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SAFA and GeoGebra Allies to Evaluate Natural and Cultural Sustainability: Yasuni Biosphere Reserve

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***Abstract*— The Yasuni Biosphere Reserve (YBR) occupies a unique biogeographic position in the world, where the richness of the four taxa (amphibians, birds, mammals and vascular plants) reaches maximum diversity. However, threats to species conservation are latent: the opening of roads, illegal logging, the advance of the agricultural frontier, oil extraction and the trade of wild meat in the western sector of the reserve. This paper aims to evaluate the sustainability of natural resources in multicultural communities: 1) Waorani Indigenous and 2) Migrant settlers, settled in the Diversity and Life Strip (DLS) in the YBR. Three households were defined per community, selected from the snowball sampling method. Thus, three methodological processes were applied: 1) Sustainability of natural resources using the SAFA program (version 2.4.1), it has four dimensions Good Governance (GG), Environmental Integrity (EI), Economic Resilience (ER) and Social Welfare (SW); 2) Direct observation; and 3) Lacing algorithm with the GeoGebra program used for the calculation of areas of simple polygons. The results showed that the dimension of least sustainability was ER in indigenous households and in-migrant settler households it was ER and SW. The largest sustainability area of 25,12 u^2 in the migrant settler household1, while in Waorani indigenous the worst sustainability area had a value of 18,69 u^2. The programs allow to promote a better understanding of the dynamics of the sustainability of natural resources. The issues identified as limited in the communities are a priority to improve sustainability.**

***Keywords*— Amazon; hotspots; migrant settlers; sustainability software; waorani.**

I. INTRODUCTION

The Western Amazon is a region of high biodiversity in the world [1], [2], and it has an extraordinary richness of species in taxa [1], [3]. The distribution of birds, amphibians, mammals and vascular plants [4] in South America (Figure 1), indicate that Yasuni National Park (YNP) occupies a unique biogeographic position in the world, where the wealth of the four taxa reaches maximum diversity (Figure 2). The YNP is an area of great importance in the western Amazon, created in 1979, with spaces where there are still intact forests [5], [6], with an area of 9,820 km^2 [7], [8], It is surrounded by a 10 km buffer zone in all directions except east, along the border with Peru [9].

The YNP is located within the "Core Amazon" in a region of high humidity, high annual rainfall and without a dry season [10]. The superposition of wealth in taxa (focus group: amphibians, birds, mammals and vascular plants) is evident in the western Amazon, where group 4 is the area where the four groups overlap; group 3 overlap three groups; group 2 overlap two groups and in group 1 a single group overlap (Figure 2).

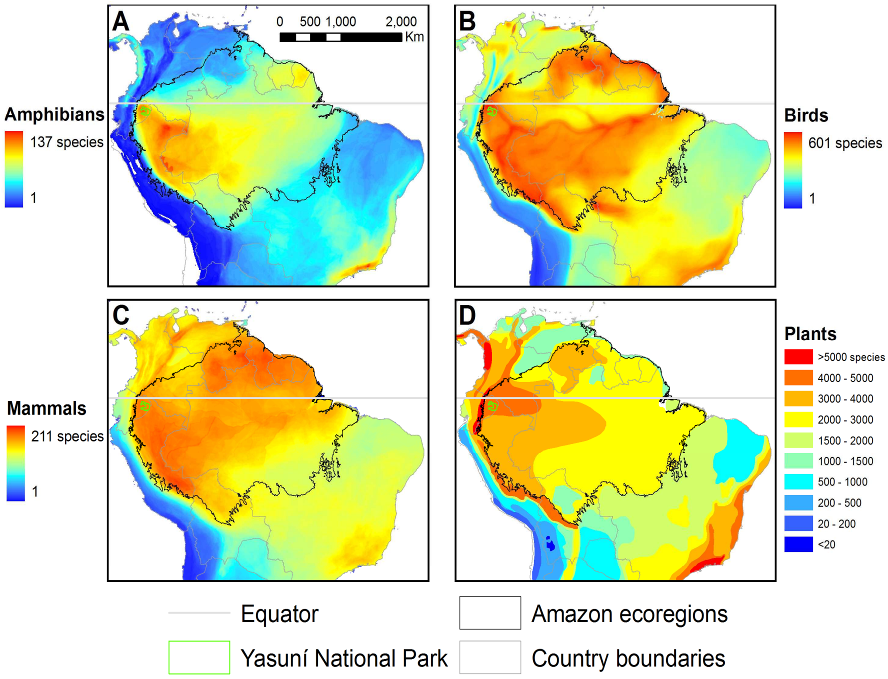

Fig 1. Wealth patterns of the species from the North of South America. Species richness for A) amphibians, B) birds, C) mammals and D) vascular plants. Source: [4].

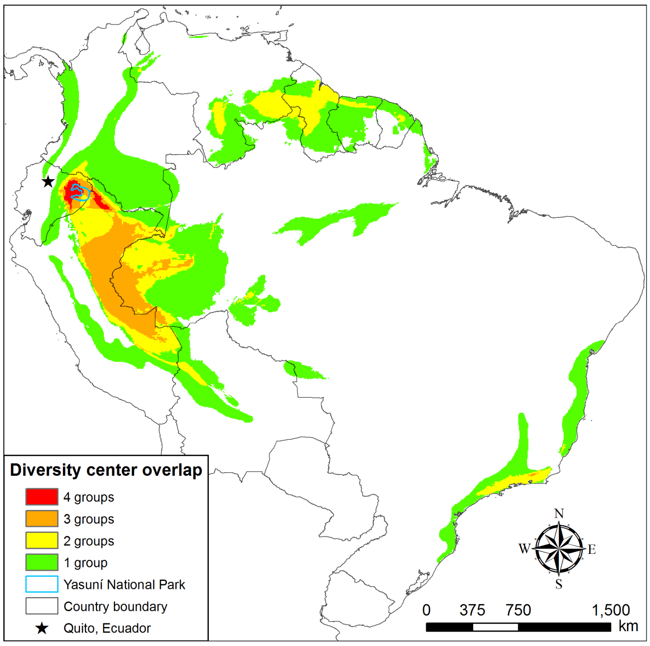

Fig. 2 Overlapping wealth centers. Richness center overlap of four key focus groups—amphibians, birds, mammals and vascular plants. A richness center is defined as the top 6.4% of grid cells for each taxonomic group. Source: [4].

The YNP concentrates numerous threats to species conservation: the opening of roads, illegal logging, the advance of the agricultural frontier, oil extraction and trade in bushmeat [11]; spatially the areas of greatest intervention is the northwestern sector 3 and is directly related to the presence of roads with direct impacts such as colonization, alteration in the path of land use. In the YNP human activity concentrates across roads and rivers (Figure 3) [12], [13], [9].

The occupation of the Yasuni Biosphere Reserve has facilitated colonization and deforestation by small migrant farmers engaged in agriculture and livestock [14], [15], and has promoted an agriculture for commercialization in indigenous populations [15]. It has been calculated that for every kilometer of road built, 120 hectares of native forest are converted to agricultural systems [15].

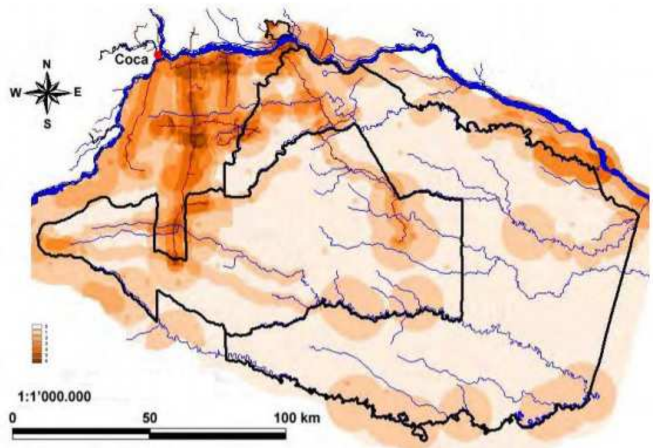

Fig. 3 Threat Index in the Yasuni Biosphere Reserve. Areas marked with values 0 (light colored) represent areas with low or absent anthropogenic disturbance levels; the areas marked with values of 6 (dark colored) represent the areas with high human activity. Source: [15].

Rural connectivity is an essential factor that has been identified as one of the main conflicts in the development of rural areas and improve the sustainability of natural resources [16], the management and use of natural resources. The use of information and communication technologies (ICTs) should be categorized as a new unexploited area with conservation and commercial goals [17].

In the rural sector, agriculture is unattractive, due to the time and investment in the products necessary for its production. Besides that, traditional products take time to mature (crop dependent) and generally produce low yields. Agricultural income is seasonally related to rainfall and harvest cycles, suggesting that, for long periods of time, producers would have no income. Insufficient innovations have led to dependence on production techniques based on traditional and arduous hand labor and the concentration on a limited range of agricultural products, mainly staple crops, which impairs the sustainability of resources [18].

The use of ICTs in the sustainability of natural resources and agriculture increases opportunities and motivates the capacities to participate in a profitable agriculture aimed at niche markets. Its use creates an occupation worth investing time, effort and financial resources. The availability of ICTs tools must be expanded; further, organizations and practitioners require that their technologies be packaged in a simple way [19]. The implementation of appropriate technology should encourage empowerment and sustainability, but always requires the participation of the community: conceptualization, development, implementation, evaluation and evaluation of technology impact [20].

The unsustainability of resources in migrant settlers' territories is evident since they use production systems characterized by extensive land clearing with the continued incorporation over time of additional forest areas in agricultural production [21]. This contrasts with a common belief that indigenous populations are associated with sustainable agricultural practices (long fallow) [22], with little environmental impact and therefore compatible with resource conservation [23], sometimes they also practice unsustainable practices, such as commercial cultivation, livestock and logging when they are in contact with the market economy [24].

These changes are cause for concern, given the importance of large indigenous territories for conservation in Ecuador and throughout the Amazon basin [25]. High rates of deforestation in colonial lands [26], high growth rates of the indigenous and migrant settlers' population [27], and the accelerated integration of indigenous peoples in the market economy [28], are driving forces for deforestation. For these reasons, the objective was to evaluate the sustainability of natural resources in multicultural populations in the Yasuni Biosphere Reserve.

II. Materials and Method

A. Study Area

The study was carried out in the communities: 1) Tobeta (Indigenous Waorani) and 2) Progreso 2 (Migrant settlers), located in the Diversity and Life Strip (DLS) created for the special management of natural resources and for protection of settlers, indigenous nationalities and peoples in voluntary isolation, adjacent to Yasuni National Park (YNP) and the Waorani Ancestral Territory (WAT) located in the Yasuni Biosphere Reserve in Ecuador (YBR) (Fig. 4).

The predominant ecosystem is the evergreen lowland forest of Napo - Curaray (BsTa02) [29]. It is one of the areas with the greatest biological and cultural diversity in the world [30], It has an extraordinary richness in several taxa (mammals, amphibians, plants and birds), has a high degree of endemism [31],

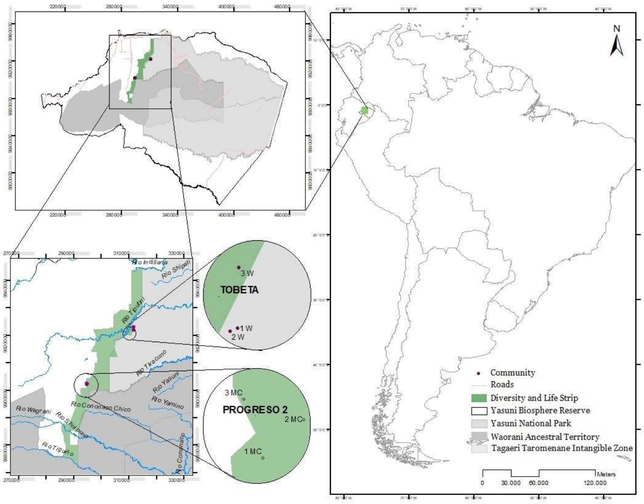

Fig. 4 Study Area: Tobeta (Indigenous Waorani) and Progreso 2 (Migrant settler), located in the Diversity and Life Strip (DLS).

1) Waorani Indigenous Community: Tobeta: The Waorani in past decades were hunters - gatherers - horticulturists [32]. The Tobeta community is currently located in the parish of Dayuma and is divided into family territories. Usually, the Waorani population have free access and do not compete for wild resources; however, cultivated resources are owned by the family that planted and care their crops [33], normally in the "chakra" a traditional agroforestry system, that combine timber and fruit trees with staple crops, as well as medicinal and ornamental plants, which contributes to food security and biodiversity conservation [34]. The Waorani population believe that everything can be given away, owned and circulated among all the members of the "nanicabo" (domestic group consisting of six to ten families living on the same roof) [35], [36].

2) Migrant-settler Community: Progreso 2 the colonization of the Ecuadorian Amazon began in the 1960s with the support of the Land Law of 1964 (Land Reform) and the Colonization Act of 1978, the migrants came mainly from Loja and Manabí provinces due to the drought that affected these Ecuadorian provinces during the 70s [37]. This study considers migratory colonization to the occupation of new sparsely populated spaces [38], [39], the Progreso 2 community belongs to the Inés Arango Parish, its populated center is 2,7 km (straight line) from the WAT and they depend heavily on natural resources [40], [41].

B. Methodology

To assess sustainability of natural resources in multicultural populations, three households were defined by case study selected from the snowball sampling method [42]. This method was considered because of the difficulty of reaching the target populations or also called hard-to-reach populations [43], hidden populations [44], [45], which is evidenced in Table 1, three methodological processes were applied: 1) Sustainability of natural resources, 2) Direct observation, and 3) Lazada algorithm or Gaussian area formula.

TABLE I
SNOWBALL METHOD FOR CASE STUDIES

Study cases	Homes
Waorani Indigenous Community: Tobeta	3 (W)
Migrant settler Community: Progreso 2	3 (MC)

1) Sustainability of natural resources: The SAFA Tool program (version 2.4.1) developed by FAO (Food and Agriculture Organization of the United Nations) in 2012 was used to assess the sustainability. SAFA is a framework FAO's strategy for capacity building, which is the process of liberating, strengthening and maintaining the capacity of individuals, organizations and society in general for the successful management of their affairs [46], and provides a set of indicators that are useful to show problems and identify solutions regarding sustainability of natural resources. Data were collected from August to September of 2019 through interviews and questionnaires at a household level. Thus, three households were randomly selected in each community. The interviews lasted between 55 and 75 minutes, intended to manage a series of questions based on the SAFA indicators [47]. The questions were translated from English to Spanish and Wao terero (language spoken by the Waorani nationality). SAFA has hierarchical levels: dimensions, themes, sub-themes, and indicators (Figure 5); includes four sustainability dimensions: Good Governance, Environmental Integrity, Economic Resilience, and Social Welfare [48].

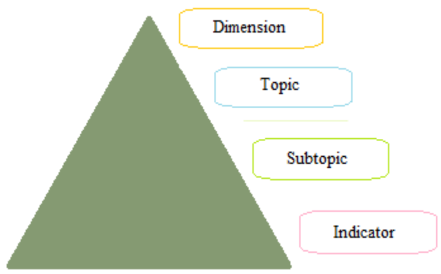

Fig. 5 Levels of sustainability assessment according to FAO. Source: [48].

It comprises 21 sustainability issues, defined by 58 sub-themes. On a more specific level, each subtopic includes several indicators, with a total of 116, which can be measured with a performance score on a scale of 1 to 5 [48]. With sustainability thresholds: unacceptable (red), limited (orange), moderate (yellow), good (light green) and better (dark green).The sustainability evaluation through the SAFA methodology is developed in four stages: 1) mapping, 2) contextualization, 3) indicators and 4) final report or report (Figure 6).

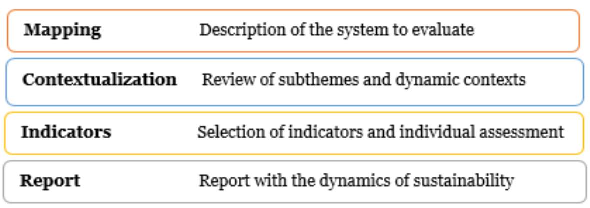

Fig. 6 SAFA program procedure (version 2.4.1). Source: FAO [48].

Each of the stages can be executed and evaluated throughout the process, being a dynamic methodology that feeds back with information obtained in each of the stages. In the SAFA Tool software (version 2.4.1) [48], the metric tools and standards for data collection are listed, which determine the level of quality of the data by attributing a score. The evaluation of the precision score can vary from 1 to 3, where 1 corresponds to low quality data, 2 corresponds to moderate quality data and 3 corresponds to high quality data [48].

2) Direct observation: The definition of the topics evaluated (Table 2) it was carried out during three field visits to the communities between the months (May - July 2019), the topic was not considered: C3 Product quality and information since no household produces or sells products labeled or with traceability quality standards; the direct observation technique was used that helps to collect data and information and that consists of using the senses and logic to have a more detailed analysis regarding the facts and realities that make up the object of study [49], the best way to evaluate is in situ [50].

TABLE II
SELECTED TOPICS OF THE SAFA METHODOLOGY

Dimension	Topics	Assessed	Not Assessed
G: Good Governance	G1 Corporate Ethics	x	
	G2 Responsibility	x	
	G3 Participation	x	
	G4 Rule of Law	x	
	G5 Holistic Management	x	
E: Environmental Integrity	E1 Atmosphere	x	
	E2 Water	x	
	E3 Earth	x	
	E4 Biodiversity	x	
	E5 Materials and Energy	x	
	E6 Animal welfare	x	
C: Economic Resilience	C1 Investment	x	
	C2 Vulnerability	x	
	C3 Quality and product information		x
	C4 Local Economy	x	
S: Social Welfare	E1 Atmosphere	x	
	E2 Water	x	
	E3 Earth	x	
	E4 Biodiversity	x	
	E5 Materials and Energy	x	
	E6 Animal welfare	x	

SOURCE FAO [48].

3) Lacing Algorithm or Gaussian Area Formula: To determine the surface (u^2) of the polygons resulting from the sustainability assessment of natural resources, the Lazada algorithm or Gaussian area formula was applied, which is used for the calculation of areas of simple polygons that have a characteristic of Euler, where its vertices are described as a set of coordinates in a plane [51].

The equation was:

$$A = \frac{1}{2}\left|\sum_{i=1}^{n-1} x_i y_{i+1} + x_n y_1 - \sum_{i=1}^{n-1} x_{i+1} y_i - x_1 y_n\right| \qquad (1)$$

Where,

A is the area of the polygon,
n is the number of the sides of the polygon and
(x_i y_i), i = 1, 2……, *n* are the vertices of the polygon.

For the application of equation (1) for the six sustainability polygons; GeoGeobra, which is a Computational Algebra System (CAS) and a Dynamic Geometry Software (DGS) [52] was used in the free program operating system [53]. GeoGebra contributes to the resolution of problems, generates a dynamic exploration of a set of data and facilitates the approach of strategies and methods of resolution [54], [55]. GeoGebra interacts with geometric and algebraic objects, for example, functions defined algebraically and then expressing them dynamically [52]. In the GeoGebra interface (Figure. 7), the coordinates for each vertex of the sustainability polygons are entered for the corresponding calculation of the areas.

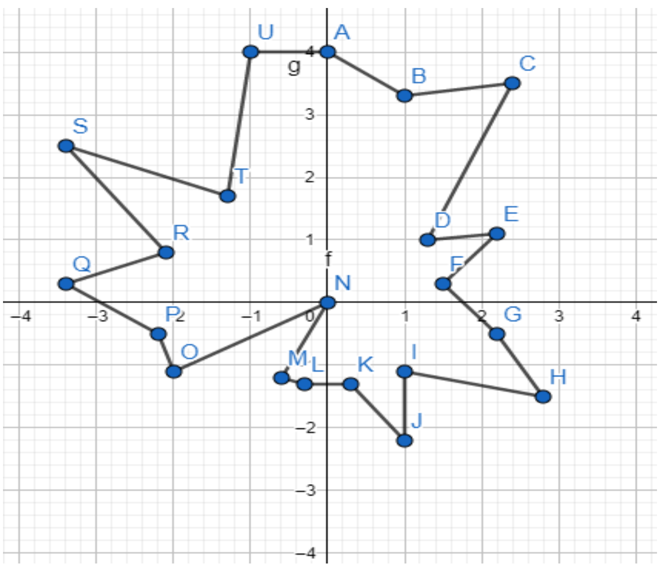

Fig. 7 GeoGebra program interface for the calculation of the sustainability area by case study.

III. Results and Discussion

The contribution of the SAFA and GeoGebra are evidenced in the results of the evaluation of sustainability of the natural resources in indigenous Waorani and migrant settlers' communities. This section presents the results from the four sustainability dimensions: 1) G: Good Governance, 2) E: Environmental Integrity, 3) C: Economic Resilience and 4) S: Social

A. Sustainability of natural resources in Waorani indigenous communities: Tobeta

The case studies in the Tobeta Community (1W: 1 Waorani - 2W: 2Waorani - 3W: 3Waorani) show different dynamics of the sustainability of natural resources by dimensions (Figure 8).

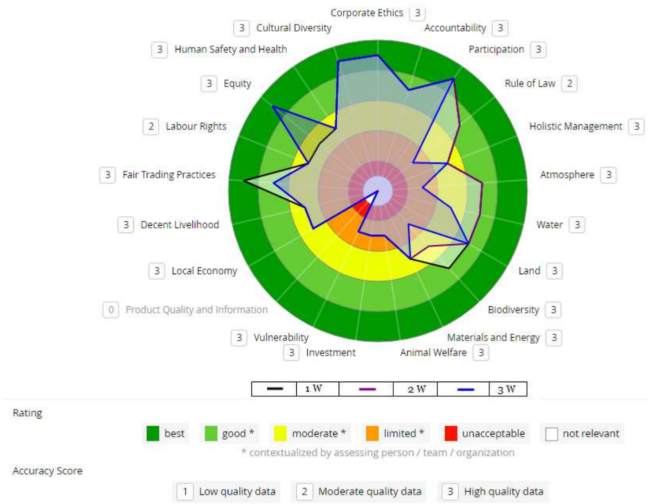

Fig. 8 Natural and cultural sustainability in the Waorani Indigenous Community: Tobeta in the amazon Yasuni National Park of Ecuador

1) Good Governance Dimension: The 1W - 2W - 3W cases in the Corporative Ethics issue were rated as Best and Good in the Responsibility issue, the Participation theme reflects 2 cases (1W - 2W) as Best and the 3W case is Limited, the issue Rule of law in the 3W case is Limited and the topic Holistic Management is Moderate and Limited in the 1W, 2W and 3W cases are Limited.

2) Environmental Integrity Dimension: The 3W case in the Atmosphere issue is Limited, in the Water issue it is Moderate and in the Earth issue the cases are Good; in the topic Biodiversity 1W, 2W and 3W are Good, Moderate and Limited, respectively; In the subject Materials and Energy cases 1W, 2W and 3W are Moderate and the topic Animal welfare cases are Limited

3) Economic Resilience Dimension: The issues of Investment and Vulnerability cases are limited, in Local Economy cases are Moderate, in all communities.

4) Social Welfare Dimension: The topics Decent Livelihoods, Labor Rights and Security - Human Health are Moderate, the Fair-Trade Practices topic the 3W case is Better and in Cultural Diversity the cases are Good.

B. Sustainability of natural resources in migrants' settlers' communities: Progreso 2.

The dynamics of the sustainability of the natural resources of case studies: 1MC, 2MC and 3MC in the migrant settler community by dimensions (Figure 9).

1) Good Governance Dimension: The 1MC - 2MC - 3MC cases in the issue of Corporate Ethics and Holistic Management are classified as Good, the Responsibility topic as Best in the cases, the Rule of Law in the 1MC case is *Moderate*

2) Environmental Integrity Dimension: In the cases of studies 1MC - 2MC - 3MC the Atmosphere, Biodiversity and Animal Welfare issues are Good, as Moderate are Water and Earth and as Limited is Materials and Energy.

3) Economic Resilience Dimension: The issues of Investment and Vulnerability cases are limited; in Local Economy they are Moderate.

4) Social Welfare Dimension: The topics Decent Livelihoods, Labor Rights, Cultural Diversity cases 1MC - 2MC - 3MC, in the issue of Equity and Security - Human Health case 1MC is Good, in cases 2MC - 3MC the same issues are Moderate, the topic Cultural Diversity in the three case studies are Moderate.

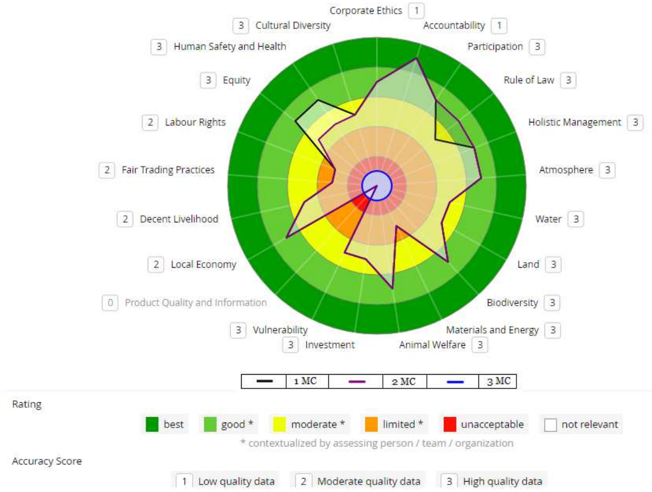

Fig. 9 Sustainability of natural resources in the Migrant settler community Mestizo – Colono: Progreso 2 in the amazon Yasuni National Park of Ecuador

C. General Discussion with the Lacing Algorithm or Gaussian Area Formula

In the calculation of the areas (u^2) of the resulting polygons for each case study, it is evident that 1MC has the best sustainability area with 25,12 u^2 greater than the 1W case with 0,15 u^2, the lowest case of sustainability in terms of areas is 3W with 18,69 u^2 (Table 3).

TABLE III
AREAS (U^2) OF THE SUSTAINABILITY POLYGONS FOR WAORANI INDIGENOUS COMMUNITY AND MIGRANT SETTLER IN THE AMAZON YASUNI NATIONAL PARK OF ECUADOR.

Indigenous Waorani: Tobeta			**Migrant settler: Progreso 2**		
1W	2W	3W	1MC	2MC	3MC
24,97	19,41	18,69	25,12	19,8	21,14

The evaluation of the sustainability of the Waorani Indigenous cases in the dimensions: Good Governance, Environmental Integrity, Economic Resilience and Social Welfare; The most sensitive issues in the comparison (Figure 8) among case studies are: Rule of Law since the indigenous population for its worldview and its abrupt process of acculturation has generated a rebellion before existing regulations and laws [56], [57]. especially in cases 1W and 2W and of similar dynamics in the Atmosphere theme. In case 1W of Tobeta Indigenous Community, its classification is limited in the subject of Biodiversity and can be considered by the number of species existing in the productive system compared to an agroforestry system of the Kichwa nationality where there is a lush number of species [58], [59], [60], but it is essential to mention that the 1W case has the area of greatest sustainability surface in relation to its peers evaluated (Table 3). The issues of Animal Welfare and Investment in all three cases are considered as Limited, since culturally the raising of animals in the Waorani nationality is not within their ancestral cultural dynamics despite a possession of minor species and the investment is minimal due to the influence of additional income that promotes greater family or individual welfare as paid work. The Waorani has conserved a significant degree of spatial, economic and cultural isolation of urban economies and the dominant mestizo culture and continues to practice traditional subsistence activities, such as the use of wild resources and small-scale agriculture in forest-dominated landscapes [61], [62].

In the case of migrants settlers the most sensitive and most relevant issues for their intervention and classified as Limited are: 1) Materials and Energy, the waste from the production processes is not recycled and the plastics are burned unlike with the farmers of Paraguay who if they recycle the generated waste whose category is Better [63], 2) Fair Trade Practices, there is some divergence between buyers and producers, to boost this issue requires four factors: the hybrid presence of the actors, similar mercantile speeches, joint tolerance to the conflict and the co-creation of common rules [64], 3) Labor Rights, it is essential to propose a strategy to strengthen labor rights to minimize collective inequality in communities [65]. The area of sustainability in the 1MC case is 25,12 u^2; It is the largest of the remaining two, showing an increase of 5,32 and 3,98 compared to the 2MC and 3MC cases, respectively.

IV. CONCLUSION

The SAFA Tool (version 2.4.1) and GeoGebra programs promote a better understanding of the dynamics of sustainability of natural resources in indigenous and Migrant settler rural populations, as an alternative for conservation and production in the Biosphere Reserve Yasuni. The issues identified as Limited in the Waorani and Migrant settler cases with the SAFA tool, are a priority for intervention in the Tobeta and Progreso 2 communities whose purpose is to improve the sustainability of natural resources in the evaluated dimensions. The areas of sustainability in the resulting polygons show a better understanding of the management of natural resources in multicultural rural populations, demonstrating that the 1MC case has a greater area of sustainability than the six cases evaluated and the area is smaller in the 3W.

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