Characterization of Cropping Systems Integrated with Cattle Raising in the Guayas River Basin, Los Rios Province, Ecuador

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ABSTRACT

The aim of this research was to characterize cropping systems integrated with cattle raising in the Guayas River basin, Ecuador. Samples from 50 farms included as study cases, and 19 variables (16 input and 3 output variables) were studied. All cases were classified by factorial and cluster analysis during the first stage, based on the principal component and non-hierarchical cluster analysis (k-mean) methods. Four clusters (I, II, III, IV) were defined and codified according to the mean values of the related variables. Finally, the productive response was evaluated by one-way analysis of variance, considering each particular codification as study factors depending on the clusters; the output variables were regarded as the productive response. The results showed the priority of the components, which expressed more variability in the systems studied, and depended on input use, residues introduced, and food produced. The classification made according to the variables included in the input component comprised half the samples in clusters III and IV with the highest values. The cropping productive response was dependent on the amount of inputs utilized, whereas, the response of cattle raising was highest in the categories with the lowest input utilization levels.

Key words: *inputs, residues, foods, productive response*

INTRODUCTION

According to Giselli *et al*. (2015), the distribution of bovines in Ecuador is based on the agro-climatic characteristics of three main distinct regions: Sierra, with a temperate climate and special intensive systems, accounting for 50.6% of the national total; and the Costa and Oriente regions (36.3 and 13.1%, respectively), with predominant warm weather, and the application of the double-purpose system.

The province of Los Ríos is located in the Costa region, its economy relies on agriculture, with 14.18% of the national production, including cattle raising. A total of 41 712 farmers live in the area, of which 47% owns up to 5-ha lots; the remaining 53% owns 5-50 ha lots and more (Troya and Hurtado, 2012).

In that sense, Reina (2016) noted that the cropping and cattle raising systems of the Ecuadoran coastline have grown due to deforestation, indiscriminate burning of crop residues, the expansion of croplands, and the implementation of new technologies, by both domestic and foreign producers. Accordingly, cattle raising has been affected by increased flooding, the existence of more attractive economic-productive alternatives, the expansion of short-cycle crop areas (soybean, maize, and rice), and poor knowledge of the ecological possibilities of the region for cattle raising.

The above has determined the existence of little utilization of local resources for cattle raising development. In addition to it, farmers have no production goals, and seasonal animal movement to inappropriate cattle raising areas is a common practice, with ensued decreases in milk and beef yields.

Moreover, previous studies characterizing cropping systems integrated with cattle raising are nonexistent; their results are based on the components that explain greater variability and provide elements for rearrangement and development of cattle raising. Accordingly, the aim of this research was to characterize cropping systems with cattle in the low basin of Guayas River, Los Rios Province, Ecuador

MATERIALS AND METHODS

The work scenario was located at the lower basin of Río Guayas, in Los Ríos province, Ecuador, made by river valleys and coastal alluvial plains with not many depressions (savannas), most of them fertile. It has a great variety of soils, predominantly inceptisols (47.28%), followed by entisols (37.24%), and alfisols (8.43%). The climate is semi-humid tropical, and megathermal, which is characterized by a single rainy maximum value, and a very dry season with mean temperatures of 24 and 26 °C. The precipitation values are 1 250-2 000 mm (AOICORP, 2014).

Sample selection and collection of information from the farms

Randomized sampling was made at the location of the study, following the criteria of Álvarez *et al*. (2014). Out of 680 farms, 50 were selected (study cases) according to the following inclusion criteria: accessibility, farmer availability for research purposes, size (10-100 ha farms were included), and the presence of cattle integrated with cropping. The information was collected using the methodology suggested by Giller *et al.* (2011), which combines different participatory research tools. It was begun by a quick rural diagnostic through interviews and documentary review. Consequently, a survey containing structural and functional variables was designed. The production records of the local offices of the Ministry of Agriculture and Livestock were used to complement the existing information. Georeferencing, soil mapping, models of digital elevation, and temperature and precipitation data, were used to estimate accurate information of the variables used on each farm.

Selection of the variables for analysis

A number of 32 variables were identified from the information collected, based on the procedure by Vargas *et al.* (2013); variable aggregation and combination was performed in order to improve and simplify data structure. That way, subgroups of variables related to a single input or item were pooled to create compound variables. Only 3 out of 23 variables corresponded to the original ones, the others were combinations of the initial variables. Four variables were discarded due to their low discriminating power (Coronel and Ortuño, 2005). The other 19 were divided into input and output (productive output) variables, as shown below:

Input variables: total area (ha); cattle raising area (ha); various crop area (ha); production costs (USD.ha^{-1}); power consumption expenses (MJ.ha^{-1}); chemical fertilizers (kg.ha^{-1}); residues produced on the farm for animal nutrition (kgMS.ha^{-1}); herbicides used (kg.ha^{-1}); requirements of animal food (MS.ha^{-1}); stocking rate (CU.ha^{-1}); residues introduced for animal nutrition (kgMS.ha^{-1}); grass production (kgMS.ha^{-1}); total food production, including pastures and residues (kgMS.ha^{-1}); met nutritional requirements (%); and number of enclosures used (number).

Output variables: milk production (kg.ha^{-1}); beef production (kg.ha^{-1}); crop production (kg.ha^{-1}); and total yields (kg.ha^{-1}), which comprised all the productions of the farm.

Procedure for information analysis

A frequency analysis was made with the input indicators, by estimating the central trend statistics and dispersion. A second stage included the classification of all cases by multivariate analysis: Factorial analysis (FA) and cluster analysis (CA). Several extraction methods were performed, until the principal component analysis was finally implemented. The rotation method was also implemented: Normalized varimax procedure (Kaiser) was performed; the Bartlett's test of sphericity was highly significant ($P<0.01$); as well as KMO=0.65 (Kaiser-Meyer-Olkin). Three components with explained accumulated variability (70% or above) were selected. Besides, the preponderant indicators (0.60 or more) were selected from each factor or principal component.

A third stage was performed to classify the farms in relation to the first component achieved in the previous stage. Cluster analysis was made based on the sequence used by Vargas *et al.* (2013), which included two phases: in the first one, Ward hierarchical clustering was used to determine the preliminary number of groups (clusters) to make. Progressive clustering levels were explored, and the optimum level was defined according to the best distribution of study cases based on the clusters formed. Definitive clustering was established during the second stage of CA. The *K-mean* nonhierarchichal method was used with the starting number of clusters previously specified as optimum in the previous stage.

Four clusters were identified as optimum and codified according to the mean values of the variables involved (I-IV). The characterization of the cases for each cluster was performed through their means.

Lastly, the productive response achieved was evaluated according to the codification obtained (analysis factors) in each study case, depending on the clusters. The theoretical assumptions of analyses of variance were verified, including data normality. One-way analysis of variance was conducted, which included the application of

Duncan's multiple values (1955) for mean comparisons in the cases that demanded it. SPSS®, 11.5, for Windows XP® was used.

RESULTS AND DISCUSSION

The analysis of frequencies made to the input indicators (Table 1) showed the heterogeneity of the areas and their distribution, with variation coefficients above 100%. In that sense, Requelme and Bonifaz (2012) evaluated the size of dairy farms in several Ecuadoran regions, using different stratums, and found average values between 3 and 120 ha, which coincided with the results presented in this study. A common element was the presence of cattle raising practices along with cropping. According to data provided by AOICORP (2014), rice accounts for 48% of the surface, followed by banana, cocoa, maize, and soybean. Concerning cattle raising, native grass and crops cover 18.6% and 11% of the total area, respectively.

The production costs were higher than the ones reported by Ochoa and Valarezo (2014), who studied this indicator on cattle raising farms based on forest-grazing systems and traditional systems in canton Yantzaza, Ecuador. Contrary to the results of the above authors, the systems studied based their productions on input use, which produced higher costs. The performance observed in this variable was related to energy expenses, including chemical fertilizers and herbicide use, with similar variation coefficients.

Guevara *et al.* (2013) evaluated the total energy consumed by two cattle farms, and reported lower values than the ones published in the analyses. Llanos *et al.* (2013) noted that the energy consumption expenses are influenced by the internal inputs used; therefore, proper use of natural resources provided by the environment will guarantee a better use of the local nutrients and energy sources.

The results achieved in terms of costs and consumed energy evidenced the existing dependence on inputs, and the underutilization of local resources. Paz *et al.* (2014) pointed out that the increase in the use of fossil fuel power involves intensification of the productive systems with an ensued potential hazard to the ecology. This consumption may be reduced with the inclusion of green power sources, like wind and solar power, and bioenergy, or even by increasing the efficiency of energy use.

Furthermore, the production of residues for animal nutrition on the farms (Table 1) was below the reports made by Reyes *et al.* (2013) for farms with similar crops; however, the same scenario was not observed in relation to the residues introduced, with higher values. These residues are supplied by farmers with better specialization in cropping systems (rice, plantain, and soybean), which is one of the main alternatives to maintain animals. Giselli *et al.* (2015) characterized double purpose dairy farms in tropical Ecuadoran regions, and found that 64.3% of foods was based on crop residues. Besides, Pereda (2017), in a different context, evaluated the utilization of residues on cattle farms and found similar values when mid and mid-high integration values were accomplished.

An analysis of the average values achieved by the animal nutrition-related variables showed that local food production, including pastures and residues, only met 52.7% of the annual needs, evidencing the deficiencies in animal food availability. This feeding scenario forced farmers to establish management variants that included seasonal grazing in neighboring areas, usually far from the farms and inadequate for cattle raising.

Another variable included was animal stocking rate, with poorer values than the studies conducted by Giselli *et al.* (2015) who evaluated this indicator on farms, considering different dimensions and agroecological areas in the province of Manabí. Meanwhile, Valdés *et al*. (2013), on their explanation about dairy farms with productions higher than 5 000 L per cow, observed that the animal stocking rates were not above 1.5 cows per hectare, which should be taken into account due to the characteristics of the region in the study.

Lastly, the number of enclosures was included. Milera *et al*. (2014) pointed out that the number of enclosures is critical for management and preservation of grasslands and their productive capacity; however, they considered that the optimum number of subdivisions to implement rotational grazing had to be set. Differently from the above authors' remarks, the farms studied only had four enclosures on average, a condition that hindered the establishment of proper management strategies.

The analysis of principal components (Table 2) showed that the variables gave place to three new components by order of priority, which accounted for more than 80% total variance. These results evidenced the importance of variable selection, and the influence they had on the systems studied. These results coincided with the reports of Chivangulula *et al.* (2014), who achieved more than 70% total variance explained for the three first components using the same model.

The analysis of the variables in the study showed factorial animal stocking rates above 0.60 in certain components. The first one was the most significant, accounting for 38% of total accumulated variance. The variables integrated in the first component had a positive correlation to the inputs used by the farms. This trend has increased in the region recently, along with the use of resource-dependent, high-cost technological packages.

Regarding input utilization and agricultural development processes in Latin America and the Caribbean, Ortiz and Alfaro (2014), said that they have been characterized by a greater use of capital, fertilizers or pesticides, which have been part of the first component analyzed.

The second principal component explained 33.8% of variance, and it was related to the used of residues on the farms. The utilization of residues has become an alternative to maintain the cattle of the studied region, due to long periods of flooding, and the increased number of areas engaged in cropping only. In this component, the need for food, the stocking rate, and the introduced residues underwent negative correlations with the factor. The first variable was conditioned by the residues introduced. This could be solved if the farms reduced their dependence on external sources, and allowed for better utilization of the resources of the productive systems to maintain their animals. Upon analysis of the animal stocking rate, the mean values of the sample were 0.90 $CU.ha^{-1}$, above the productive capacity of agroecosystems. It was determined by long periods of flooding, little availability and quality of pastures, and the conditions to establish a proper strategy for management and nutrition. In that sense, Cuellar *et al.* (2015) who studied milk production in herds with stocking rates higher than 1 $CU.ha^{-1}$, reported a decrease in milk production that also affected the existing vegetable surface. The other variables showed positive correlations, and expressed their relation with the extracted factor.

The third component was termed *foods*, and accounted for 16% of variance. Three variables were integrated in it, which were linked to total food production, pasture production, and cattle raising. This factor should be addressed due to the current need to implement new alternatives, like animal movement to other areas or the introduction of residues to enhance food production on the farms.

Cluster analysis was based on inputs (first component), and showed that the study cases had a balanced distribution of the clusters formed (Table 3). The first group was made of 14 cases, which represented 25% of the sample; the second and third ones comprised 13 and 18 cases, for 25 and 30%, respectively. Lastly, the fourth cluster (13 cases) accounted for 20% of the sample.

An analysis of the studied variable means (Table 3) showed that the values of clusters III and IV were 100% higher than the means of clusters I and II. Clusters III and IV contained 50% of the total cases in the sample, and posed an alert on high input use by farmers.

This result lays the foundations to evaluate sustainability of the local productive systems, which are sensitive due to their ecological, economic, and social characteristics. In that context, Gaspar *et al.* (2008) referred to certain intensification processes of ovine production systems, which include capital investment. They noted that these led to loss of competitiveness of traditional cattle raising systems, lack of sustainability, and negative effects on agroecosystems. Also Fernández *et al.* (2006) established the relation between degradation and loss of productivity in grasslands and faulty use of technology, and dependence on external inputs.

Table 4 shows the productive response by cluster with significant differences ($P < 0.05$) among the groups formed, particularly between groups I and IV. The highest beef and milk values were observed in cluster I, which indicated the link between these productions and the low levels of inputs used. In that context, López *et al.* (2015), after evaluation of dairy system inputs, remarked the importance of forage and feed production and quality, which might improve energy balance and utilization, and optimize milk production and/or quality.

Moreover, Díaz (2008), in a study of cattle fattening systems, referred to the advantages of introducing legumes. However, according to the author, it was impossible to produce more than 1 000 g of mean daily gain without proper supplementation with feeds, which justified their inclusion. If the previous is considered, the low levels of productive response in terms of beef and milk are justified.

Generally, the local cattle production is an alternative for household and local consumption, as well as a way to generate additional income. This situation leads to inadequate production conditions, and the lack of attention regarding the use of technology and resources for production, in addition to low productive yields (Table 4).

The same scenario does not take place in cropping and total yields, with significant differences ($P<0.001$) for clusters III and IV. The results observed indicated that the inputs used are mainly allotted to cropping, due to the economic advantages brought by the market.

In keeping with the above, Magallanes (2016), noted that in the Guayas River basin soil is mainly used for cropping, due to the abundance of natural resources, like water and soil fertility. The cropping system is highly intensive and technological, whose main crops (banana, cocoa, coffee, tropical fruits, sugar cane, rice, etc.) are either exported or sold domestically. This is one of the most highly cultivated crop areas in Ecuador.

Despite the above, the crop productivity potential of the region is not properly integrated with cattle raising, and the available resources are not used efficiently. Monzote *et al.* (2001) referred to the advantages of cattle-crop integrated systems, since they are sustainable, efficient, and productive alternatives to specialized production systems. The above-mentioned authors provided evidence that by combining all the components as a coherent whole, the results can be improved in terms of energy and production, as well as in available natural resources. These results lay the foundations for new diversified productive systems in the region studied. They could benefit cattle raising with better management strategies and, therefore, lead to an increased productive response.

CONCLUSIONS

The results showed the priority of the components with the greatest variability of the systems studied, and were associated with input use, introduced residues, and food produced. The classification made according to the variables included in the input component comprised half the sample of clusters III and IV, with the highest values. The cropping productive response was determined by a substantial use of inputs; however, the response of cattle raising was higher in the categories with the lowest input utilization levels.

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Table 1. Descriptive statistics for the input variables studied

Variables	Mean	SD	VC (%)
Total area (ha)	34.3	41.9	122.0
Cattle raising area (ha)	16.9	24.1	143.0
Various crop area (ha)	13.3	18.5	139.2
Production costs (USD.ha^{-1})	1 182.1	677.1	57.3
Energy expenses (MJ.ha^{-1})	10 079.7	6 975.9	69.2
Chemical fertilizers (kg.ha^{-1})	123.8	87.8	70.9
Herbicides used (kg.ha^{-1})	6.4	4.5	70.5
Residues produced (kg.DM.ha^{-1})	460.9	328.1	71.2
Residues introduced (kg.DM.ha^{-1})	984.9	685.0	69.5
Food requirements (kg.DM.ha^{-1})	3 101.7	1 500.2	48.4
Pasture production (kg.DM.ha^{-1})	764.1	524.5	68.6
Total food production (kg.DM.ha^{-1})	1 224.9	433.4	35.4
Annual food requirements met (%)	52.7	39.2	74.4
Animal stocking rate. CU.ha^{-1}	0.9	0.4	49.6
Number of enclosures used	3.7	1.7	47.0

Table 2. Correlations between the indicators studied and the three principal factors extracted

Components	1	2	3
Self-value	5.706	5.075	2.410
Explained variance %	38.043	33.830	16.069
Accumulated variance %	38.043	71.874	87.943
Indicators	Inputs	Residues	Foods
Financial costs	0.992	0.075	0.025
Energy expenses	0.989	0.095	-0.088
Chemical fertilizers	0.989	0.096	-0.088
Residues produced	0.988	0.098	-0.089
Herbicides	0.985	0.117	-0.093
Food requirements	-0.023	-0.943	0.164
Animal stocking rate	-0.020	-0.940	0.171
Residues introduced	-0.011	-0.939	-0.047
Food requirements met	0.307	0.786	0.342
Various crop area	0.382	0.748	0.361
Enclosures	0.375	0.710	-0.022
Total area	-0.125	0.704	0.248
Total food production	0.159	0.013	0.954
Pasture production	-0.486	-0.051	0.844
Cattle area	-0.399	0.438	0.624

Table 3. Mean values and number of cases according to pertinent clusters

Indicators	I (n=14)		II (n=13)		III (n=18)		IV (n=13)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Financial costs	330.5	203.0	1 632.5	188.3	919.0	215.0	2 047.4	180.8
Energy expenses	1 316.1	1 272.6	14 612.0	1 967.3	7 211.9	1 926.8	19 304.3	1 366.0
Chemical fertilizers	14.0	16.1	180.3	24.7	87.0	23.5	240.6	17.1
Residues produced	52.2	60.2	672.5	92.3	322.21	90.8	897.45	63.9
Herbicides	0.7	0.8	9.32	1.2	4.61	1.4	12.42	0.8

Table 4. Productive response according to the clusters formed

Indicators	I	II	III	IV	SE±	P
Milk production ($kg.ha^{-1}$)	178.8[a]	102.1[bc]	133.8[b]	89.3[c]	14.37	0.014
Beef production ($kg.ha^{-1}$)	54.6[a]	18.4[b]	31.2[b]	23.8[b]	4.59	0.032
Crop production ($kg.\ ha^{-1}$)	96.0[d]	561.0[c]	1 103.4[b]	1 443.6[a]	69.35	0.000
Total yields ($kg.\ ha^{-1}$)	329.5[d]	726.2[c]	1 224.0[b]	1 556.7[a]	64.61	0.000

Rows with equal letters differ significantly, according to the Duncan's test.