SOCIOECONOMIC CHARACTERIZATION OF BOCAS DEL TORO IN PANAMA: AN APPLICATION OF MULTIVARIATE TECHNIQUES

CARACTERIZACIÓN SOCIOECONÓMICA DE BOCAS DEL TORO EN PANAMÁ: UNA APLICACIÓN DE TÉCNICAS MULTIVARIADAS

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Abstract

The objective of this work was to identify the main socioeconomic characteristics of the villages with an agricultural vocation in the Bocas del Toro district, Panama, through multivariate techniques. The two principal components that accounted for 84.0% of the total variation were selected using the Principal Components Analysis. This allowed a classification in three strata, discriminating the populated centers of greater agricultural activity in the district. The study identified that the factors with the greatest impact on the characteristics of the population studied were: the development of agriculture in indigenous territories, the proportion of economically inactive people and economic occupation other than agriculture; This characterization serves as the first approach to the study of sustainable land management in indigenous territories.

Keywords: Applied Economy, Biodiversity, Crops, Multivariate Statistics, Sustainability.

Resumen
El objetivo de este trabajo fue identificar las principales características socioeconómicas de los poblados con vocación agrícola del distrito Bocas del Toro, Panamá, a través de técnicas multivariadas. Mediante el Análisis de Componentes Principales se seleccionaron los primeros dos componentes que explicaban el 84.0 % de la variación total. Esto permitió una clasificación en tres estratos, discriminando los centros poblados de mayor actividad agrícola en el distrito. Se detectó que los factores de mayor incidencia en las características de la población estudiada fueron: el desarrollo de la agricultura en territorios indígenas, la proporción de personas económicamente inactivas y la ocupación económica distinta a la agricultura; esta caracterización sirve como primera aproximación al estudio del manejo sostenible de la tierra en territorios indígenas.

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Introduction

Family farming produces over 70% of food in Latin America, represented mainly by crops such as corn, beans and other food products such as fruit, vegetables and roots, also in high quantity (SALCEDO et al., 2014; PITTI et al., 2019). However, research conducted by FAO (2013) and recently by IANAS (2017) indicates that six out of ten households that depend on agriculture live in poverty and food insecurity. In rural indigenous areas, it is estimated that two out of three people live in poverty (CAMACHO et al., 2018).

In Central America, the indigenous economy has been composed in a broad sense, by a traditional economy linked to a market economy segment (sale of crops, handcrafted products, among others), which could be of greater or lesser magnitude, depending on indigenous culture (CAMACHO et al. 2018). In general, the market economy segment presents certain intercultural adaptations such as goods that are produced with traditional labor techniques or organizations for sale to the market or whose income was applied to reciprocities or traditional complementarities (PITTI et al., 2019; OLIVARES & FRANCO, 2015).

Development in rural territories is a function of various economic, social and political factors. In general, economic development can be evidenced by the growth of Gross Domestic Product (GDP) and GDP per capita of a given territory (Torres, 2015). However, the notion of economic growth is accompanied by socio-cultural and political dimensions (MICHELINI, 2013; ZAMBRANO et al., 2015), with the participation of the State as responsible for planning development policies and beneficiaries as actors that guarantee of the sustainability of local development (TERLUIN, 2003).

Consequently, it should be noted that development is achieved, with the ability to be able to enter the global market and attract foreign investment, as well as strengthening basic competitive capabilities such as infrastructure (roads, energy and water resources), education , research and innovation (OLIVARES & CORTEZ, 2017) and the institutional fabric (ESPARCIA, 2014).

In Panama, although agricultural activities have been developed experimentally by various indigenous communities, they are not yet an important component of agricultural research in development, planning and execution in the country (PITTI et al., 2019). However, this is the direction in which development should be oriented if there really is an awareness that many people benefit from the food grown by small farmers, the product of their own immediate ecosystems.

From the University of Panama in conjunction with research organizations such as the Campus of International Excellence in Environment, Biodiversity and Global Change (CEI Cambio), emphasis is placed on studies that consider this type of agriculture, which is part of tropical biodiversity of the country, where the positive interaction of the nature-society system, and the capacity of adaptation of the crops to the different agroecological conditions, accompanied by the good management of natural resources, would represent the bases to be considered to respond to agri-food security and sovereignty of current and future generations.

The objective of this work was to identify the main socioeconomic characteristics of the villages with an agricultural vocation in the Bocas del Toro district, Panama, through multivariate techniques; as well as obtaining a close approximation of the crucial characteristics of the way of life of these settlers, which could serve as a theoretical and practical basis for possible plans for sustainable management of indigenous lands.

Materials and methods

Description of the study area

The study refers to the Bocas del Toro District, which is one of the divisions that make up the province of Bocas del Toro, located in the Republic of Panama. It has a population of 16,135 (INEC, 2010), and five regions: Bocas del Toro, Bastimentos, Cauchero, Punta Laurel and Tierra Oscura (Table 1) (MEF, 2016). The economy of this district is based on the cultivation of bananas for export, as well as tourism (tourist services, hotels, restaurants and tours) as a growing source of income.

Table 1: Regions (Corregimientos) of the Bocas del Toro District, Panama according to INEC (2010).

ID	Regions	Total populated centers
1	Bocas del Toro	17
2	Bastimentos	22
3	Cauchero	25
4	Punta Laurel	10
5	Tierra Oscura	22

Data analysis

The data matrix **X** (equation 1) was comprised of the set of vectors of the observations **X**[ij], j=1,...,p and where each vector **X**[ij] presented the j- th variable for all observations and where **X** was the data matrix formed by "n" observations with "p" variables (96 observations or population centers x 7 variables studied).

$$\mathbf{X} = (x_{(ij)}) = \begin{bmatrix} x_{(i1)} & \cdots & x_{(1p)} \\ \vdots & x_{(ij)} & \vdots \\ x_{(n1)} & \cdots & x_{(np)} \end{bmatrix} \qquad (1)$$

A preliminary analysis was carried out with the 18 original variables related to the sociodemographic and housing characteristics, which allowed eliminating those that added very little and only contributed to distort the analysis. Subsequently, only 7 variables were selected whose units were expressed as a percentage: schooling, occupation, agriculture, unemployed, economically inactive, illiterate and percentage of people with disabilities.

For the analysis of the information collected in the study, the Principal Component Analysis (PCA) was applied, which represents a descriptive technique that allows studying the relationships that exist between quantitative variables, without considering a priori, any structure, or variables , nor of individuals (PLA, 1986; DEMEY et al., 1994; CUADRAS & FORTIANA, 2000; OLIVARES, 2014; OLIVARES et al. 2016).

The PCA analysis was performed using the prcomp package of the statistical software R version 3.6.0 (R Core Team, 2015), being the guidelines of Xia et al. (2009), Chong, and Xia (2018) for the generation of own values and proportion of the variance explained; the proportion of the original variation explained by each principal component of the correlation matrix and the biplot graphs between the first and second principal components.

To select the number of components to be included, the Kaiser criterion was used, which included only those whose own values were above average (DEMEY et al., 1994; OLIVARES et al. 2017b). As the main components were generated via matrix R, the components whose own values were greater than 1 were considered.

The Partial Least Squares - Discriminant Analysis (PLS-DA) was applied, which is a supervised method that uses multivariate regression techniques to extract through the linear combination of original variables (X) the information that can predict class membership (Y). The PLS regression was performed using the *plsr* function provided from the R *pls* package (MEVIK & WEHRENS, 2007). Classification and cross-validation are carried out using the corresponding wrapper function offered by the *caret* package (KUHN, 2008).

Subsequently, the hierarchical cluster analysis was applied, which consists in that each sample begins as a separate cluster and the algorithm proceeds to combine them until all the samples belong to a cluster. The hierarchical grouping was carried out considering two parameters, the first is the measure of similarity: Euclidean distance and the other parameter is the grouping algorithms, which include the Ward link (grouping to minimize the sum of squares of either of the two groups) . Hierarchical clustering is done with the *hclust* function in the R *stat* package following the protocols described by Chong, Wishart and Xia (2019); Xia, and Wishart (2016).

Finally, K-means clustering was used as a non-hierarchical clustering technique creating k random clusters (k is supplied by the user). The program then calculated the average of each group. If an observation was closer to the centroid of another group, then the observation becomes a member of that group. This process was repeated until none of the observations were reassigned to a different group. The analysis of K-means was performed using the *kmeans* function in the statistic of the R *stat* package (XIA & WISHART, 2016).

Results and Discussion

The exploratory analysis allowed to establish that this district concentrates the agricultural activity represented by the production of Musáceas such as Banana (*Musa paradisiaca* L.), Banana (*Musa balbisiana* Colla) and Buchu (*Musa acuminata* AA). The new transformed variables called Principal Components (PC) no longer have the same meaning as the original ones, which means that each component is the result of a linear combination of the variables in which each one has a different weighting, in proportion to the magnitudes of each element that makes up the respective autovector (BALZARINI et al. 2015). Therefore, the meaning of each PC will depend on the magnitude of such weights and the sign assigning logical and practical sense from a technical point of view. Figure 1 presents the peer-scoring graph, which provides an overview of the various patterns of separation between the most important CPs in the study.
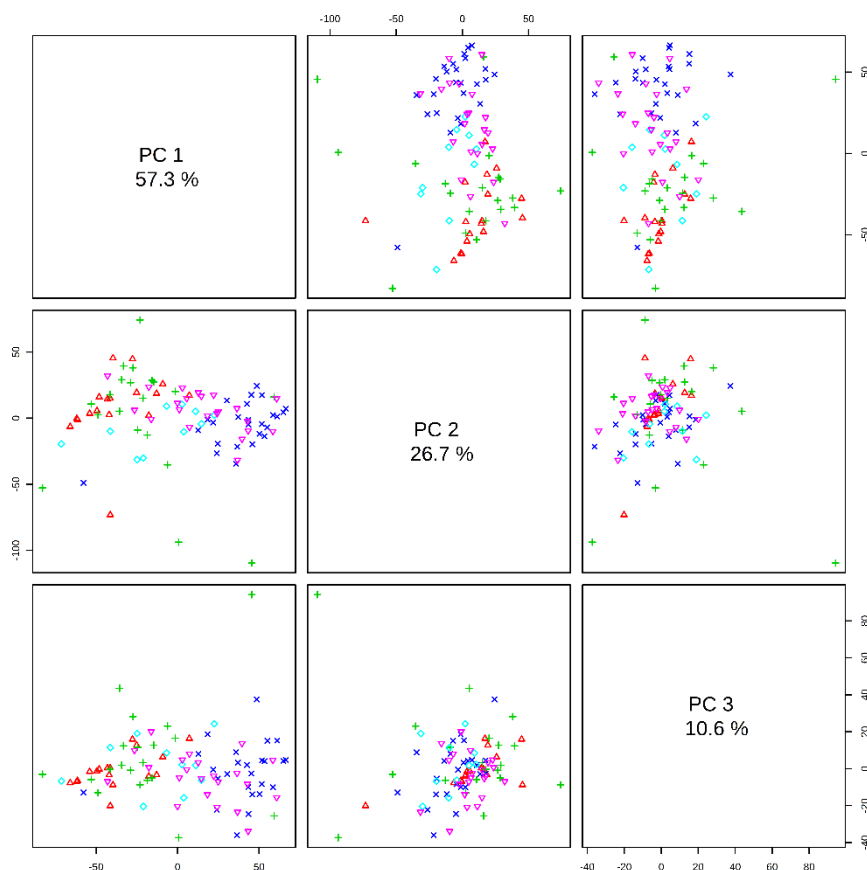
Figure 1: Pairwise score plots between the selected PCs. The explained variance of each PC is shown in the corresponding diagonal cell.

Using the criterion of including only those own values that were greater than 1, two main components were selected (figure 1), which explain 84.0% of the variation, being a significant proportion of the total (> 70.0%), since loses 16.0% of the variance, which considerably simplifies both the interpretation and the subsequent treatment of them.

First component

The first component is the one with the highest variance and therefore the greatest explanatory capacity of the data. In this case it reaches 57.3% of the total, whose variables with greater weight are constituted by agriculture (0.84) and the proportion of economically inactive population (0.37). The grouping of the scores shows the 5 groups of differentiated corregimientos in Figure 2a.

The indigenous population in the regions represents 63.3% of the district total, distributed mainly in the towns of the Cauchero and Tierra Oscura districts, developing subsistence agriculture or the contribution of labor in the production of bananas, roots and tubers as Cassava (*Manihot*

esculenta Crantz), Yam (*Dioscorea alata* L.) and Taro (*Colocasia esculenta* L.) or animal husbandry. Figure 3b shows the positive values of the variable associated with the population dedicated to agriculture as a means of subsistence and to a lesser extent the positive values of the economically inactive population.

The economic dynamics of the province of Bocas del Toro have revolved around banana monoculture; being still today the axis that moves the Bocatoreña economy, still representing the most important source of wealth and employment, to the point that it is estimated that 80% of the economy of Bocas del Toro depends on bananas.

The communities of the Teribe develop their indigenous production system which has as its main characteristic the basic sustenance of the family, essentially with a vision of cultural and spiritual use, in favor of the identity of a conglomerate of settlers. The activities carried out by the indigenous communities under study are extremely agricultural and crafts. In relation to agriculture, this is done at the level of productive yards, with traditional management and low profitability. One of the limitations of this productive activity is the lack of a road infrastructure in better conditions for the commercialization of its produce.

The differentiation of all communities is the result of the combination of several activities under a community-based management approach to local natural resources. That is, the family farming system is determined by the percentage of cultivated plants, by the diversity of production and by the needs of consumption.

Based on the above, indigenous agriculture is characterized by the production of small-scale local crops, which constitute traditional food products in Panama and in much of the indigenous territories of South America (OLIVARES et al., 2017a), basically oriented towards family consumption; however, there was a notable production of roots and tubers as well as certain legumes, vegetables and fruit trees that respond to market demands.

Figura 2: (A) Chart of weights between PC1 and PC2, the variations explained are shown in parentheses. (B) Graph of linear combinations of the variables in the PCs.
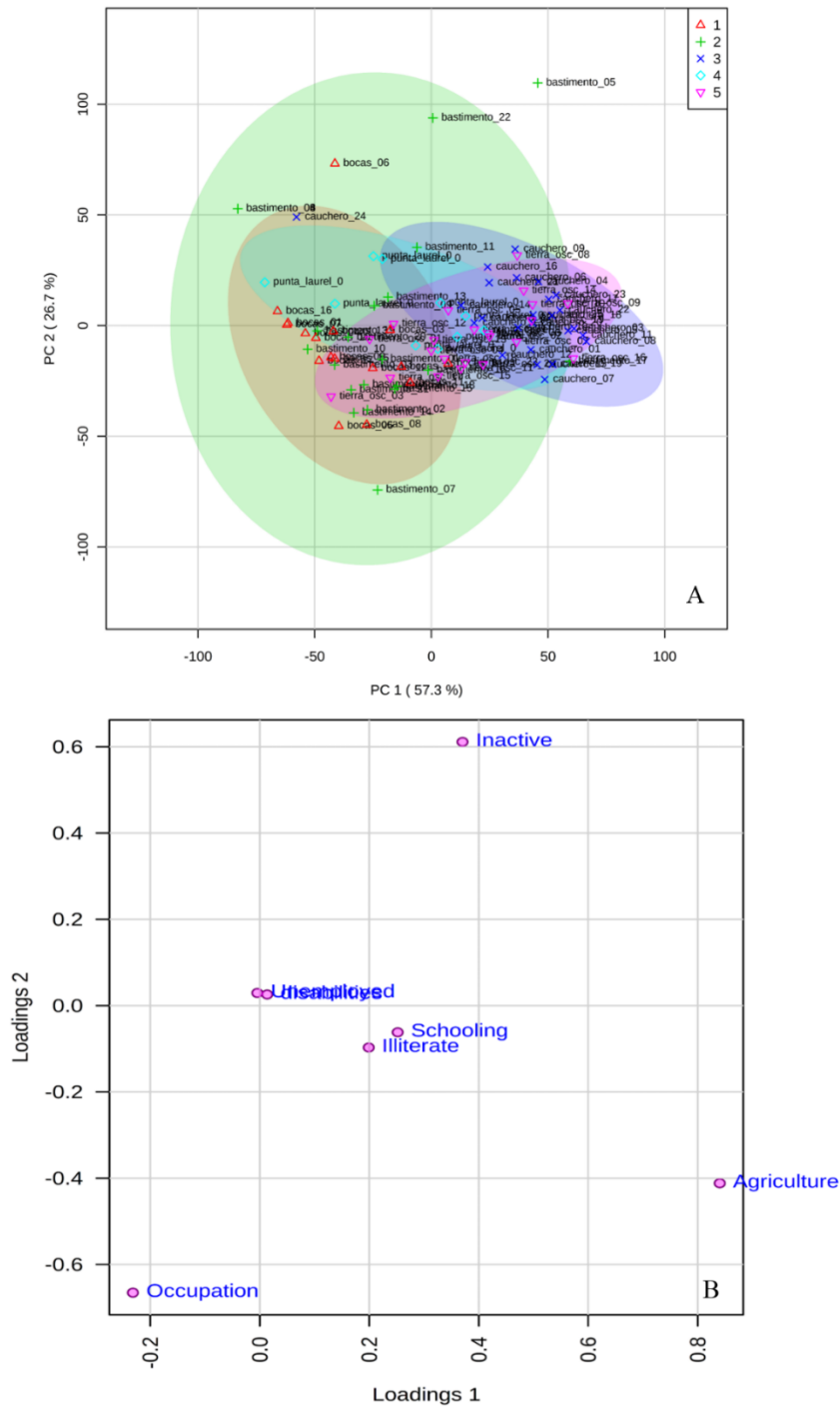
Second component

The second component interprets 26.7% of the total variability. It refers to the regions that present high proportions of population employed in different economic activities (0.66) (figure 4b). The highest percentage of the economically active population works in agricultural activities mainly in banana plantations. However, there is a significant proportion of the population involved in private enterprise activities (52.9%); followed by self-employed workers (22.5%) and government employees (14.6%) (figure 3a).

Figure 3: Three-dimensional representation of the first principal components. (a) 3D score plot between the selected PCs. (b) 3D loading plot between the selected PCs.
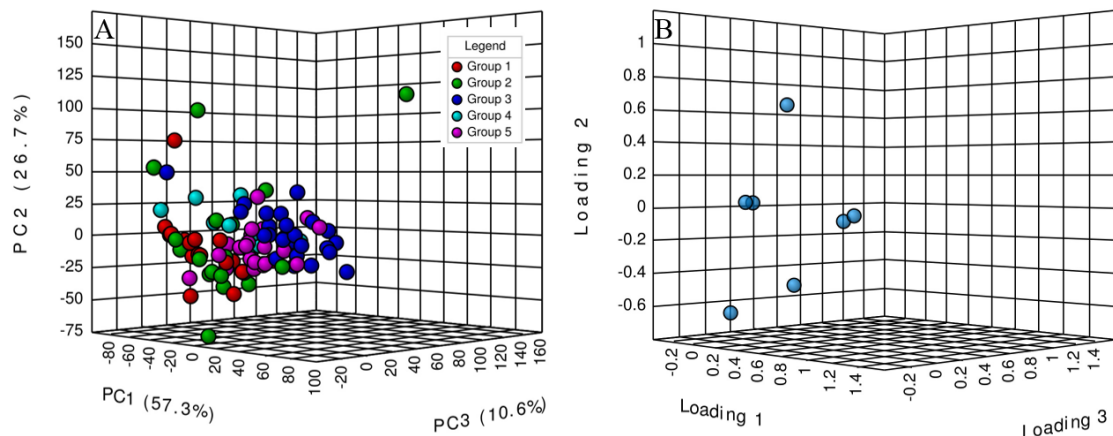

The territory of Bocas del Toro has been historically inhabited by various indigenous cultures; however, the original inhabitants of the islands are the Ngäbe. Other indigenous peoples who have been present in the territory are the Buglé, Naso, Bokota and Bri – Bri. Today, the Province is characterized by having a culture enriched by the ethnic variety that has been established in its territory throughout its history, since in addition to the indigenous groups originating in the region, immigrants settled in Bocas del Toro Europeans, Afro-Caribbean, North Americans and Asians (MARÍN, 2004).

According to reports from the INEC (2010) in the Changuinola district of the province of Bocas del Toro, 2,882 banana farms distributed in all the districts were registered, where the economy of the Province is based on the banana industry that provides employment to more than 8,000 workers . Another important crop is cocoa. Likewise, the main product of temporary crops is represented by the high proportions of the population that grows rice with an area of 1,576 hectares. Regarding corn, it is grown in all the regions, mainly in the Teribe area with 173 farms planted.

Biplot (Figure 4) allows simultaneous display observations and variables of the data file. In this case, the lengths of the vectors are proportional to the variances of the variables. In summary, the right-oriented variables will have high values in the cases oriented in the same direction and the left-facing variables will have high values in the cases oriented to the left.

Figure 4: (a) PCA biplot between the selected PCs. (b,c,d) boxplots of the main variables: b) Agriculture; (c) employed population; (d) economically inactive population. (Group 1: Bocas del Toro; 2: Bastimento; 3: Cauchero; 4: Punta laurel; 5: Tierra oscura).
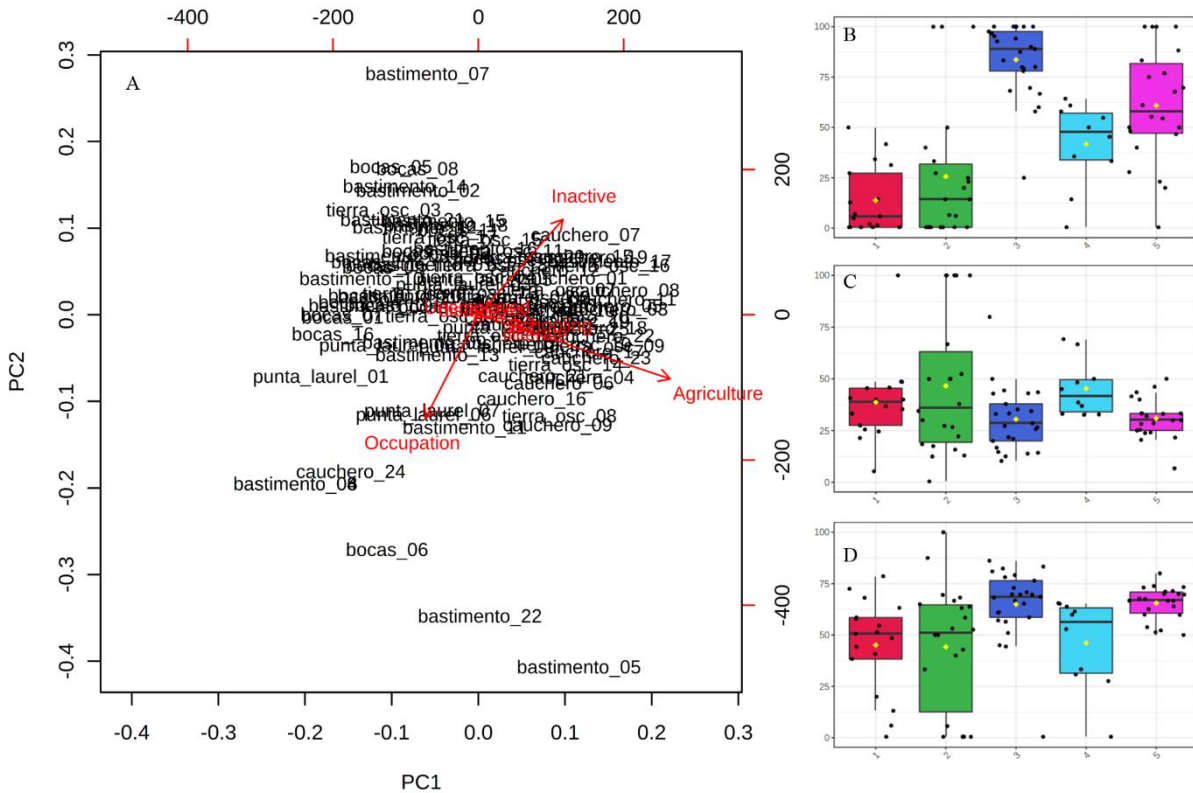
From the populated centers as initial units, groups were formed, ascendingly, until at the end of the process all the treated cases were included in the same conglomerate. Figure 5 shows the result of the dendrogram grouping. The heat map provides an intuitive visualization of the data used, each color cell on the map corresponds to a concentration value in the data table, with the variables in the rows and the 5 regions in columns. The figure shows the high proportions of the population with low schooling and illiterate population centers of the Bastimentos district because it is one of the smallest towns or with the largest number of population centers.

Figure 5: Clustering result shown as heatmap (distance measure using euclidean, and clustering algorithm using ward.D). (Class 1: Bocas del Toro; 2: Bastimento; 3: Cauchero; 4: Punta laurel; 5: Tierra oscura).
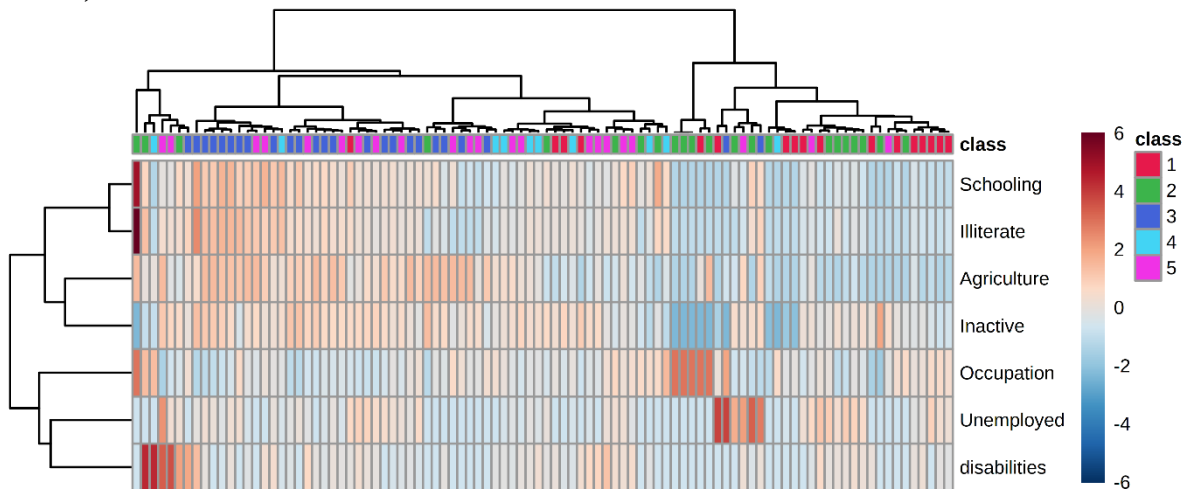

Figure 6 shows the Variable Importance in Projection (VIP), the colored boxes on the right indicate the relative proportions of the corresponding variable in each group under study. The

population variable dedicated to agriculture has high proportions in the Cauchero region and to a lesser extent in Tierra Oscura.

According to the MEF (2016) for the year 1992, in the province of Bocas del Toro, the area under agricultural use was estimated at about 27,580 ha., and increased in the year 2000 to 31,280 ha., Which means an increase of use of a total of 3,700 ha. The agricultural frontier has grown by 88.1%, at a rate of 370 hectares / year. Services and agricultural activities are the economic categories that contribute most to the composition of GDP in Bocas del Toro.

Figure 6: Important features identified by PLS-DA by PC1 and PC2

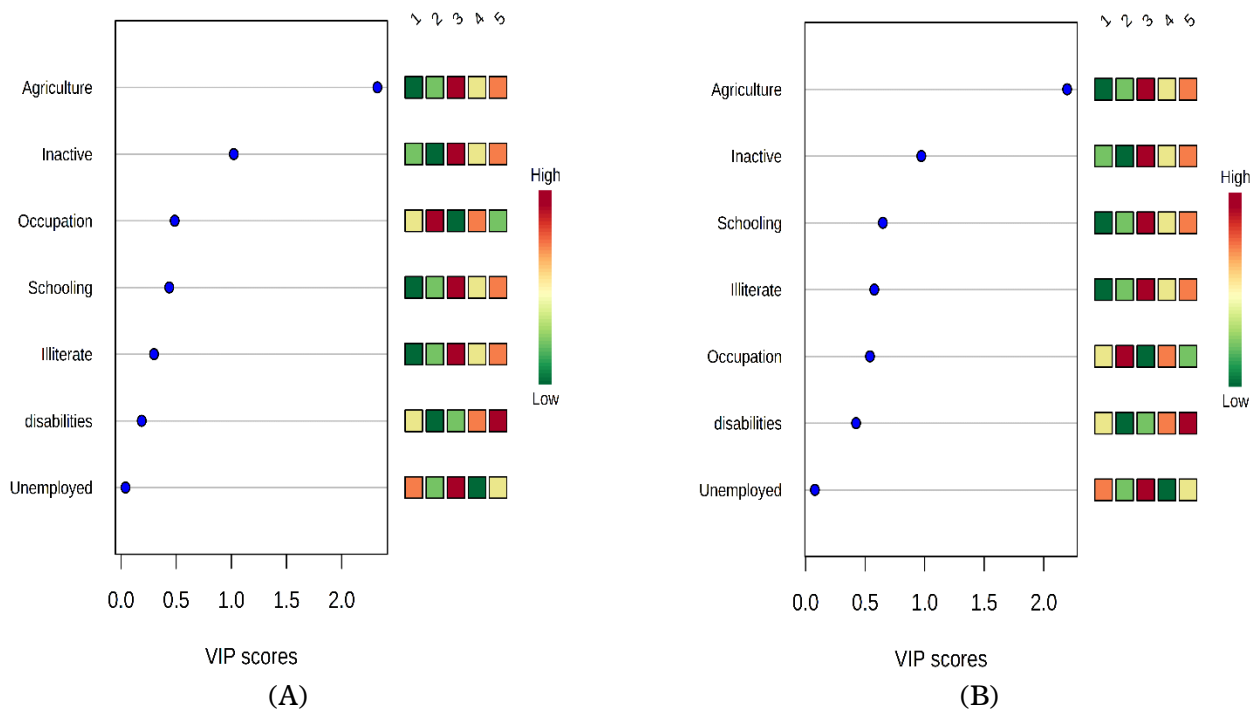(A)   (B)

Figure 7 shows the grouping of the results into three groups according to the characteristics of the population. Cluster 1 represents by those regions that have high proportions of economically inactive population. Cluster 2 integrates those corregimientos that have high proportions of population employed in commercial or tourist activities and, finally, cluster 3 includes those corregimientos whose main activity is linked with agriculture mainly the Cauchero region.

Within the internal and external factors that characterize agriculture in this district are: (a) the lack of capital from internal and external investment (b) the new trend of very palpable immigration in recent years and the inability to engage in activities productive factors further aggravate the problem of quality of life. (c) poor infrastructure for the management of perishable goods, lack of collection, drying, processing and storage centers for basic grains, cocoa, coconuts, vegetables and vegetables. (d) deficiencies of the internal market and export mechanism that can guarantee local producers the continuous and sustained sale of their products, factors that influence the higher cost paid by the bocatoreño for the basic products of the family basket because they depend of products and intermediaries from other provinces.

Figure 7: K-means cluster analysis. The x-axes are variable indices and y-axes are relative intensities. The blue lines represent median intensities of corresponding clusters
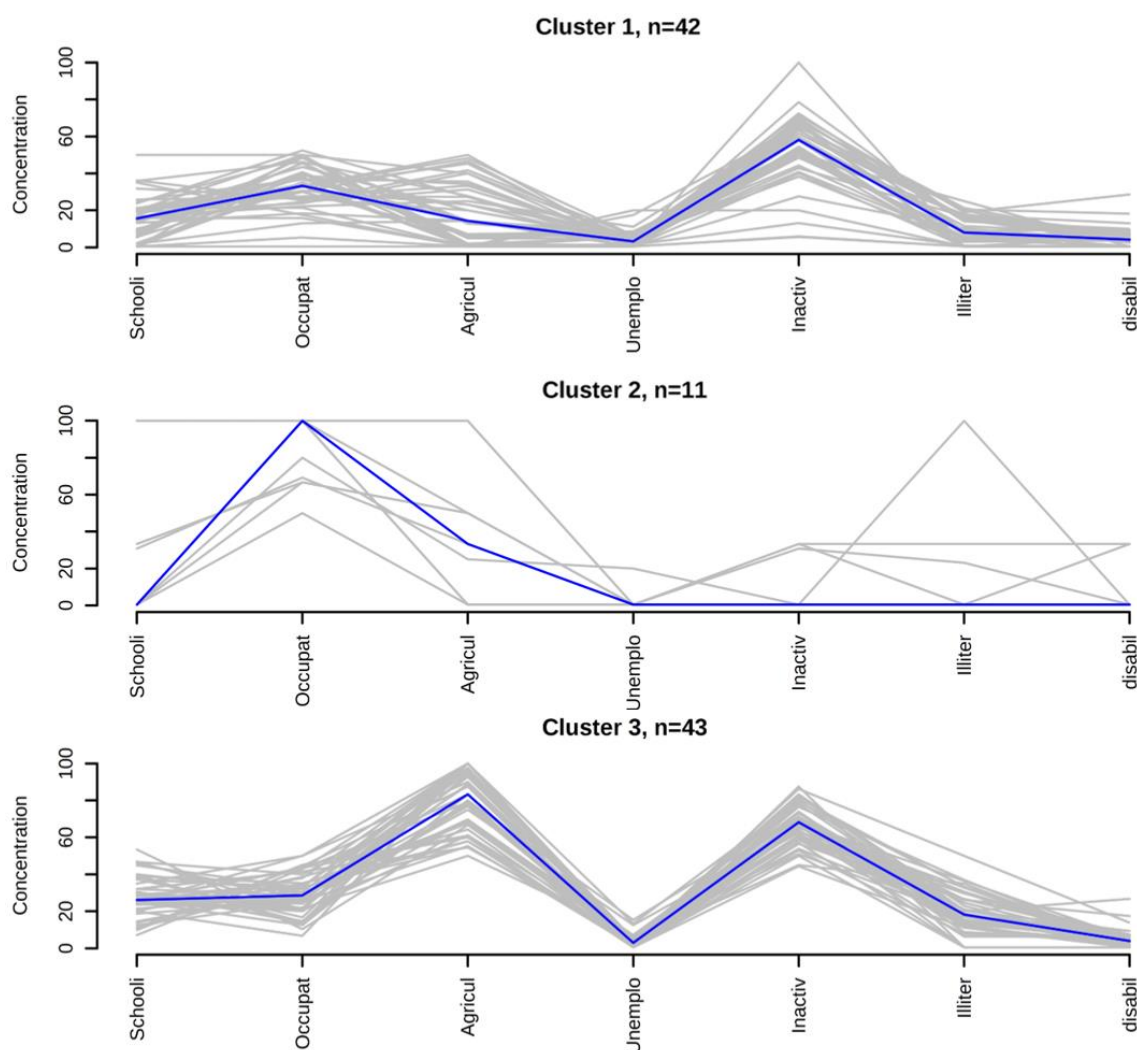
In other words, this research aims to provide technicians, managers, planners and professionals in general of the units assigned to agriculture and environment agencies, with a tool that allows progress in the double task of guiding productive activity within communities and transfer it to the generic objectives defined in the agrarian policies of Panama. Especially, in those linked to productive diversification within the strategy of strengthening own resources; as well as the application of agricultural production methods compatible with the environment and with the conservation of rural spaces.

The lines for sustainable rural development in the District should be oriented to) promote female work in non-agricultural activities; b) look for new sources of employment in culture, leisure, services and the environment (PITTI et al., 2019); c) value traditional knowledge (OLIVARES et al., 2017a); e) design new professions in the rural world (CARPIO, 2002); f) mobilize local savings and investment through the participatory approach (MICHELINI, 2013); g) call emigrants to invest in a new way of return; Among some strategies that would help improve the socioeconomic situation of the district (RODRÍGUEZ et al., 2016).

Table 2 presents the members in each group of the K-means analysis. This type of unsupervised learning algorithm shows patterns in the data without having a specific prediction as objective (there is no dependent variable). Instead of having an output, the data only has one input which would be the multiple variables that describe the data. It is observed that cluster 1 is represented by 42 populated centers, cluster 2 by 11 populated centers, this being the cluster with the least number of populated centers and cluster 3 characterized by 43 populated centers. This

information would be useful for the formulation of projects or plans related to the agricultural and social environment.

Table 2: Clustering result using K-means

Cluster	Populated centers
1	Big Creek, Bluff, Boca De Drago, Bocas Del Toro, Boquet Bay, Chimborazo, Ground Creek, Isla Carenero, La Cabaña, La Carretera, La Colonia Santeña, La "Y" Griega, Mimitimbi, Paunch, Punta Caracol, Quebrada Matombal, Bahia Honda, Bahía Roja, Bastimentos, Jack Analy, Cays, Macca Bite o Ensenada de Espino, Ola Chica, Punta Juan Brown, Punta Oro, Punta Vieja, Quebrada Alvarez, Quebrada Bryan, Quebrada Sal, Red Frog Beach, Short Cut o Red Frog, Solarte, Isla Popa No. 2, Isla Tigre, Playa Caracol, Aguacate, Bella Vista, Bella Vista o Bay View, Isla de Bagui, Loma Partida, Pueblo Nuevo (P), San Cristobal, San Cristóbal Arriba.
2	Caracol Chiquito, Cayo Coral o Isla Coral, Cedral Creek, German Soldier Cay, Kaeyan Cal, Punta Bonita, Wizards Beach, Río Uyama, Buena Vista, Isla Venado, Mina de Carbon.
3	Quebrada Maríano, Alto Caña, Barriada La Fe, Boca de Negrita o La Negrita (P), Cauchero, Cauchero Arriba, Cayo Mono, Cerro Palma, Dos Bocas (P), El Desierto, Loma Azul (P), Loma Cuchilla o Cerro Piedra, Loma Estrella (P), Loma Fría, Los Higuerones, Los Naranjos, Pueblo Nuevo (P), Punta Peña (P), Quebrada del Pueblo, Quebrada Huaca, Quebrada Mina, Quebrada Mono, Quebrada Pinzon, Quebrada Platano, Siloe, Cayo de Agua, Isla Popa No.1, Punta Laurel, Quebrada Piscina, Bahia Grande o Big Bay, Bocatorito, Buena Vista, Cerro Brujo, Cuan Bay, Finca Carlos Peterson, Finca Nessin Yismi, Hope Well o Buena Esperanza, Pichini Creek, Punta Afuera, Secretaria, Shark Hole o Quebrada Marañon, Tierra Oscura, Valle Escondido o Bahia Escondida.

Acknowledgments

Conclusions

The multivariate techniques used were a valuable tool to identify and describe the main characteristics of the indigenous communities in Bocas del Toro, Panama. The study indicates that there are three factors that are the most important in the socioeconomic development of Bocas del Toro: the development of agriculture in indigenous territories, the proportion of economically inactive people and the population engaged in commercial and tourist activity; This characterization serves as the first approach to the study of sustainable land management in indigenous territories.

This type of study represents an advance of great methodological utility because it provides new approaches to study this type of subject in indigenous settings, with an approach that increases existing knowledge based on theoretical and statistical foundations. Likewise, this methodology can be applied in other institutions, communities or organizations. In addition, it presents concordance with the sectoral sustainability strategies, emanating from the respective Panamanian institutes and ministries, oriented towards areas of agricultural development, in search of territorial development and sustainable land management.

This research represents an important part in the establishment of the reference point on the location of agricultural production in the rural development areas of the Bocas del Toro district, local production technology, technical results and the relationships of residents with the environment. In addition, it presents agreement with the sectorial strategies of sustainability, stemming from the respective institutes and ministries, specifically oriented towards agricultural development areas of Panama, in search of sustainable territorial development.

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