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Extended Abstract

Towards the Sustainability of Traditional Agroforestry Systems Kichwa: Sumaco Biosphere Reserve Case, Amazonia †

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Abstract: In the Amazon, the Sumaco Biosphere Reserve (SBR) is considered a key point of natural and cultural diversity. It is populated by several indigenous groups, including the Kichwa, who are characterized by their traditional production systems, which are a means of subsistence and socio-ecological integration, The objectives were: (a) identify the sociodemographic characteristics at the household level, (b) quantify the multitemporal change in land cover and (c) determine the sustainability of traditional agroforestry systems Kichwa. The study was carried out in the Sumaco Biosphere Reserve, with the participation of 376 indigenous Kichwa have 157 traditional agroforestry systems distributed in three communities. The sociodemographic structure and distribution was identified through twelve demographic indicators, through the google earth engine platform in 5 consecutive years and distributed in two periods (1) 2015–2017, (2) 2018–2020 and the response-inducing sustainability evaluation (RISE) methodology was used according to the social, economic and ecological dimensions, expressed through 10 indicators of 50 parameters, valued from 0 (worst case) to 100 (best case), the results are expressed in a polygon, defined by the areas: (1) good performance, (2) medium performance and (3) poor performance. A pyramidal structure of a progressive type characteristic of young populations was identified, as well as the multitemporal change between the different categories of land cover from vegetative to non-vegetative type, and four indicators with low performance were identified: use of materials and environmental protection, energy and climate, economic viability, farm management; which are guidelines for local and regional decision makers.

Keywords: carbon footprint; greenhouse effect gases; grazing management; livelihoods

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1. Introduction

The Kichwa populations of the Ecuadorian Amazon Region (EAR) have been characterized by their traditional agroforestry systems called *chakra* for thousands of years. This system was previously oriented to subsistence, integrated with the cultivation of basic foods, such as cassava (Manihot esculenta Crantz), the banana (*Musa paradisiaca* L.), the peach palm (Bactris gasipaes Kunth), etc., as well as medicinal plants [1,2]. It is characterized by its high level of diversity [3] and its ability to provide security and sovereignty in matters of food and health [4–6]. *Chakra* plots in the northern Ecuadorian Amazon range between 0.05 and 3.0 ha [3,7,8], have high levels of ecological and social integration [9,10,] and can mitigate both the impact of population growth in the Amazon. [2], the effects of climate change [11]. Expansion of the agricultural frontier and the consequent deforestation [12], decreasing the quantity and quality of ecosystem services [13]. Therefore the objectives of this research were: (a) identify the sociodemographic characteristics at the household level, (b) quantify the multitemporal change in land cover and (c) determine the sustainability of traditional agroforestry systems.

2. Materials and Methods

2.1. Geographic Location

The Kichwa populations settled in three indigenous communities were studied: (A) Verde Sumaco, (B) San José de Payamino and (C) Ávila, together with the Sumaco National Park (PNS), an area belonging to the Sumaco Biosphere Reserve (SBR). The SBR is considered one of the areas with the greatest biological and cultural biodiversity on the planet [14], located in the EAR. Ecuador is one of the 17 megadiverse countries [15] (Figure 1).

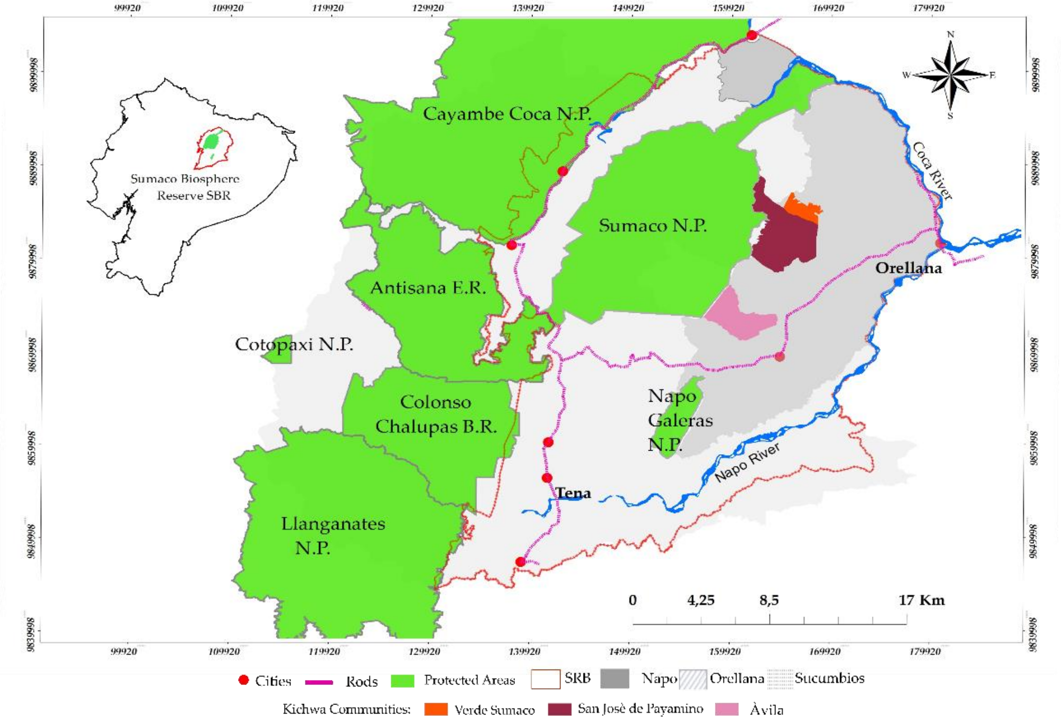

Figure 1. Indigenous communities in the Sumaco Biosphere Reserve of the Ecuadorian Amazon.

2.2. Data Collection and Sampling System

The type of sampling used was by reference chain [16], due to the difficulty of constructing a sampling frame due to the scarcity of demographic information in the intervention area and the complex logistics to travel and move around the communities. With the support of the German Agency for Development Cooperation (GIZ-Ecuador), all approaches were made to producers and the principles of ethical research were explicitly applied [17].

2.3. Socio-Demographic Characteristics of Households

Surveys were conducted to 157 Kichwa households with chakras in january 2018, the average area of the chakras was 0.5 ha in 60 ha of titled land per household. We studied the Kichwa population structure and its distribution by sex and age from a population pyramid (statistical representation) [18] to examine its implications with traditional production systems [19]. We calculated the following indices: (1) proportion of young population (<14 years) (Pyoung people); (2) proportion of adult population (between 15 and 64 years, Padults); (3) ratio of children to women, defined as the number of children under 5 years of age for each woman of reproductive age (R); (4) the ratio of men, consisting of the ratio of men for every 100 women in a given population, considered as the first indicator for analyzing the distribution by sex in the population (R.M.); (5) youth dependency ratio, which is the relationship between the potentially dependent age population (<15 years) and the potentially active age population (between 15 and 64 years, (I tdj); (6) the structure index of the active age population, which is the relationship between the population from 40 to 64 years and the population from 15 to 39 years (I r); and (7) the rate of change of the active age population (I tr), which is the relationship between the population from 60 to 64 years and the population from 15 to 19 years [20].

2.4. Quantify the Multitemporal Change in Land Cover

In this study, two periods including 2015 to 2017 and 2018 to 2020 were analysed using Landsat 8 (OLI/TIRS) imagery. A supervised classification was applied in Google Earth Engine (GEE) using the random forest algorithm and the imagery was classified into four categories: forest (forest with open and close canopies); grassland (cropland and herbaceous); soil (bare soils, mixed drylands, oil fields, exposed rocky areas and built-up areas); and water (e.g., rivers, streams, canals, reservoirs, estuaries and lakes). These categories were selected as relevant to studies of indigenous communities in the region [6]. Ground truth data for land cover (LC) classification and accuracy assessment were collected using visual interpretation data. The ground truth data were collected from Google Earth using a time-sliding image [21,22]. Using a simple random sampling technique, 770 sample points were collected from representatives of the LC classes for each study year [23]. Of this total number of reference points, 370 and 400 were used for the assessment of image classification accuracy for the period 2015–2017 and 2020, respectively.

2.5. Sustainability of Traditional Agroforestry Systems

The RISE methodology was applied to evaluate the sustainability of the traditional agroforestry system (chakra). The dimensions considered were economic, social and ecological [24], which were analyzed and compared the degree of sustainability between the chakras. RISE seeks to generate a tangible scientific evaluation that allows initiating the creation of measures to improve sustainability [25] and to initiate a constructive dialogue between producers and processors to spread the philosophy of sustainable production [24]. The methodological process began with an interview with the owner of a chakra. The RISE questionnaire was designed with three types of questions: open, drop-down list and Boolean, the duration of the questionnaire was 75 min. For the systematization and analysis of the data, the RISE 3.0 Software [26] was used, developed by the Swiss College of Agriculture (SHL), based on the 10 standard indicators according to 50 parameters, valued from 0 (worst case) to 100 (best case). case). case). As a result, a sustainability polygon was issued, defined by the following areas: (1) good performance, green coloration (66.66–100); (2) medium yield, yellow coloration (33.34–66.65); and (3) low yield, red coloration (0–33.33). The red line superimposed on the polygon indicates the degree of sustainability by indicator, which is based on the arithmetic mean of four to seven parameters that have the same weight [25].

3. Results and Discussion

3.1. Socio-Demographic Characteristics of Households

The Kichwa population was divided into 186 men and 190 women, with a mean age of 14 and years, respectively. The resulting values by indicators are as follows: (1) young population: 21.28% men and 21.54% women, (2) adult population: 28.19% men and 28.99% women, (3) ratio of children to women: 0.63, (4) the ratio of men: 75%, (5) youth dependency ratio: 75%, (6) the structure index of the active age population: 44% and (7) the rate of change of the active age population: 10%. The demographic dynamics identified are different from the indigenous Kichwa who inhabit the banks of the Napo River in the Yasuni Biosphere Reserve [27].

3.2. Quantify the Multitemporal Change in Land Cover (LC)

The LC accuracy assessment result for this study shows that for 2015–2017, the overall accuracy was 95.5% with a kappa coefficient of 0.9; for 2018–2020, the overall accuracy was 90.5% with kappa coefficients of 0.9. User accuracy of the individual LC class ranged from 85.7% to 95%, and producer accuracy ranged from 77.7% to 97% in all classification years (Table 1).

Table 1. Accuracy of Land cover classification of the region Sumaco.

	2015–2017		**2018–2020**	
LC	**Producer's**	**User's**	**Producer's**	**User's**
Forest	100	100	89.13	91.11
Grassland	77.77	93.33	91.67	91.66
Soil	97.05	94.28	95.45	85.71
Water	100	86.66	85.71	94.73
Overall	95.53		90.47	
Kappa	0.93		0.87	

The distribution of LC types in the study area in the periods 2015–2017 and 2018–2020 are presented in Figure 2.

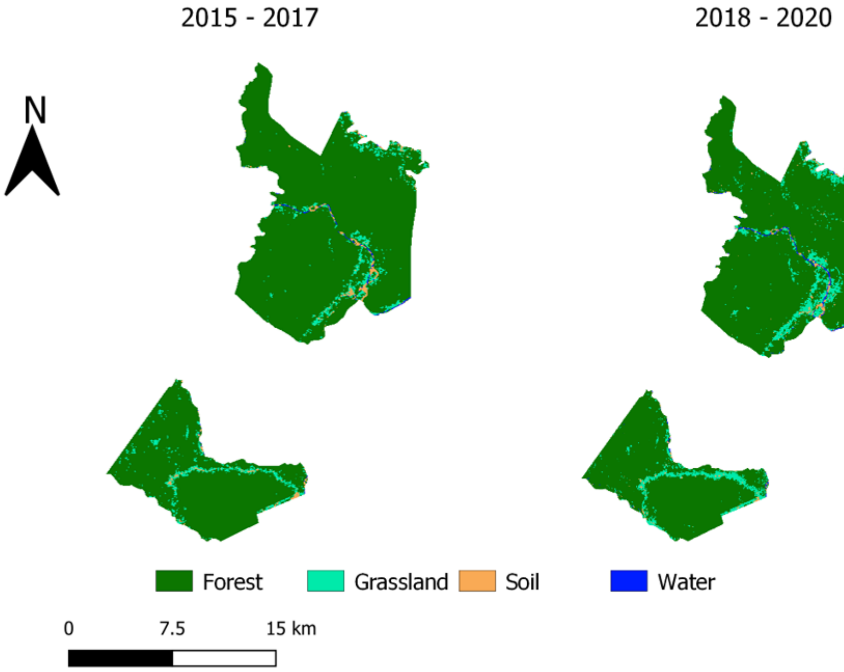

Figure 2. Land cover classification of region Sumaco.

As shown in Table 2, there were significant changes in LC during the last 5 years in the Sumaco region. During the first period time interval of the study (2015–2017), forest type was the most dominant, covering 93.52% of the total area, followed by grassland (4.89%), soil (1.22%) and water bodies (0.37%). In the second period (2018–2020), forest decreased by 3.65% and grassland increased by 3.47% compared to the first study period; similar dynamics to the Kichwas community located south of the Sumaco Biosphere Reserve [28] and contrary to the dynamics of land cover that occur in communities of the Galapagos Biosphere Reserve [29].

Table 2. Land cover distribution of the region Sumaco for 2015–2017 and 2018–2020.

	2015–2017		**2018–2020**	
	Area (Km^2)	**Area (%)**	**Area (Km^2)**	**Area (%)**
Forest	318.12	93.52	305.70	89.87
Grassland	16.64	4.89	28.45	8.36
Soil	4.15	1.22	3.62	1.07
Water	1.24	0.37	2.38	0.70
Total	340.16	100.00	340.16	100.00

According to Table 3, forest type lost 3.77% and grassland gained 10.18% during the transition period. Most of the forest type lost was converted to grassland (3.39%) and soil (0.28%).

Throughout the entire study period (2015–2017), almost 94.65% of the landscape experienced no change in land cover, and 5.35% of the area showed a transition from one LC class to another Table. forest type lost 3.77% and grassland gained 10.18% during the transition period. Most of the forest type lost was converted to grassland (3.39%) and soil (0.28%). These results suggest that, during the study period, the forest type was the most dominant in terms of persistence, followed by grassland land cover. However, this dominance can be attributed to the fact that forest accounts for the largest proportion in the studied landscape. Similarly, the greatest gain in the landscape was occupied by grassland, but the greatest loss occurred under forest cover compared to other LC classes in the landscape.

Table 3. Land cover transition matrices (%) of the region Sumaco from 2015–2017 to 2018–2020.

	Forest	**Grassland**	**Soil**	**Water**	**Total**	**Loss**
Forest	90.78	3.39	0.28	0.10	94.55	3.77
Grassland	0.71	3.02	0.46	0.03	4.21	1.2
Soil	0.03	0.19	0.73	0.12	1.07	0.34
Water	0.01	0.00	0.03	0.14	0.18	0.04
Total	91.52	6.60	1.49	0.38	100	
Gain	2.55	10.18	0.77	0.63		

3.3. Sustainability of Traditional Agroforestry Systems

The sustainability scores at the community level and the evaluated indicator show different dynamics (Figure 3): in the land use indicator: the community with the best score was Verde Sumaco; In animal production, the worst score (8.96) was presented in the Ávila community, while in the indicator use of materials and protection the registered values are similar with an average score of 39.65 and in the indicator water use a value of 72; Regarding the energy and climate indicator, in the Ávila community, the traditional production systems had the worst score (43.93).

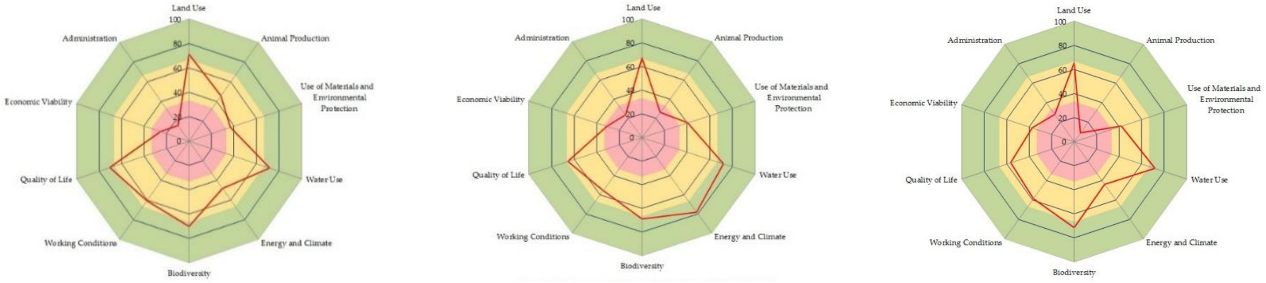

Figure 3. Polygons of sustainability in the communities: (**A**) Verde Sumaco; (**B**) Sané de Payamino; (**C**) Ávila, from the Sumaco Biosphere Reserve in the Ecuadorian Amazon.

In terms of biodiversity, they present optimal scores of 70.26 (average), the worst working conditions are presented in the San José de Payamino community (55.53), in terms of economic viability of the traditional productive systems in the communities: San Vicente and San José de Payamino, the most precarious scores are presented, 25.11 and 30.89, respectively. Regarding the administration, the scores in the three communities are low: 15.67, 23.58 and 27.96 for the communities: Verde Sumaco, San José de Payamino, Ávila, respectively. Among the global sustainability scores, the San José de Payamino community had the best score: 51.61, followed by Verde Sumaco: 52.89 and Ávila: 48.44, values diverging from the traditional systems evaluated in the Yasuní Biosphere Reserve [27], in global terms, field schools should be promoted to generate sustainable behaviors among the indigenous Kichwas and in their traditional agroforestry systems [30], promote activities that promote conservation psychology [31] to strengthen capacities [32].

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