GEOGRAPHIC DISTRIBUTION AND CONSERVATION OF ANDEAN AGROBIODIVERSITY IN THE PROVINCE OF IMBABURA – ECUADOR

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ABSTRACT

The ever-increasing relevancy of agrobiodiversity studies is motivated by its important role in food security, conservation, and economic value for rural communities. In order to determine geographic distribution and state of conservation of agrobiodiversity in the Andes' highlands of the province of Imbabura – Ecuador, 606 farmers were surveyed from 85 communities located over 2,500 masl. Standard Deviational Ellipse was used to determine the trend of spatial distribution; Shannon - Weinner, Simpson, and Margalef indexes, as well as cluster analysis were used to study abundance and conservation. Inverse Distance Weighted interpolation was used to determine the trend of uses. The spatial autocorrelation Moran's I index and the 'Near' tool were used to define the influence of proximity to urban areas, and the correlation coefficient to establish the relationship between ethnicity and conservation. The study identified 47 species from seven different groups of crops. Most agro-biodiverse zones were located in Otavalo. Most abundant specie was corn (*Zea mays*), (19.11% abundance). Pimampiro has a greater Shannon diversity (H'= 1.118). Otavalo has the highest maximum diversity (Hmax = 1.602), and Urcuquí has the greatest Shannon evenness among species (J'=0.931). Highest Simpson dominance index (D= 0.15) was found in Antonio Ante. Corn has the highest number of uses. Highest levels of agrobiodiversity conservation were found in Gonzalez Suarez and Otavalo. Ethnicity and conservation showed an inverse correlation (correlation coefficient = -0.77). Agrobiodiversity conservation shows spatial autocorrelation and values show tendency to clustering (Moran's I=0.25; z-score=2.80 and p-value=0.005). This research supports the conclusion that the most agro-biodiverse areas, with higher levels of conservation of agrobiodiversity are in Otavalo.

Keywords: Agricultural diversity, *in situ* conservation, distribution, spatial autocorrelation, spatial interpolation.

1. INTRODUCTION

The relevancy of agrobiodiversity studies has been increased due to its important role in food security, conservation of genetic resources, and economic value for rural communities. Agrobiodiversity is an indicator of sustainability, and its conservation is a key issue that concerns both academic and development institutions (Leyva & Lores, 2012; Hilgert et al., 2013; (Signore et al.). The Andes' highlands are one of the most important centers of agrobiodiversity in Ecuador (Sánchez, 2014; (Montúfar & Ayala, 2019). The limited information on the characteristics, geographical distribution, and dynamics of agrobiodiversity in the province of Imbabura, makes it difficult to focus on the conservation of biodiversity. That is the reason why the understanding of agrobiodiversity in this area is becoming more significant.

Diversity of species is a measure of biodiversity within an ecological community that incorporates two aspects: The species richness (number of species in a community), and evenness of species abundance (McGinley, 2014). In order to evaluate these factors, diversity indices have been used. Meerman (2004), He & Hu (2005), Camus (2008), and Lores et al. (2008), have used Shannon - Wiener, Margalef, and Simpson diversity indices to assess biodiversity. Similarly, cluster analysis is a multivariate technique that groups elements or variables aiming to measure maximum homogeneity in each group and the biggest difference among groups. This analysis has been used in studies of species richness and biodiversity by authors such as Casatti et al., (2003) and Majumder et al. (2013). One of the most used software is Biodiversity Professional, an open-source program which automatically calculates several biodiversity indices (Nsabimana et al., 2013; McAleece et al., 2007).

Additionally, the ever-increasing advance in Geographic Information Systems (GIS) has made it possible their use to support the study of genetic resources, making the application of GIS almost essential (De Pasquale & Livia, 2022; Flachs & Abel, 2019; Santillán-Fernández et al., 2021). In recent years, there have been several studies that applied GIS and Ecogeography to generate information about distribution, morphological diversity, and eco-geographical diversity, as well as to facilitate or improve some tasks related to the conservation of agrobiodiversity (Parra, Iriondo & Torres, 2012; Tapia, 2015; Raggi et al., 2022).

The goal of this study was to determine the geographical distribution and conservation of agrobiodiversity in the Andes' highlands of the province of Imbabura. Specifically, the study focused on geographic areas where there is a greater concentration and conservation of agrobiodiversity, and to the influence of proximity to urban areas and ethnicity.

2. MATERIALS AND METHODS

The study was conducted in the province of Imbabura (Fig. 1), located in the northern Ecuador. The study area included all rural communities located over 2500 meters above sea level (masl) in six cantons, primarily populated by Indigenous Ecuadorians. Field data was collected between March and December 2015.

Imbabura has a rich cultural and ethnic diversity. Its location in the Andes has promoted the development of a varied biodiversity. It has upheld traditional agriculture and use of agrobiodiversity. This province is considered one of the agrobiodiversity microcenters of the country because of the wide number of species and varieties grown in the farmers' fields. This agrobiodiversity richness is due to ancestral agricultural practices and its production is mostly intended to self-consumption. This is also associated to the variety of uses in traditional cuisine (INIAP, 2005; Tapia, 2005).
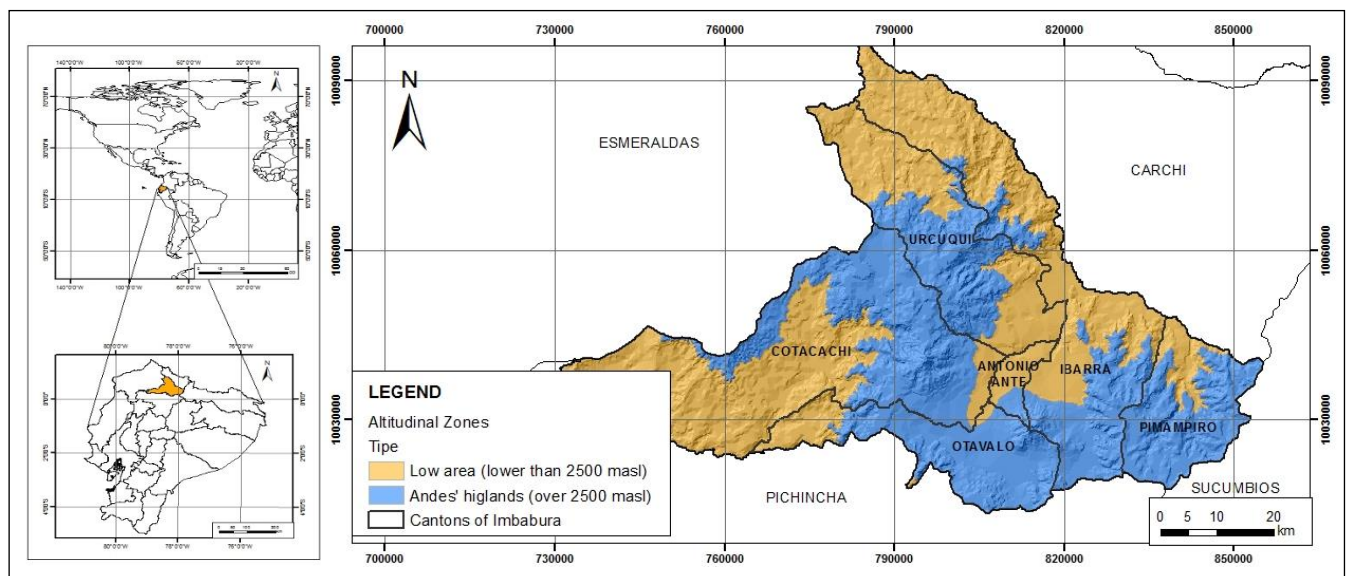

Fig. 1: Province of Imbabura - Area of study

Primary georeferenced information was collected in rural communities of 12 parroquias (political subdivisions) in six cantons of the Imbabura province (Fig. 1). These parroquias were chosen in order to obtain a representative sample. Presidents of each of the 12 parroquias provided a list of small holder farm households. From this list, households were randomly sampled using GIS mapping. The size of the sample was calculated considering as the universe the number of inhabitants over 18 years of age in each community, in order to keep the proportionality of the sample in relation to the size of the community. The samples comprised

606 small holder farm households. The information gathering focused on the agrobiodiversity of crops intended for human consumption.

The information was processed in ArcGIS software v. 10.2, using Universal Transverse of Mercator (UTM) Projection, World Geodetic System (WGS) 1984 Datum, and 17 South Zone. In order to establish the trend of crop distribution, a Directional Distribution (Standard Deviational Ellipse) tool was used. This technique has been widely used as a versatile GIS tool, to define the geographical distribution (Wang et al. 2015). The richness and conservation of agrobiodiversity was cartographically determined using symbology by quantities, based on the variable number of crops.

The statistical analysis program Biodiversity Professional v. 2 (McAleece et al., 1997) was used to identify sites with higher agrobiodiversity. The Shannon – Wiener diversity – equity index $[H = \Sigma pi \, log \, pi]$, as well as the Simpson dominance index $[DSi = \sum_{i=1}^{S} pi^2]$ (Leyva and Lores, 2012) and Margalef index $[DMg = \frac{S-1}{InN}]$ were determined. R-mode cluster analysis was also executed to determine the similarity between data (Majumder, Lodh and Agarwala, 2013). The trend of agrobiodiversity use was determined by applying the Inverse Distance Weighted (IDW) spatial interpolation method. This method helps understanding ecological patterns and trends of behavior of specific variables (Angulo et al, 2013; Norris, Fortin & Magnusson, 2014; Gumiere et al, 2014). The raster cell size was 20 meters for the province and 5 to 10 meters for each canton, depending on the scale. The influence of distance to urban areas in agrobiodiversity conservation was found by spatial autocorrelation analysis. Spatial autocorrelation "Moran's I" tool, and proximity analysis were performed. In order to determine the influence of ethnicity on agrobiodiversity conservation, regression analysis was performed. This methodology was selected, based on the study by Skarbø (2014).

3. RESULTS

Standard deviation ellipses, applied to five (most abundant crops) of the 47 crops found in this study, showed a tendency to elongated distribution, among Otavalo, Antonio Ante and Ibarra cantons, where the agrobiodiversity of the province is concentrated (Fig. 2).
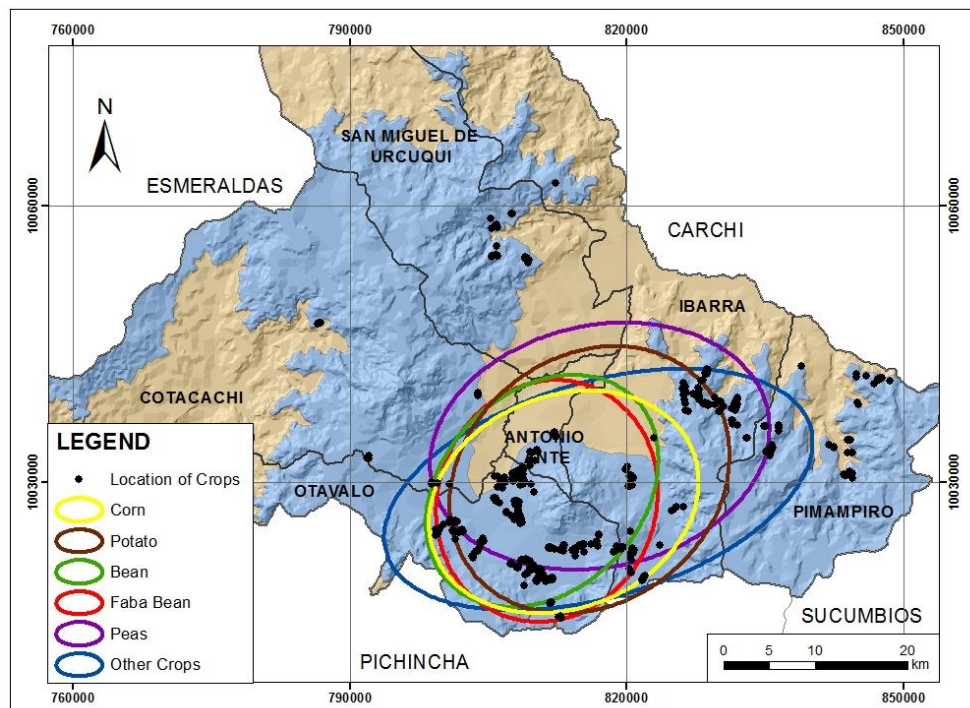
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Fig. 2: Standard deviation ellipses showing geographic distribution tendency on cantons.

The most abundant specie is corn (*Zea mays*) (19.11%), followed by potato (*Solanum tuberosum*) (14.46%), beans (*Phaseolus vulgaris*) (13.23%), faba beans (*Vicia faba*) (12.26%) and peas *(Pisum sativum)* (8.53%). Other crops represent 32.41%.
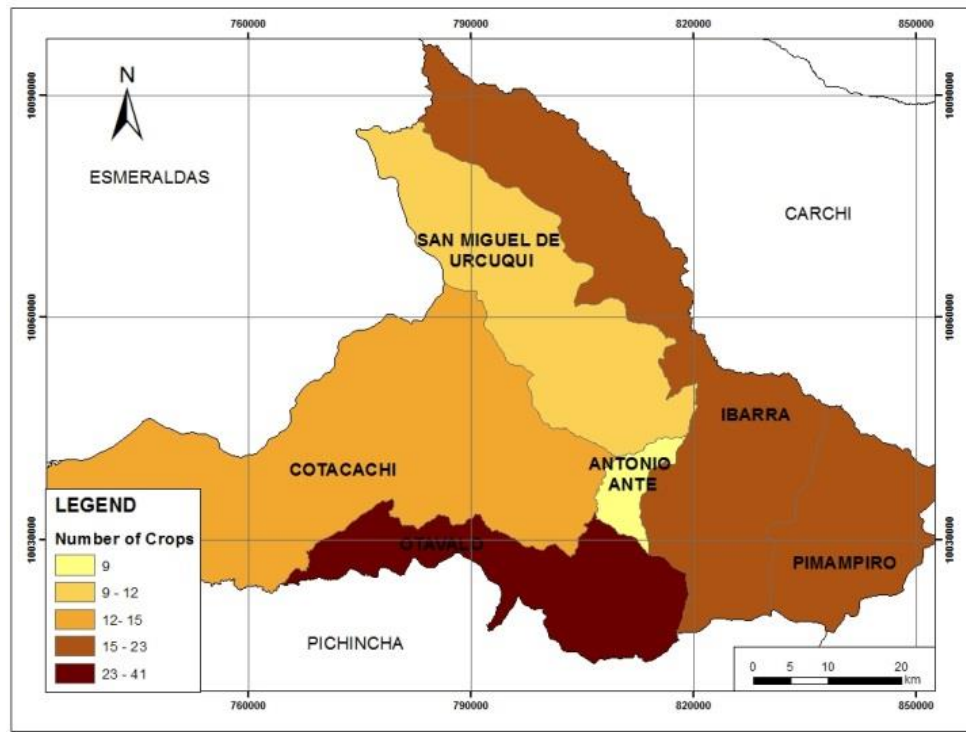
Fig. 3: Crop richness on cantons.

Cultivated species found in each crop group are presented in Table 1. The results show that canton Otavalo has the largest number of crops, meaning the greatest agrobiodiversity richness by crop group (Fig. 3).

Table 1: Agrobiodiversity richness by crop group.

Crop Group	Antonio Ante	Cotacachi	Ibarra	Otavalo	Pimampiro	Urcuquí
Leguminous (*Phaseolus vulgaris, Pisum sativum, Lupinus mutabilis, Vicia faba Cicer arietinum, Lens culinaris*)	4	4	5	5	4	4
Gramineous (*Avena sativa,Zea mays, Hordeum vulgare,Triricum*spp.)	2	2	3	4	3	3
Roots and Tubers (*Smallanthussonchifolius, Solanum tuberosum, Ullucustuberosus, Tropaeolum tuberosum, Oxalis tuberosa, Ipomea batatas, Arracaciaxanthorrhiza, Daucus carota*)	1	6	5	7	4	3
Chenopodiaceae and amaranthaceae	1	1	2	2	1	1

Crop Group	Antonio Ante	Cotacachi	Ibarra	Otavalo	Pimampiro	Urcuquí
(*Chenopodium quinoa, Amaranthus* spp.)						
Fruits (*Persea americana, Caricapentagona, Prunus* spp.*, Fragaria* sp.*, Passiflora spp., Citrus* spp.*, Pyrus malus, Rubus glaucus, Solanum betaceum, Physalis peruviana*)	1	0	2	11	10	1
Cucurbits (*Cucurbita* spp.)	-	-	1	2	-	-
Vegetables (*Brassica* spp.*, Beta vulgaris, Allium* spp.*, Lactuca sativa, Raphanus sativus*)	-	2	1	10	1	-
Total Number of Crops	**9**	**15**	**19**	**41**	**23**	**12**

The results of the application of biodiversity indices (Table 2) indicate that canton Pimampiro has a greater Shannon (H ') diversity. The canton with the highest maximum diversity (H max) is Otavalo. Urcuquí shows the highest values of homogeneity (Shannon J '). The Simpson dominance index (D) show the probability that two individuals randomly selected from a sample will belong to the same species. The values of Simpson dominance in this study suggest that Pimampiro has more diverse cultivated species. The results of Margalef index show that all sampling sites have a high diversity of species (values over 5).

Table 2: Diversity Indices

Indices	A. Ante	Cotacachi	Ibarra	Otavalo	Pimampiro	Urcuquí
Shannon H' Log Base 10	0.848	1.050	1.014	1.089	1.118	0.931
Shannon Hmax Log Base 10	0.954	1.204	1.279	1.602	1.322	1
Shannon J'	0.888	0.872	0.793	0.680	0.845	0.931
Simpson Diversity (D)	0.15	0.105	0.121	0.115	0.095	0.119
Margalef M Base 10	24.384	23.657	17.005	15.307	20.975	22.759

Cluster analysis, Fig. 4, shows that there is 73% of similarity between species (crops) in Cotacachi and Antonio Ante cantons. That was the largest similarity found among the six cantons of the province.
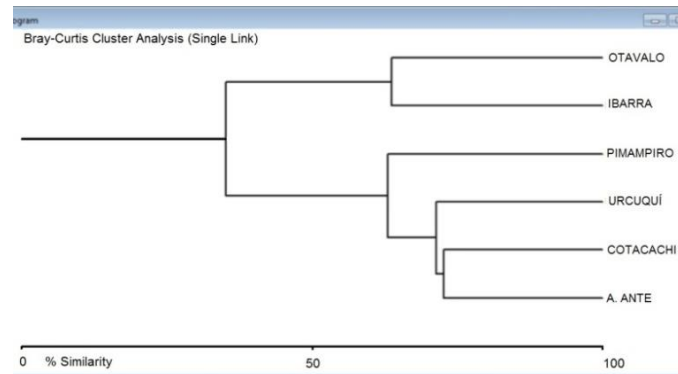
Fig. 4: Cluster Analysis.

The areas with greatest use richness are Angel Pamba, Ilumán Bajo and San Luis de Agualongo in Otavalo, Florida and San Clemente in Ibarra and Ugshapungo in Cotacachi (Fig. 5).
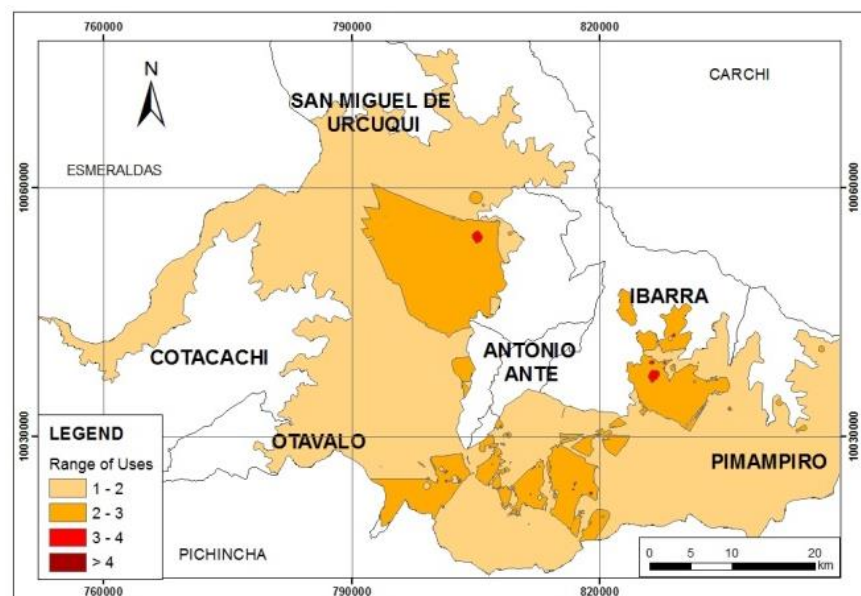

Fig. 5: Agrobiodiversity use ranges.

Correlation analysis (Fig. 6) shows a result of -0.77, suggesting an inverse correlation between ethnicity and conservation of agrobiodiversity. The result of the application of spatial autocorrelation analysis Moran's I (Fig. 7) recognizes the existence of a pattern of spatial distribution of crops. The resulting correlation coefficient between the variables number of crops and distance to urban areas is 0.15. This value represents a low positive correlation, showing a slight tendency of agrobiodiversity to be found away from urban areas.
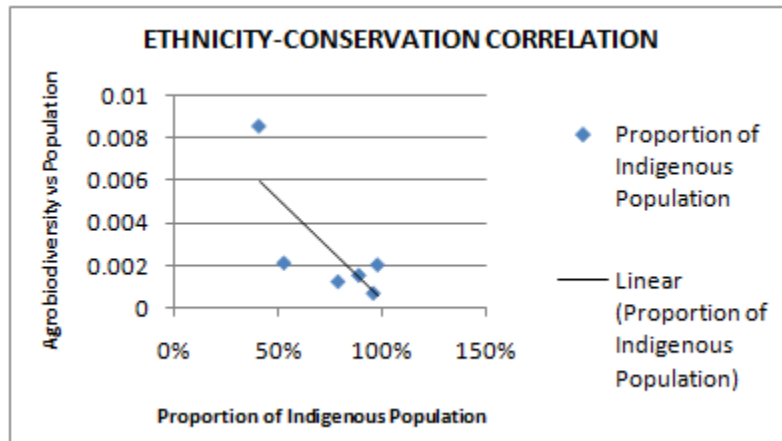
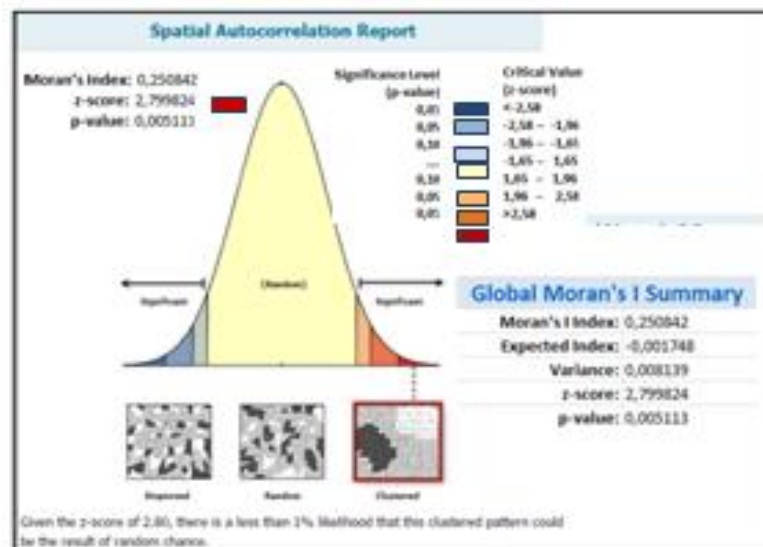**Fig. 6: Ethnicity – Conservation correlation.**

Source: Based on INEC, 2010.

Fig. 7: Spatial autocorrelation and Moran's I.

Source: Based on INEC, 2010.

4. DISCUSSION

The results related to the trend of aggregate spatial distribution of agrobiodiversity are consistent with the findings of COPISA (2012), because agrobiodiversity was found in Otavalo and Cotacachi. It can be concluded that the most agrobiodiverse areas are located, predominantly, in

canton Otavalo. COPISA (2012) also supports the statement that Imbabura has important diversity microcenters. The results may probably be due to the concentration of agricultural production in rural communities and areas with irrigation water.

A common perception is that beans and corn are the main crops in all cantons. Tapia (2015) stands that in Ecuador, corn is a major crop in both area and importance in food. According to Lores et al. (2008), crop diversity has a strategic value in the rural economy.

The results show that Shannon (H') index presents a low diversity in all cantons (values lower than two), although Pimampiro shows a greater Shannon diversity. Considering that this research was based on agrobiodiversity, rather than ecological diversity of species, these values can be considered normal for this type of study. The Simpson (D) dominance index shows that there is less diversity in canton Antonio Ante. The Margalef index range from 15,31 in Otavalo to 24,38 in Antonio Ante. According to Gamito (2010), the difference in Margalef index is greater when the sampled area is smaller. Cluster analysis shows that the highest similarity between cultivated species occurs between cantons of Antonio Ante and Cotacachi. This result is, among other factors, related to the geographical distribution of these two cantons. Due to their adjacency, soil and weather conditions, as well as cultural backgrounds are similar, and therefore there is a greater tendency for crops to be similar.

Concerning the use of Andean agrobiodiversity, many of the preparations are specific to the area and allow maintenance of certain varieties because of their importance in the cultural context. Taste, texture and cooking time are some of the aspects that farmers consider before choosing the varieties they grow (Tapia, 2015). As mentioned by Guerra (2012), family farming is the main provider of basic food in rural Andes. It can be concluded that the most cultivated species is corn. Tapia (2015) supports the argument that diversity of corn maintained by farmers represents the basis of their diet, and it has a direct relation to multiple uses and cultural practices.

This work further demonstrates that there is an inverse correlation between ethnicity and quantity of crops that producers grow (correlation coefficient = -0.77). However, these variables could show another type of correlation that is not exactly linear correlation. This may be because there are other factors that determine the number of products they grow, for example, market.

In terms of Moran's I values, the estimation confirms a tendency to clustering. It can be said that agrobiodiversity conservation shows spatial autocorrelation. This result is logical, because the cultivation of certain products and agrobiodiversity conservation tend to be similar among close producers. This study found that proximity to urban areas slightly affects the agrobiodiversity conservation, while ethnicity shows an inverse influence on the number of crops that producers conserve. These results are similar to those found by Gomez & Antošová (2015).

5. CONCLUSIONS

The current study shows that the most agrobiodiverse areas with higher levels of conservation are located in Otavalo. The most abundant cultivated species have important strategic value in the rural economy and food security. It can also be concluded that there is a greater number of uses of agrobiodiversity in Otavalo and Cotacachi, promoting more conservation.

With regards to the influence of proximity to urban areas in agrobiodiversity conservation, we can conclude that the spatial autocorrelation found, confirms that there is a larger level of conservation to a limited extent in locations further from cities.

Finally, this work allows the results to be used in subsequent studies of agrobiodiversity in the province of Imbabura.

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