand the patterns and factors that may influence land cover change in order to guide optimal land-use planning decisions.

Modelling spatial scenarios of land cover change can be an effective tool for natural resource use management and planning, as it allows us to explore the origin over time of certain changes and thus support important conservation decisions. Our objectives included: (i) analysis to explore changes in land use within Kichwa community territories in the periods 2013-2014 and 2019-2020, and (ii) determine the relationship between Kichwa community sustainability indicators and changes in vegetation.

2. Materials and Methods

2.1. Study area

The target area is located along the Napo River, in the north of the YBR, where the Kichwa populations live. The Kichwa of this region are the most numerous indigenous populations in the EAR (60,000 inhabitants) [5]. The study was conducted in two sectors, A and B, located in the Yasuní National Park (YNP), which is considered one of the areas with the greatest biological and cultural biodiversity on the planet [6], including the Yasuní National Park (YNP,) Waorani Ancestral Territory (WAT), Tagaeri Taromenane Intangible Zone (TTIZ), and the Fringe of Diversity and Life (FDL), located in the EAR. The YBR was announced by UNESCO in 1989; it is located in the provinces of Orellana (51.96%), Pastaza (39.40%) and Napo (8.64%).

2.2. Data Collection and processing

Multi-sensor remote sensing data were used in this study to map and analyze the land-cover change in the study area. Specifically, the data included Landsat Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) satellite data from the United States Geological Survey (USGS) at 30 m spatial resolution. The data were preprocessed and derived from Google Earth Engine (GEE) [7]. To estimate land-cover change in the study area, two maps of land cover were created for the periods 2013-2014 , and 2019-2020.

2.3. Land cover classification and change detection

The LC classification is based on a supervised approach that, as usual, needs to collect from the training points the necessary information used to train the classifiers [8]. We use random forest classification to classify forest, pasture, bare-soils and water, within the two land cover maps. To train and test the effectiveness of the classifier, 432 points were collected as reference data using high-resolution imagery from Google Earth. The data is then randomly divided into training (50 %) and test (50 %) datasets. Accuracy assessment is an important step to know the accuracy of the result in order to be able to use the data correctly [9].

The change detection technique enables us to describe and quantify images of the same scene at different times including the spatial-temporal dynamic patterns, magnitude and rate of variations observed over the study period. We calculated the area (km2 and %) of the different land covers and also to observe and identify the changes occurring in the different LC classes in 2013-2014 and 2019-2020. We also elaborated a transition matrix to show the transition sizes of the LC between the classified periods.

2.4. Data collection for: sociodemographic conditions and sustainability indicators.

Surveys were conducted in 133 Kichwa households with traditional agroforestry systems (Chakras) in 2018, sampling was carried out using the reference chain or snowball methodology [10]. They were distributed by sector: Sector A (61) and Sector B (72). We studied the socio-demographic conditions, the characteristics of accessibility to viability and marketing opportunities for chakra products.

The sustainability of the chakras was assessed using the RISE methodology to integrally evaluate the sustainability of the traditional agroforestry system (chakra). The dimensions considered were economic, social and ecological, which made it possible to analyse and compare the degree of sustainability between the chakras. An interview was conducted with the owner of a chakra and lasted 95 min[11]. For the systematisation and analysis of the chakra data and the holistic evaluation, the RISE 3.0 software was used, based on the 10 standard indicators: 1. land use, 2. livestock production, 3. use of materials and environmental protection, 4. water use, 5. energy and climate, 6. biodiversity, 7. working conditions, 8. quality of life, 9. economic viability and 10. administration. The indicators are based on 50 parameters, rated from 0 (worst case) to 100 (best case). As a result, a sustainability polygon was issued, defined by the following areas: (1) good performance, green colouring (66.66-100); (2) medium performance, yellow colouring (33.34-66.65); and (3) poor performance, red colouring (0-33.33). The rating values in the RISE method are fixed and cannot be changed. The red line superimposed on the polygon indicates the degree of sustainability per indicator.

2.5. Relation between NDVI and sustainability indicators.

Annual values of NDVI and sustainability indicators in the study area have been extracted in order to estimate the relationship between them. The values were statistically analyzed to create a multiple linear regression model using Scikit-Learn, a machine learning package available in Python.

3. Results and Discussions

3.1. Land cover classification

LC maps of the study area are shown in the figure 1. The classified images showed an OA of 89.21%, and 89.62% in 2013-2014 and 2019-2020 images, respectively, with a kappa statistic of 0.8561, and 0.8614, respectively.

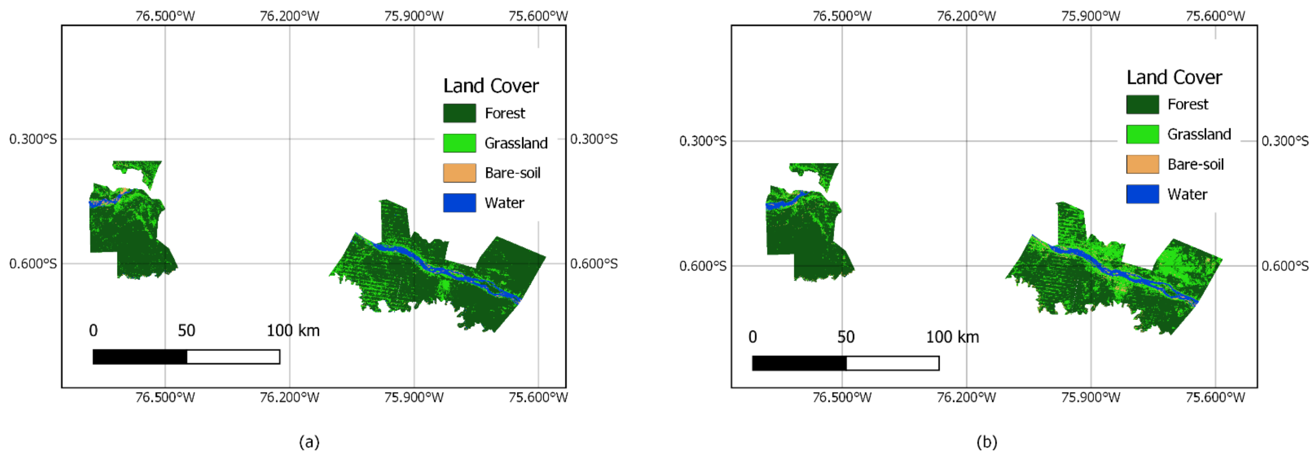

Figure 1. Land cover maps for the periods (**a**) 2013-2014 and (**b**) 2019-2020.

3.2. Land cover dynamics (2013 - 2020)

The classification results for 2013-2014 and 2019-2020 are summarised in Table 1. The most representative land covers during this period were forest and grassland, with 79.72% and 14.43% of the area, respectively. Forest was the land cover with reductions at the end of the period. Forests showed the highest rate of loss for the period, 12.16%, while grassland and soil showed the highest rates of gain for the period, 10.86% and 1.25%, respectively.

The dynamic conversions between the different LC classes can be seen in Table 2. There was a fundamentally dynamic conversion between forests and grasslands, 17.55% of the forests were converted to grasslands during the study period.

Table 1. Land-cover change between 2013-2014 and 2019-2020. The gain/loss per category is presented as the exchange rate (%).

	2013 - 2014		**2019 - 2020**		
	Area (Km2)	**Area (%)**	**Area (Km2)**	**Area (%)**	**Gain/ Loss (%)**
Forest	1122.26	79.72	951.01	67.55	-12.16
Grassland	203.14	14.43	355.96	25.29	10.86
Soil	13.20	0.94	30.86	2.19	1.25
Water	69.19	4.91	69.95	4.97	0.05
Total	**1407.78**	**100.00**	**1407.78**	**100.00**	

Table 2. Transition table of Land-cover classes change between 2013-2014 and 2019-2020.

		2019 - 2020				
		Forest	**Grassland**	**Soil**	**Water**	***Total***
2013-2014	**Forest**	61.92	17.14	0.64	0.02	79.72
	Grassland	5.59	7.89	0.85	0.10	14.43
	Soil	0.04	0.23	0.59	0.08	0.94
	Water	0.01	0.03	0.11	4.77	4.91
	Total	67.55	25.29	2.19	4.97	100.00
	Gain	2.55	10.18	0.77	0.63	

3.3. NDVI on the study area

The results presented in Figure 2 show that the high NDVI values due to the dominant land cover is the density of forest vegetation. The NDVI values have varied slightly between sectors A and B during the study period, however the vegetation index has decreased markedly in recent years within sector B.

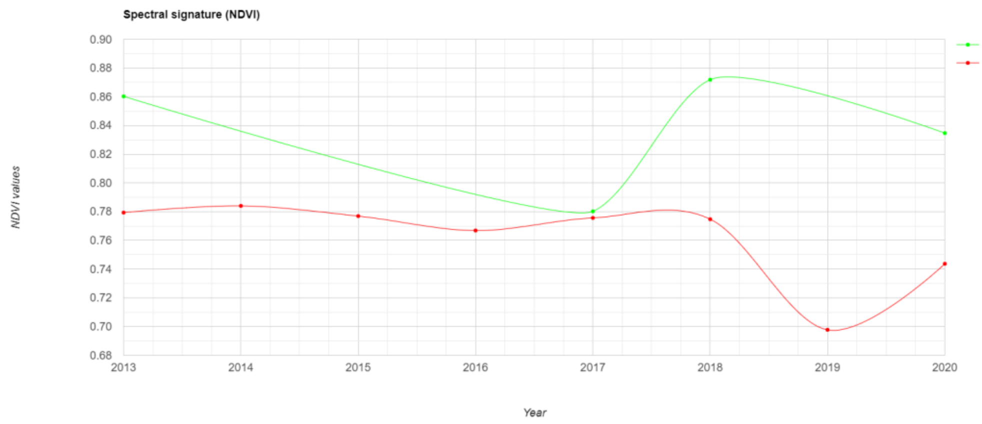

Figure 2. Spectral signature for the Sector A and Sector B from 2013 to 2020.

3.4. Sustainability indicators

The results of sustainability indicators are shown in Figure 3, using hierarchical cluster analysis, three groups were obtained in a dendrogram, with a Euclidean distance (measure of association) [11].

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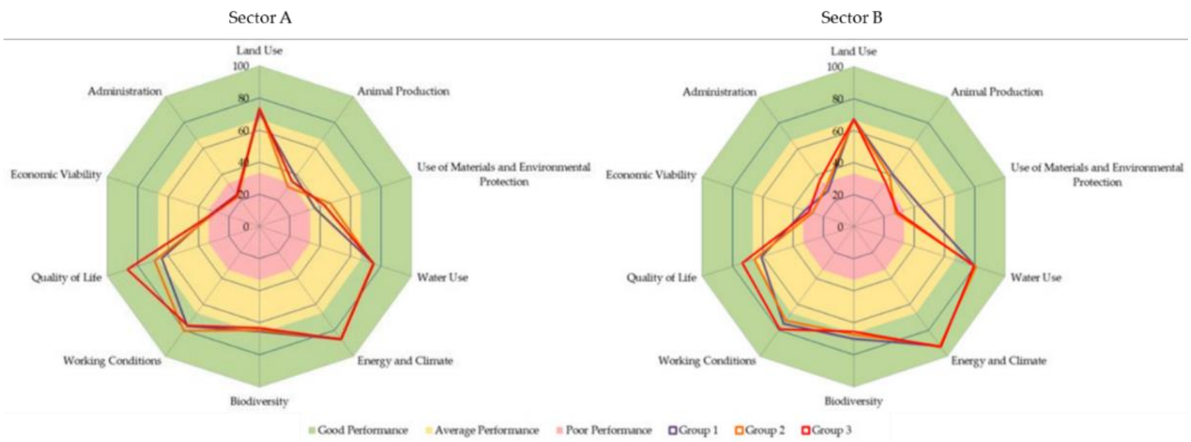

Figura 1. Degree of sustainability of traditional Kichwa agroforestry systems for groups 1, 2 and 3 of sectors A and B in the north of the Yasuní Biosphere Reserve in the Ecuadorian Amazon Region..

3.5. Relationship between NDVI and sustainability indicators

A multiple regression model has been used to determine the relationship between the sustainability indicators and NDVI. Here, NDVI is taken as the dependent variable and 10 standard sustainability indicators are taken as independent variables. The coefficient of determination is represented by the R-square, which shows the proportion of the variance of the dependent variables that can be explained by the independent variables. The R-squared value is 0.703; therefore, more than 70.3% of the variance in NDVI (dependent variable) is explained by the sustainability indicators.

Sustainability indicators have a significant impact on NDVI variations and were identified with a p-value <0.05. A higher p-value (non-significant) suggests that changes in the independent variable are not associated with changes in the dependent variables, as material use and animal production, water use, energy and climate are not related to NDVI change Table 3.

According to the results of this study and other research, the predominant trends of land use change such as agricultural expansion or industrial development affect the

NDVI. It has also been shown that the dynamics of vegetation is related to economic variables and population growth. Also the amount of green areas is related to the quality of life [12,13,14].

Table 3. Multiple regression model table for sustainability indicators and NDVI .

	Coef	Std err	t	P
Land use	0.2949	0.029	10.054	0
Animal production	-0.0269	0.018	-1.534	0.151
Use of materials and environmental protection	0.3245	0.046	7.06	0
Water use	0.0059	0.026	0.226	0.825
Energy and climate	0.0197	0.028	0.71	0.491
Biodiversity	0.0412	0.016	2.643	0.021
Working conditions	0.2204	0.013	16.391	0
Quality of life	0.3308	0.036	9.238	0
Economic viability	0.0413	0.003	14.704	0
Administration of the chakra	-0.1596	0.039	-4.135	0.001
Global indicator of sustainability	0.1092	0.001	98.254	0

4. Conclusion

Between 2013-2020, a gradual loss of forest was observed in the study area. An increase in secondary vegetation such as grasslands was also found, which is consistent with an expansion of agriculture and deforestation previously reported in the Amazon region, especially within indigenous communities.

Some sustainability indicators of the Kichwa community are potentially influenced by NDVI variation. It is therefore recommended to promote the continued use of green projects to address biodiversity conservation in the area and to improve the lives of indigenous communities.

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References

1. Myers, N. Threatened biotas:"Hot spots" in tropical forests. Environmentalist 1988, 8, 187–208.
2. Killeen, T.J.; Douglas, M.; Consiglio, T.; Jørgensen, P.M.; Meika, J. Dry spots and wet spots in the Andean hotspot. J. Biogeogr. 2007, 34, 1357–1373
3. Napolitano, D.A.; Ryan, A.S. The dilemma of contact: Voluntary isolation and the impacts of gas exploitation on health and rights in the Kugapakori Nahua Reserve, Peruvian Amazon.
4. Torres, B.; Günter, S.; Acevedo-Cabra, R.; Knoke, T. Livelihood strategies, ethnicity and rural income: The case of migrant settlers and indigenous populations in the Ecuadorian Amazon.
5. Reeve, M.E. Los Quichua del Curaray: El Proceso de Formación de la Identidad; Editorial Abya Yala: Quito, Ecuador, 2002; ISBN 9978-22-020-8.
6. Villaverde, X.; Ormaza, F.; Marcial, V.; Jorgenson, J. Parque Nacional Yasuní: Historia, Problema y Perspectivas; WCS–Programa Ecuador: Quito, Ecuador, 2005Author 1, A.B.; Author 2, C. Title of Unpublished Work. *Abbreviated Journal Name* stage of publication (under review; accepted; in press).
7. Gorelick, N.; Hancher, M.; Dixon, M.; Ilyushchenko, S.; Thau, D.; Moore, R. Remote Sensing of Environment Google Earth Engine: Planetary-scale geospatial analysis for everyone. Remote Sens. Environ. 2017, 202.
8. Nyland, K.E.; Gunn, G.E.; Shiklomanov, N.I.; Engstrom, R.N.; Streletskiy, D.A. Land cover change in the lower Yenisei River using dense stacking of landsat imagery in Google Earth Engine.

9. Porsche, H.; Fischer, M.; Braga, F.; Häni, F. Introduction of the sustainability assessment tool RISE into Canadian agriculture. Work. Pap. J. Univ. Guelph 2004, 11, 11–19.
10. Foody, G.M. Status of land cover classification accuracy assessment. Remote Sens. Environ. 2002, 80, 185–201.
11. Heredia-R, M.; Torres, B.; Cayambe, J.; Ramos, N.; Luna, M.; Diaz-Ambrona, C.G.H. Sustainability Assessment of Smallholder Agroforestry Indigenous Farming in the Amazon: A Case Study of Ecuadorian Kichwas. Agronomy 2020, 10, 1973. https://doi.org/10.3390/agronomy10121973Author 1, A.B. Title of Thesis. Level of Thesis, Degree-Granting University, Location of University, Date of Completion.
12. Pham, Thi Mai Thy, et al. "Specifying the relationship between land use/land cover change and dryness in central Vietnam from 2000 to 2019 using Google Earth Engine." Journal of Applied Remote Sensing 15.2 (2021): 024503.
13. Gui-feng, Han, and Xu Jian-hua. "A Study on the Relation between Temporal NDVI and Economy and Population."
14. Rhew, Isaac C., et al. "Validation of the normalized difference vegetation index as a measure of neighborhood greenness." Annals of epidemiology 21.12 (2011): 946-952.