Delineation of Agricultural Systems in a Major Tropical Area of Cacao Production (Barlovento, Venezuela) by Means of Multivariate Analysis[1]

M. Barrios, L. Arias**, J. J. San José**

ABSTRACT

Agricultural systems in the Barlovento Valley, a major tropical area of cacao (*Theobroma cacao* L.) production, were studied according to multivariate statistical methods based on factor analysis. Basic data of samples were selected at random from a census of 850 production units, encompassing three main components of the systems: producer's economic rationality, technology, and natural environment. Thirty simple variables were reduced to 11 compound variables or factors. Results indicated that the main factors were related to the technological and economic rationality components of the agricultural systems. Factors were classified by a cluster analysis and farms were grouped into five sets, which defined a spatial pattern in the Barlovento Valley.

RESUMEN

Se estudiaron los sistemas agrícolas ubicados en el Valle de Barlovento, Venezuela -principal área tropical productora de cacao (*Theobroma cacao* L.). Se usaron métodos estadísticos multivariados con base en el factor de análisis. Se seleccionaron al azar datos básicos de un total de 850 unidades de producción censadas, a partir de tres componentes fundamentales de los sistemas agrícolas: racionalidad económica del productor, tecnología y entorno natural. Se escogieron once variables compuestas de treinta variables simples. Los resultados indicaron que los factores principales se relacionaron con los componentes tecnológicos y de racionalidad económica de los sistemas agrícolas. Los factores se clasificaron por medio del análisis de conglomerados, agrupando las fincas en cinco grupos, las cuales definieron un modelo especial en el Valle de Barlovento.

INTRODUCTION

Agricultural systems are a multivariate function of complex interdependent and interaction variables integrated by the components of economic rationality, technology and environmental characteristics (Meza 1980; Molina *et al.* 1983). In tackling this situation, multivariate analysis is a major research approach (Greigh-Smith 1983; Orloci 1978; Pielou 1977, 1984; Ter Braar and Prentice 1988), because a large number of complex sampled variables could be reduced to a few factors (Bravo 1979) and the data structure is revealed for interpretation.

Agricultural systems are classified as open, complex systems (Rosnay 1978) with internal hierarchical levels of synergical organization, interrelations between components, and interconnections between the levels and the organized whole. The study of these systems involves the analysis of the levels, beginning with the country, followed by the administrative region, sub-regions, micro-regions, exploitation and sub-systems. Complex hierarchical models with a manageable number of levels are ideal for such an analysis. This description is suitable for the Valley of Barlovento (Miranda State, Ven.), a major tropical area of cacao production, where such factors as usage and tenure of the land, as well as its agricultural characteristics, are relatively homogenous (Barrios *et al.* 1989). The Barlovento Valley is bordered by the Cordillera de la Costa in the North and the Cordillera del Interior in the South (Fig. 1) and it has more cacao (10 500 ha) than other traditional crops.

The purpose of this work is to delineate the variables that correspond to the components of agricultural systems (economic rationality, technology and environment) in the Barlovento Valley by using a multivariate analysis approach (factor and cluster analysis). The region pattern of the farms is also analyzed by classification of the resulting factors, using cluster analysis.

1 Received for publication on August 25, 1992
We are greateful to Eng. Cesar Medina (Caucagua Experimental Station, FONAIAP) for providing us with survey material and assistence during the field trips. We would also like to thank Dr. R. Lairet (PDVSA) for his suggestions on the photointerpretations of the Barlovento Valley, and Lic. Judith Rosales (IVIC) for her important help with the computer programs.

* Centro de Ecología, Instituto Venezolano de Investigaciones Científicas, Apartado 21827, Caracas 1020-A, Ven.
** Sección de Ecología, Instituto de Investigaciones Agrícolas Generales, CENIAP, Apartado 4653, Maracay 2101, Ven.

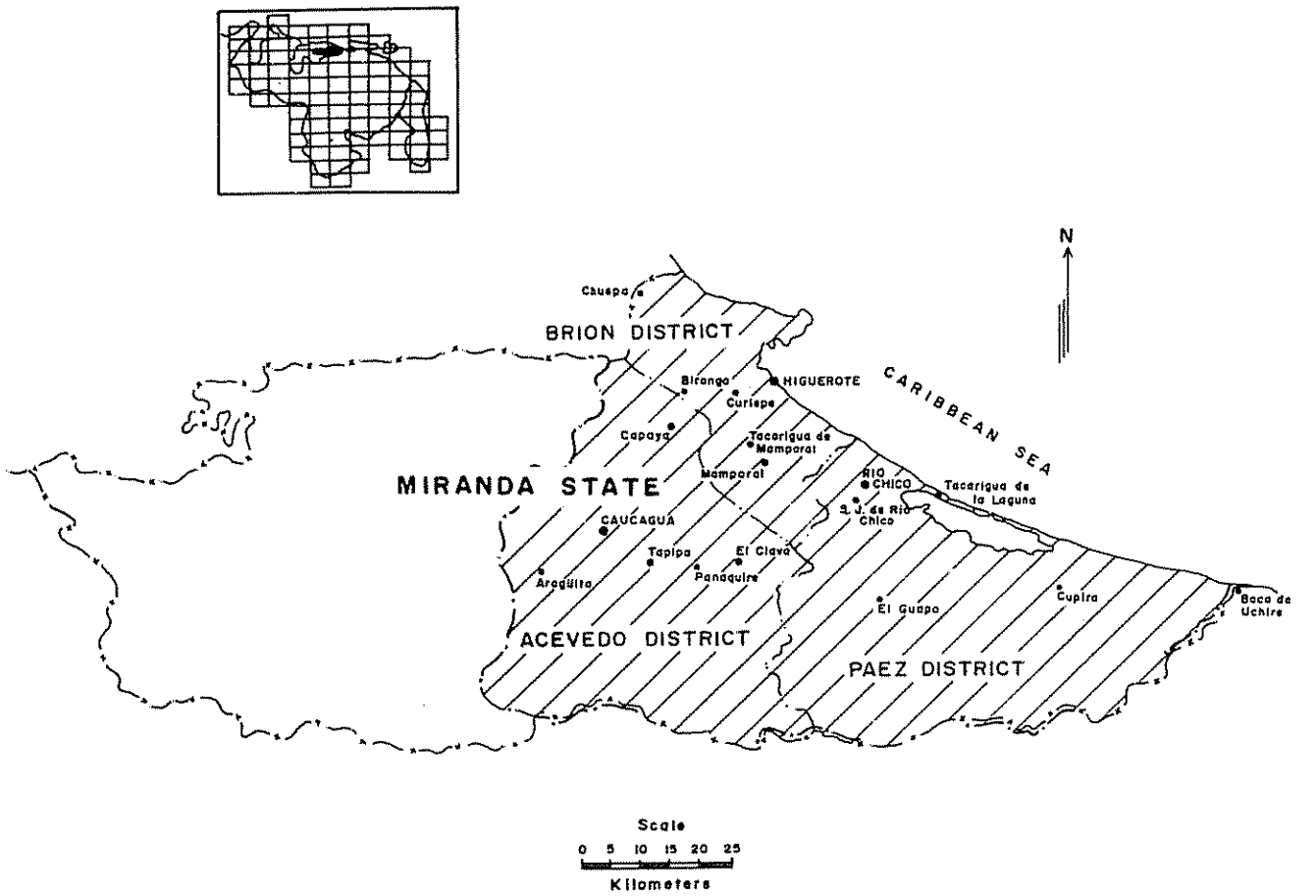

Fig. 1. Region of Barlovento (Miranda State, Ven.) and its relative position.

MATERIALS AND METHODS

Studied area

The studied area in the Barlovento Valley included 43 751 ha (Fig. 1). Climate is characterized by annual precipitation ranging from 1500 to 3400 mm and a mean annual temperature of 26 °C. The area was originally covered by dry and humid tropical forests, according to the classification of Ewel and Madriz (1968). In addition to agricultural activities, human impact on the area due to tourism has recently increased (MARNR 1980).

Temporary changes in the use of land, agroecological characteristics, land tenure regime and socioeconomic structure were interpreted by analyzing aerial photographs (1:35 000) corresponding to the photomosaic Guatire - Cabo Codera - Altagracia de Orituco (Miranda, Misión D-8 1952), and other photoplans (1:25 000) (Mision Chirimena-Guatopo-Sabana de Uchire 1978).

Variables used in the analysis

Eight hundred and fifty production units were censured for the National Project Bio-socioeconomic Diagnosis of Production Systems (PNDB) (Experimental Station of Cagua, FONAIAP). This census included the components of the agricultural systems (producer's economic rationale, technology and environment) of the Barlovento Valley. A sample of 487 production units was selected at random and additional information was obtained from the farms corresponding to this sample.

Soil series and classification according to land use capacity were obtained by locating each of the sampled units on the maps of the agroecological study (MAC 1963) (1:50 000 CIA 1963), as well as the agroecological units and political division of Barlovento (Sánchez 1982), (1:200 000, FONAIAP 1955).

Table 1. Variance "explained" by factors corresponding to the components of the Barlovento Valley agricultural system.

Factor	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Accumulated per cent of the explained variance	12 02	22 27	30.07	36 96	43 05	48 42	53 23	57 71	61 61	65.33	68.87

Table 2. Factors defined in accordance to variables presenting a significant correlation coefficient with the factors for the production systems of the Barlovento Valley (Miranda State, Ven).

Factor	Component	Variable	Correlation coefficient	Factor definition
I	Economic rationality form foundation	- Years since	0 811	Principal use; cacao
		- Machinery ownership	0 674	
		- Machinery limitation	0 659	
	Technology	- Cacao surface	0 802	
		- Musaceous surface	0 755	
II	Technology	- Orchard surface and crop age	0 652	Limitation by shading
	Economic rationality	- Shading limitation	0 701	
		- Crop age limitations	0 713	
III	Economic rationality	- Shading limitation	0 515	Control of pest and diseases
		- Crop age limitations	0 529	
	Technology	- Evolution in land use since plot foundation	0 562	
		- Pest and diseases limitations	0.587	
	Natural environment	- Series of soil	0 524	
IV	Economic rationality	- Credit type	0 748	Financing
		- Credit limitation	0 768	
V	Economic rationality	- Machinery ownership	0 475	Use of machinery
		- Machinery limitation	0 499	
VI	Economic rationality	- Dedication to farming	0.692	Dedication to farming
		- Other activities apart from production	0 499	
VII	Natural environment	- Use capacity	0 433	Land use capacity
		- Infrastructure limitation	0 577	Infrastructure limitation
		- Technical assistance limitation	0.495	
	Natural environment	- Flooding limitation	0 450	
IX	Technology	- Limitations by weeds	0 622	Limitations by weeds
	Natural environment	- Flooding limitations	0 454	
		- Use capacity	0.421	
X	Economic rationality	- Technical assistance limitation	0 553	Technical assistance limitation Economic rationality
XI	Economic rationality	- Electricity limitations	0.488	Crop diversity
	Technology	- Number of crops	0.434	

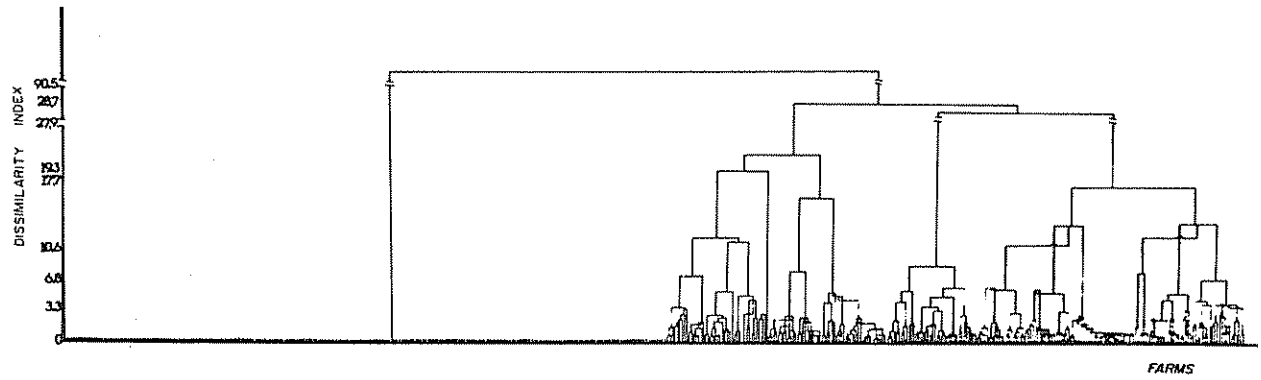

Fig. 2. Classification tree of compound variable (factors) corresponding to the components of the agricultural systems present at the Barlovento Valley (Miranda State, Ven.).

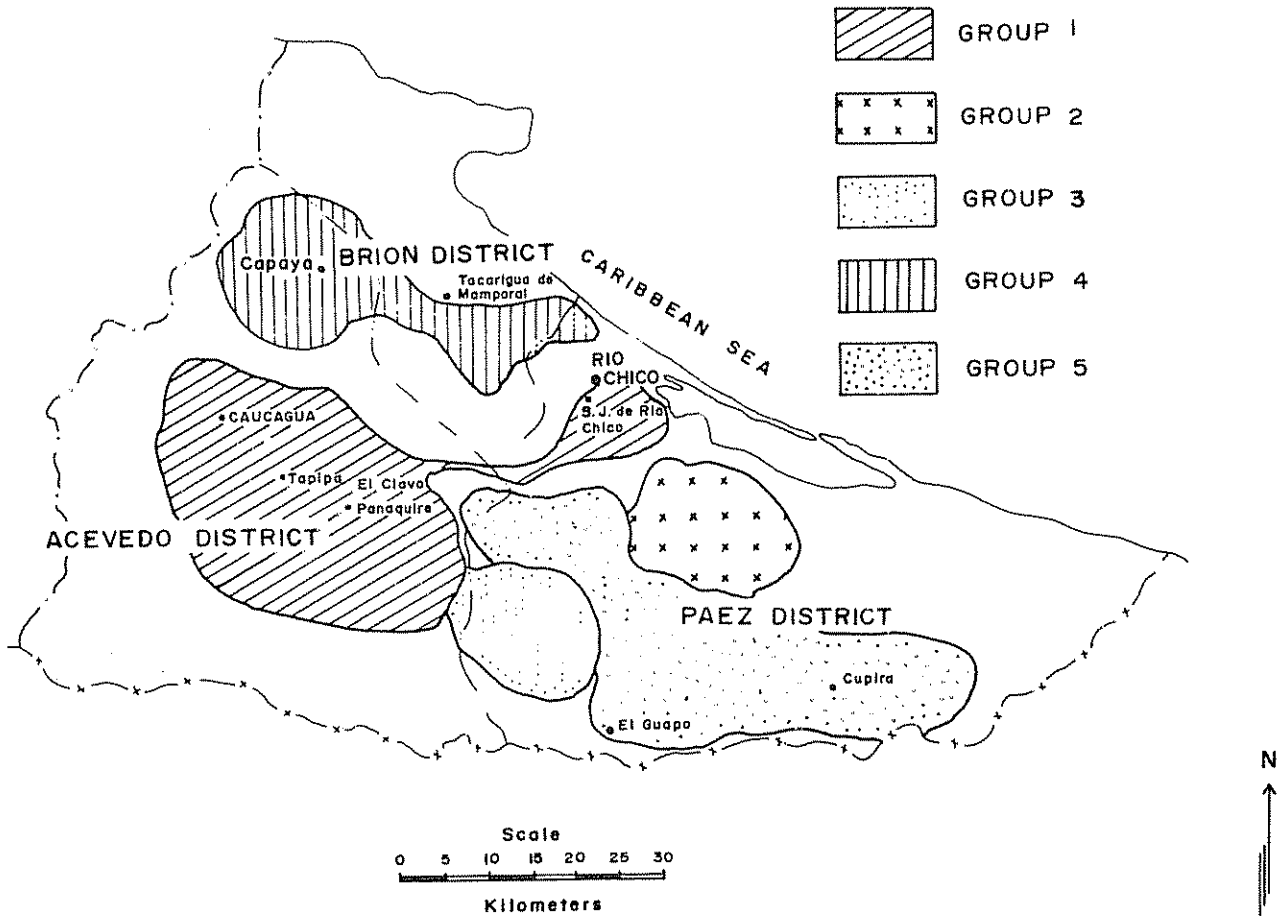

Fig. 3. Distribution pattern of farms in the area of Barlovento (Miranda State, Ven.) obtained as a result of the classification of the factor corresponding to the components of the agricultural systems.

Data treatment:
Factor analysis

Data from the farms were processed with the statistical programs BMDP (Biomedical pack elaborated by Dixon and Brown, 1979), with the Burroughs 6700 systems at the School of Computer Studies of the Central University of Venezuela, and fitted and modified for the present project. Farms (cases) and variables were stored in a 487-case x 30 variable matrix as a data file (BMDP) of fixed format.

Factors were extracted by the principal components method, based on a correlation matrix. Those variables which "explained" more than 70% of the variance were considered as descriptive factors of the system, and each factor was then defined to include the variables on the basis of the highest significant correlation between the factor and the variables.

The matrix of factor scores, including the values of each spatial unit index studied in each factor (axis of variation in the ordination), was used as data input for the classification of the farms by means of cluster analysis techniques. The chi-square test was used as a measure of similarity and the mean distance as a criterion for group linkage.

RESULTS AND DISCUSSION

Thirty original variables were reduced to 11 combined variables (factors) and the accumulated percentage of variance "explained" by the factors is shown in Table 1. These factors were defined on the basis of significant correlations between the factor and the variables (Table 2). Thus, factor I (Table 1), was defined by the land use variables as technological components of the agricultural systems, and this factor "explained" the highest percentage of variance (12.02%). Factor II was related to the producer's economic rationale, especially the variable crop age, since 78% of the plantations in the region were established more than 30 years ago. Factor III corresponded to the inefficient control of pests and disease, which greatly affected crop yields. Financial limitations, restrictions in the use of machinery, and deficient technical assistance were also common. In con-trast with the components of the technological and economic rationale environmental variables explained a relatively lower percentage of the common variance, except for land use capacity.

The resulting classification tree (Fig. 2) shows five classes or groups of farms (Fig. 3) based on dissimilar factor values. In accordance with these results, the Barlovento area presents five homogeneous groups of farms, mainly located in the Acevedo (Group 1), Páez (Groups 2, 3 and 5) and Brion districts (Group 4). A characterization of the limits of the groups, introduced technologies, and available resources are identified below.

Group 1 represents 29% of the total number of farms. Farm area ranged from 0.5 to 150 ha and land-use capacity varied from 2 to 3, according to the classification used. The cacao-musaceous association was introduced to the area less than 30 years ago, and producers mostly chose to use this agricultural system exclusively. Financial support for the plantations is based on public loans and local resources.

Agricultural labor is provided by the nuclear family, with a smaller proportion from temporary contract workers.

On the farms of this group, traditional agricultural practices have been extensively used, and recent technologies based on low shade-high input resources have not been introduced to the system. The agricultural infrastructure is deficient, especially as regards water drainage and control. Marketing is archaic and reduction of cacao yield by pests, disease and weeds are evident.

Group 2 represents 69% of the total number of farms in the region. The farms ranged from 0.25 to 225 ha, with land use classes varying from 3 to 4. Orchards associated with traditional crops were introduced to farms formerly dedicated to cacao with musaceous crops. Thus, a diversification of cacao to include additional crops, so as to use labor on a full-time annual basis was accomplished. Thirty-one percent of the plantations were established after 1950, and the owners lived on the farms; however, 50% of them carry out a commercial activity other than cacao. Labor for agricultural activities was exclusively family members. Funds to support the agricultural systems were provided by public loans.

Technical assistance to this group of farms was practically absent, and infrastructure, including transportation systems, was underdeveloped. In relation to

marketing, a delay in payments introduced a considerable distortion in the currency. The uncontrolled incidence of weeds, pests and disease has reduced cacao yield and quality.

Group 3 represents only 4% of the total number of farms, but their area is the greatest (40-900 ha), as compared to that of the other groups. The owners are exclusively dedicated to cacao, and live in the area, where they contract farm labor. Agricultural activities are financed through farm income.

Technological assistance is inadequate, but the producers have renewed their plantations and agricultural practices are generally mechanized. Local marketing systems should be improved in order to increase farm income.

Group 4 makes 20% of the total number of farmers. Farm area varies from 0.5 ha to 15.0 ha, and the class of land use from 3 to 5. Cacao and cacao-musaceous plots are the rule, and were established before 1950. Advanced crop age and inadequate shading have considerately reduced the cacao yield in a cultivation system based on high shade-low farm input. The producers were settled in the area, where they are exclusively dedicated to their plantations, using hand labour from family members. Delay in the payments of public loans has introduced a vicious circle of continuing depletion of public funds.

Shortages in technical assistance has caused financial losses. Infrastructure and reliability of transportation are necessary to increase cacao supply. Internal marketing for the commodity is no longer able to cope with expanding demand.

Group 5 makes up 31% of the total number of farms. Farm area varies from 0.5 ha to 1200 ha, although 95% ranged from 0.5 ha to 12 hectares. Land use class is around 2, according to the classification system. The predominant plant cover is the cacao–musaceous association, whereas traditional crops cover 20% of the farm as complementary crops, which may increase farm income per unit of land. Plantations are older than 30 years and yield is decreasing. As in the previous group, the producers live on the farms and annual income is exclusively from farm activities, using hand labor from family members and contracted workers. Funds to support agricultural activities come from both public loans and farm income.

Limitations on crop yield are mainly related to pests and diseases. Marketing policies to ascertain customer need are necessary in order to establish a long-term production-export policy.

In summary, the groups can be classified according to the increase in the area of the cacao plantations. Limitations due to crop age follow the same trend, with Groups 1 and 3 the most affected. Major financial problems occurred in Groups 2 and 3, where machinery for agricultural activities is not available. In Groups 3 and 5, the producers were exclusively dedicated to crop production, and Groups 2 and 5 presented a relatively higher land use capacity. The major infrastructural constraints (absence of roads and drainage) were identified in Groups 3, 4 and 5.

The spatial pattern of the grouped farms based on the similarity of the factors extracted by principal component techniques appeared to be related to the historical evolution of the Barlovento area, as well as to human activities. Thus, farms of Group 1 are located in the Acevedo District, where most local communities were settled as early as 1621 (Guerra 1984), with activities focusing mainly on cacao cultivation, using traditional agricultural practices. In contrast, the farms of Group 5 are located in the Páez District, where most of the population was established between the end of the XVII and beginning of the XVIII centuries. In this case, the traditional techniques for cacao plantation have been continuously improved by introduction of in-creasingly appropriate technologies and available resources.

Data analysis suggest that agricultural systems in the Barlovento area, have been mainly shaped by the influence of factors unrelated to potential agricultural productivity; instead, the economic rationale of the producers and the level of technological inputs seemed to be key.

The marketing problems observed at present seem to be similar to those reported for most cacao-exporting countries. Thus, Scheu (1989) has indicated the urgent need to increase diversity of production as well as improving access to overseas markets. The empirical model of the international cacao market as elaborated by Robinson (1989) shows that it is necessary to develop technological strategies to increase plantation yield, rather than the overexpanded the surface are under cacao production.

Results of the present work could assist in determining management priorities that could improve the productivity of each group defined here. It will be necessary: 1) to improve living conditions in the area (housing facilities and public services in order to stimulate permanent producer residence, and 2) to develop technological strategies to increase crop productivity and to change the agricultural pattern from high shade-low input resources to a sustainable agricultural system taking into account the conservation of the area as well as crop diversification and yield.

LITERATURE CITED

BARRIOS, M ; ARIAS, L ; SAN JOSE, J.J. 1989. Multivariate analysis and classification of agricultural systems in a major area of cacao production (Barlovento, Ven.). Turrialba 39(4):477-482.

BRAVO DE DELGADO, M.T. 1979. Análisis factorial: Ejemplos de la aplicación en geografía. Trabajo de Ascenso. Mérida, Ven., Universidad de Los Andes, Facultad de Ciencias Forestales, Escuela de Geografía.

DIXON, W.; BROWN, M. 1979. Biomedical programmes. P. Series Berkeley University of California.

EWEL, J.; MADRIZ, A. 1968. Zonas de vida de Venezuela. Caracas, Ven., FONAIAP, MAC.

GREIGH-SMITH, P. 1983. Quantitative plant ecology. 3 ed. Oxford, England, Blackwell Scientific Publication.

GUERRA, F. 1984. Esclavos negros, cimarroneras y cumbes de Barlovento. Caracas, Ven. Cuadernos LAGOVEN.

MAC (MINISTERIO DE AGRICULTURA Y CRIA). 1963. Estudio agrológico tipo reconocimiento de la zona de Barlovento. Maracay, Ven., Centro de Investigaciones Agropecuarias.

MEZA, S. 1980. Bases conceptuales para el estudio de la agricultura: Los sistemas de producción agrícola. Maracay, Ven., Universidad Central de Venezuela, Facultad de Agronomía, Instituto de Economía Agrícola y Ciencias Sociales.

MARNR (MINISTERIO DEL AMBIENTE Y DE RECURSOS NATURALES RENOVABLES). 1980. Esquema de ordenamiento del litoral Barlovento. Caracas, Ven.

MOLINA, C.; ARIAS, L., COURBOIN, R. 1983. Diagnóstico agroeconómico y social del cultivo de cacao en los asentamientos campesinos de Barlovento. FONAIAP, Ven., Estación Experimental Caucagua.

ORLOCI, L. 1978. Multivariate analysis in vegetation research. 2 ed. The Hague.

PIELOU, E. 1977. Mathematical ecology. Wiley, New York.

PIELOU, E. 1984. The interpretation of ecological data. New York, Wiley.

ROBINSON, H. 1989. Un modelo econométrico del mercado internacional del cacao desde la perspectiva de los países centroamericanos. Turrialba 39(4):511-518.

ROSNAY, J. DE. 1978. Le macroscope: Vers une vision globale. Du Seville (Ed.). France.

SANCHEZ, A. 1982. Unidades agroecológicas del área de Barlovento en el Estado Miranda. FONAIAP-CENIAP, Maracay, Ven.

SCHEU, J.J. 1989. World cacao marketing systems, problems and priorities: An importer's perspective. Turrialba 39(4):534-541.

TER BRAAR, C.J.; PRENTICE, J.C. 1988. A theory of gradients analysis. Advances in Ecology Research 18:172-313.