Impact index for the characterization of factors affecting milk production in farms of Ciego de Ávila province, Cuba

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In order to characterize the factors affecting milk production in farms of Ciego de Ávila province, a methodology to calculate the impact index for each principal component (PC) was used. It depends on the indicators of higher preponderance in each PC and expresses the highest or lowest effect of each indicator per study case. A total of 372 farms were studied as well as the productive, physical and of efficiency indicators. Five PC explained 72.1 % of the variance. The PC 1, representing the total area of natural grasslands, undesired plants and stocking rate, had higher index in the farms of Majagua municipality and lower in Florencia, while the indicators of the second PC (production and efficiency) showed higher indexes in Florencia. The impact index of PC 3 (feeding basis) indicated higher forage areas in the farms of Majagua and Florencia, while that of PC 4 (reproductive performance) showed a wide variation. The index of PC 5 showed low mortality. It is concluded that considering these factors related with the management, feeding basis, productive and reproductive component and mortality that affect the productive efficiency of the farms is necessary to adjust from the use of a strategy of technological management and of control of sustainability indexes. The impact index contributed to explain the great variability between farms and indicated the higher or lower relative importance of the indicators in the farms of each municipality.

Key words: *rural dairy systems, multivariate analysis, principal components, efficiency.*

Different methodologies have been applied in the analysis of cattle rearing systems according to the objectives and concrete situations of each geographical area. Those referred to the multivariate methods have allowed analyzing information of different characteristics in order to define the elements causing more variation and are important to deciding changes, distributing the resources, improving the marketing of products, introducing technologies or applying policies to preserve the environment.

The studies of Benítez *et al*. (2008) demonstrated that the factors having a negative environmental effect on cattle rearing farms of the mountain area of Granma province, Cuba, are related with the variables determining the management alternatives of the grazing systems. Guevara *et al*. (2004), with the multivariate analysis described, dynamically and integrally, dairy production units belonging to Basic Units of Cooperative Production (BUCP) in a region of Camagüey. Acosta and Guevara (2009) worked with cattle entities, but with an environmental approach and determined the effect of cattle rearing on the environment.

The methodology proposed by Torres *et al*. (2007) is also based on a combination of multivariate methods and allows determining and analyzing the impact indexes offering information about the positive or negative nature of the environment and the performance of individuals or cases under study (Torres *et al*. 2008). This technique was applied in studies of Febles *et al*. (2011) to interpret the relative influence of edaphoclimatic factors on the tropical seeds production but its use in the study of dairy rural farms is unknown.

The objective of this study was to use the impact index to characterize factors affecting milk production in farms of Ciego de Ávila province, Cuba.

Materials and Methods

The study was conducted in Ciego de Ávila province that has ten municipalities. Out of them, the seven with higher milk production (Ciego de Ávila, Majagua, Florencia, Baraguá, Chambas, Primero de Enero and Bolivia) were selected, with 88.3 % of the province production. The Cooperatives of Credits and Services (CCS) are responsible there for the milk production (79.6 % as average). A total of 372 units belonging to farmers were studied. Dedication, of three or more years, to the dairy activity, regularity on milk production during the whole year and availability of reliable productive information at the cooperative level were used as selection criterion.

The indicators studied were divided in physical, productive and of efficiency.

Physical indicators (ha). The total areas, uncultivated pastures, cultivated pastures, sugarcane and king grass were included here, as well as the areas of undesired species and those for protein banks, together with the area corresponding to the number of paddocks. Later, other secondary variables were included: percentage of uncultivated pastures, cultivated pastures, sugarcane, king grass and undesired species. In the king grass areas, which were of cut, the differentiation per species could not be established due to their diversification and mixture.

Productive indicators. They corresponded to the total cows' annual average (u), annual milk production (kg), annual total deaths (u) and calves deaths (u).

Efficiency indicators. The percentage of milking cows and birth rate, annual milk production/total cow, milk/ha and stocking rate (LAU/ha) were included. These variables were generated from the primary data. For calculating the large animal units (LAU), the equivalent of 1 LAU=bovine of 500 kg liveweight was used.

The methodology proposed by Torres *et al*. (2006) was applied and the fulfillment of the mathematical assumptions according to Torres *et al*. (2008) was proved. The analysis of the principal components was repeatedly used to select the variables of greater importance when differentiating the dairy units.

The principal components (PC) with eigen value over 1 and the variables with weight factors or of preponderance over or equal to 0.58 were selected. The impact index of the principal components was calculated for each farm, depending on the variables with higher preponderance in each PC and allowing interpreting the performance or level of the variables in each PC, in each case or farm under study. The analyses were conducted with the statistical software SPSS of Windows, version 11.5.1 (Visauta 1998).

Results and Discussion

The analysis showed that the sphericity test of Barlett was highly significant ($P < 0.01$), and the statistical one KMO (Kaiser-Meyer-Olkin) obtained value of 0.65. This indicates that the data have the assumptions required for a factorial analysis.

The application of this method allows a better interpretation of the data, with the obtainment of five new variables or components (table 1), which express the higher amount of information of the dairy farms. The high number of preponderant variables should be highlighted, which may indicate the feasibility of their use in the study.

Five PC were obtained, explaining 72.1 % of the total variability of the total data. The PC 1 was named management and was represented by the variables total area, uncultivated grasses area, undesired plants and stocking rate, this last with a negative correlation.

The PC 2 (productive component) represented the cows, the annual production, per cow and per hectare and explained 18.6 % of the variance. The area dedicated to the sowing of uncultivated pastures and forages (sugarcane and king grass) explained 13 % of the variance in the PC 3 (feeding basis component). Meanwhile, the PC 4 was represented by reproduction and PC 5 by mortality.

The application of the multivariate analysis allowed reducing the number of variables when explaining the variance. The percentages of improved pastures area, sugarcane and king grass were eliminated from the analysis for having a high correlation with the extension

Table 1. Matrix of the preponderant factors between the principal components and the variables studied in the dairy farms

Variables	Principal components				
	1	2	3	4	5
Total area	0.81	0.21	0.38	0.01	0.15
Area of uncultivated pastures	0.84	0.08	0.31	-0.00	0.13
Area of cultivated pastures	0.10	-0.02	0.68	0.01	0.04
Sugarcane area	-0.04	0.05	0.74	-0.01	-0.02
King grass area	0.14	-0.04	0.73	0.01	-0.01
Area with undesired plants	0.58	-0.09	-0.25	-0.01	-0.02
Number of paddocks	0.09	0.35	0.58	-0.19	0.07
Total of cows	0.40	0.59	0.16	-0.24	0.49
Annual milk production	0.17	0.93	0.13	0.05	0.10
Total deaths	0.01	-0.03	0.02	0.05	0.84
Percent of milking cows	0.04	0.10	0.11	0.86	-0.01
Percent of birth rate	0.01	0.04	-0.21	0.86	0.01
Liters per total cows	-0.14	0.73	0.01	0.35	-0.36
Liters per hectare	-0.55	0.76	-0.05	0.07	0.03
Stocking rate	-0.64	0.32	-0.16	-0.22	0.43
Eigen value	3.53	2.80	1.95	1.49	1.03
Variance, %	23.5	18.6	13.0	9.9	6.9
Accumulated, %	23.5	42.2	55.2	65.2	72.1

1- Management
2- Production
3- Feeding basis
4- Reproduction
5- Mortality

of their respective areas, the calves mortality for its high correlation with the total mortality and the variable of protein banks or areas for planting trees for their use in animal feeding as they did not exist in these farms. This is a negative element as the use of protein plants and legumes influences on the nitrogen contribution to the systems and, therefore, favors the efficient recycling of this nutrient. Besides, it diminishes its extreme needs and increases the diversity of the resources used in cattle feeding (Murgeitio *et al*. 2006).

The results of the preponderance coefficients of table 1 show that the variables used are important to define the variability among the farms studied. From the practical point of view, they can be used to classify these farms and should be considered to plan the feeding and managing of the herds.

The dairy farms studied were characterized by having herds with lower amounts of total cows, in milking and annual total production (table 2), compared with other intensive dairy systems belonging to different ways of cooperative production such as those used in studies of Guevara *et al*. (2004) and Acosta and Guevara (2009). However, the land was poorly used as the mean production per hectare was inferior to 500 L. This can be related with the lack of areas dedicated to the forage sowing and can endanger the amount of available feed in the dry season. Somda *et al*. (2005) and Díaz (2008) demonstrated the necessity of technologies in cattle systems. The establishment of biomass banks to guarantee the basic feeds during the dry season is an option for the dairy systems in the tropics (Martínez 2004).

The little variation in the number of paddocks, with mean of 2.95 and a standard deviation of 2.23 in 372 cases, indicated that they are insufficient to achieve the efficient management of pastures to guarantee the necessary resting time (Senra *et al*. 2005) and not compromise the sustainability indexes of the grassland and animals (Senra 2005).

The productive indicators of the farms studied showed a wide variation margin. This confirm the necessity of conducting a classification to determine similar groups that allow planning, deciding and managing the actions to increase the efficiency levels in milk production.

The impact index of PC 1 (figure 1) shows the irregularity in the total area of the whole farms, which also relates with the areas of uncultivated pastures, undesired plants and stocking rate. There was tendency to the predominance of positive and high indexes in the farms of the Majagua municipality. This indicates higher size of the farms in this territory and lower amount of animals per hectare, as the stocking rate had a negative correlation in respect to the total area and of uncultivated pastures. This situation differs from that occurring in Florencia, where the negative impact indexes predominate, while the index was variable in the rest of the municipalities.

The total areas and of uncultivated pastures are indicators that may be a starting point to classify the farms, and express the productive potentialities depending on the extension and efficiency use of the land. In this sense, Buysse *et al*. (2005) stated the necessity to plan actions to achieve an efficient use of the pastures, as main feeding basis of the herds.

The variation of the PC 1 impact index shows the differences of the farms and reaffirm the necessity of taking account these indicators to establish a correct management of these systems with uncultivated pastures as basic feeding. Besides, the model explains the tendency to reduce the efficiency of land use as the

Table 2. Descriptive values of the productive indicators in dairy farms

Indicators	Minimum	Mean	Maximum	SD
Total area (ha)	4.17	36.3	129.5	26.3
Area of uncultivated pastures (ha)	2.08	22.2	67.1	15.3
Area of cultivated pastures (ha)	0.0	0.35	8.8	1.11
Sugarcane area (ha)	0.0	0.37	4.16	0.68
King grass area (ha)	0.0	0.33	4.0	0.72
Area with undesired plants (ha)	0.0	2.05	33.5	4.88
Number of paddocks (u)	1.0	2.95	21.0	2.23
Total cows (u)	2.0	21.0	82.0	13.0
Milking cows (u)	1.0	10.8	48.0	7.6
Annual milk production (L)	1200.0	11971.2	72400	10717.4
Total deaths (u)	0.0	0.71	10.0	1.41
Percent of milking cows	11.11	52.0	92.11	16.3
Percent of birth rate	14.2	55.3	85.7	15.9
Liters per total cow (L)	64.36	566.2	2785.28	301.6
Liters per hectare (L)	36.94	399.9	2381.48	308.9
Stocking rate (LAU/ha)	0.08	0.70	2.60	0.39

farms have higher extension.

The index of PC 2 (figure 2) relates the production level with indicators of the system. They prove, all together, the results of the interactions of different factors influencing on the productive process and its efficiency. Several authors, like Martín and Rey (1998), Guevara *et al*. (2003), Lerdon *et al*. (2008) and Senra (2011), define the amount and breed of the cows, the feeding quality, the stocking rate used, the pastures and animals management, the man training and technology used, as important factors for managing the dairy systems.

In the farms of Florencia municipality, in spite of the negative indexes of PC 1, there was a superior level in that of the PC 2, together with the first third of the farms of Baraguá municipality. Three farms highlighted with indexes over 4, two in Florencia municipality and one in Ciego de Ávila. However, in most of them the indexes were low or negative.

This result allows inferring that the total annual production of milk per farm, as well as the total production per cow and hectare was only superior in a reduced number of farms. Besides, it demonstrated the importance of using these variables to measure the productive efficiency in these systems. The need of studying the cases of Florencia municipality is also evidenced.

In this sense, factors related with the knowledge of producers to control systematically fundamental sustainability indexes that allow the proper adjustment of the technologies applied should be considered. Likewise, a positive final effect is assured (Senra 2011).

The impact index of PC 3 (figure 3) showed a more regular performance. This index related the characteristics of the feeding base in every farm. There was predominance of superior indexes in the farms of Majagua, Florencia and two cases of Ciego de Ávila municipality. This indicates that there was superiority in the amount of feed, as well as higher feeding safety compared with the rest of the farms, where the basic feeding comes from uncultivated pastures with low yields.

These results corroborate the importance of planning the feeding and apply, consequently, the feeding balance in some ways. Besides, it implies establishing a program, at the cooperatives levels, for introducing, establishing and exploiting forage species and improved pastures that allow increasing the biomass availability and quality in these farms.

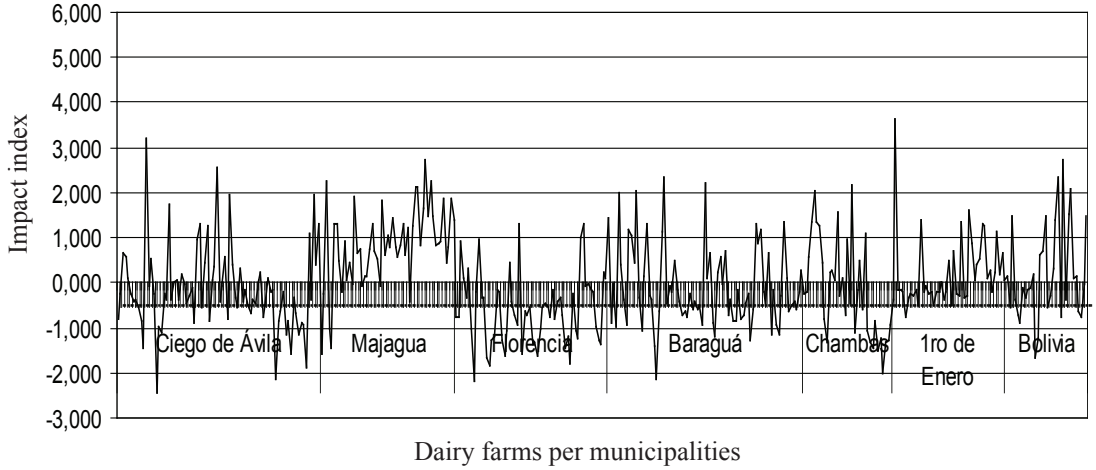

Figure 1. Impact index of the total area, of uncultivated pastures, undesired plants and stocking rate.

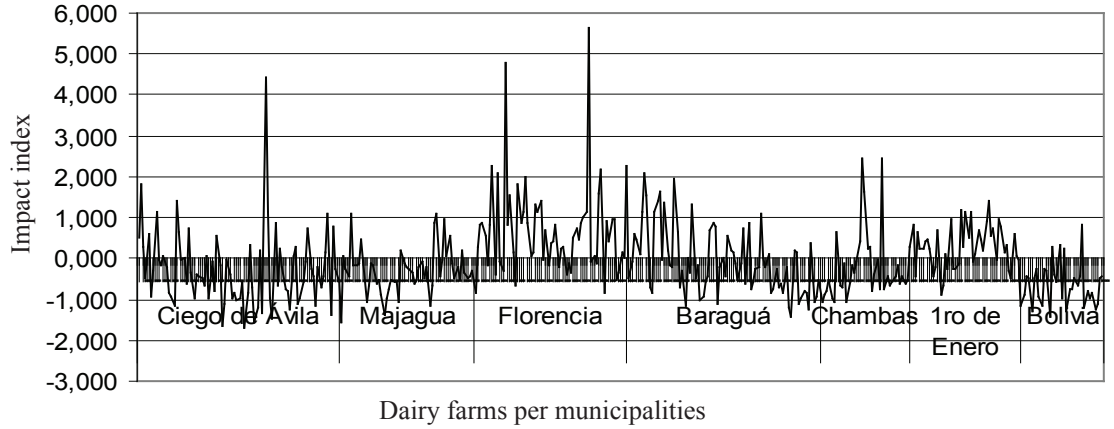

Figure 2. Impact index of the milk efficiency and total production.

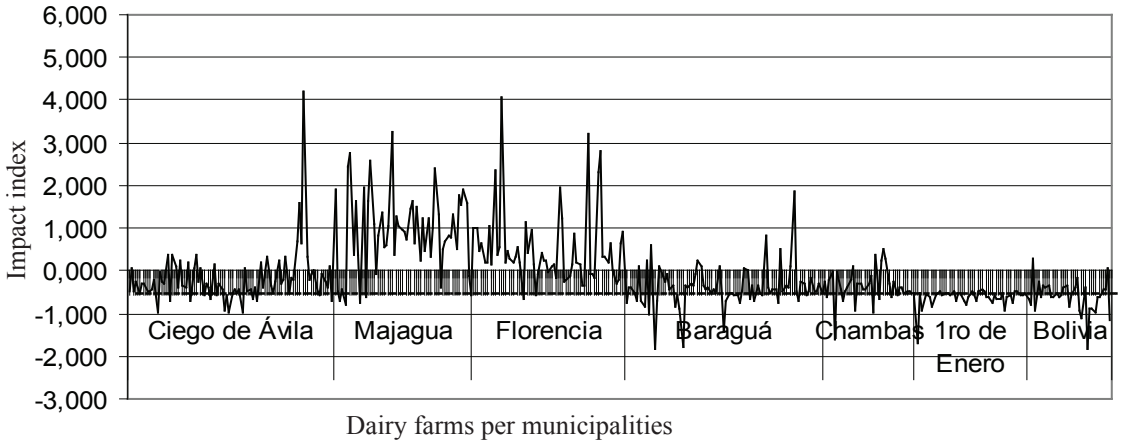

Figure 3. Impact index of the improved pastures, forages and paddocks.

These results should be considered to decide actions to transform the feeding base of these herds. The previous statement can be achieved from the planned establishment of forages, like sugarcane (*Saccharum officinarum*) and elephant grass (*Pennisetum purpureum*) (Martínez *et al*. 1994), which allow the biomass accumulation during the growth period of pastures.

The impact index of PC 4 (figure 4), that related the percent of milking cows and that of birth rate, showed a wide differentiation in the dairy farms of the province, predominating the indexes below 1 and negative. This result shows that favorable results on the reproductive performance of the herds were only achieved in few farms. Therefore, this finding explains one of the main causes damaging growth and production of milk in these systems, where there are not reproductive controls of the herd. Avilez *et al*. (2010) stated that controlling reproduction through the use of records has a favorable effect on the system milk production.

This performance shows the high variation of birth rate and the percent of milking cows (table 2), which is the result of the reproductive performance of these dairy systems and that may be influenced by the type of rearing of the calf (Lima *et al*. 2009). Other factors, such as the low quality of the basic feeds and not using mineral supplementation (Fajardo 2009), may increase the inter-parturition intervals.

These results show the necessity of training strategies for the producers, so they have the minimum reproductive controls and apply strategies of nutritional improvement and reproductive management, like heat detection and control and organization of reproduction (Brito *et al*. 2001). It is also necessary to assess the main sustainability indexes of animals, like body condition, daily weight gain and daily milk production, which, all together, would imply adjustments in the system to improve the reproductive performance (Senra 2005).

The values of the PC 4 index are the result of combining multiple factors intervening in the reproductive performance of cattle, such as nutrition and energy balance established during the first stage of lactation (Estrada *et al*. 2006). They, if are not controlled, compromise the sustained growth of the cattle population (Bertot *et al*. 2006).

The impact index of PC 5 (figure 5) related with mortality, although low values predominated, the

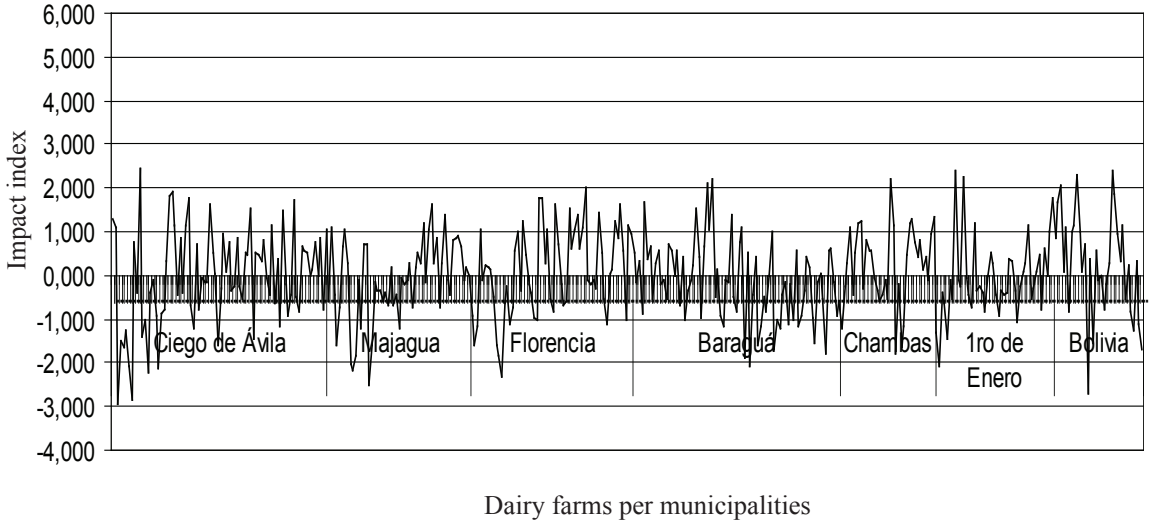

Figure 4. Impact index of the percentage of milking cows and birth rate.

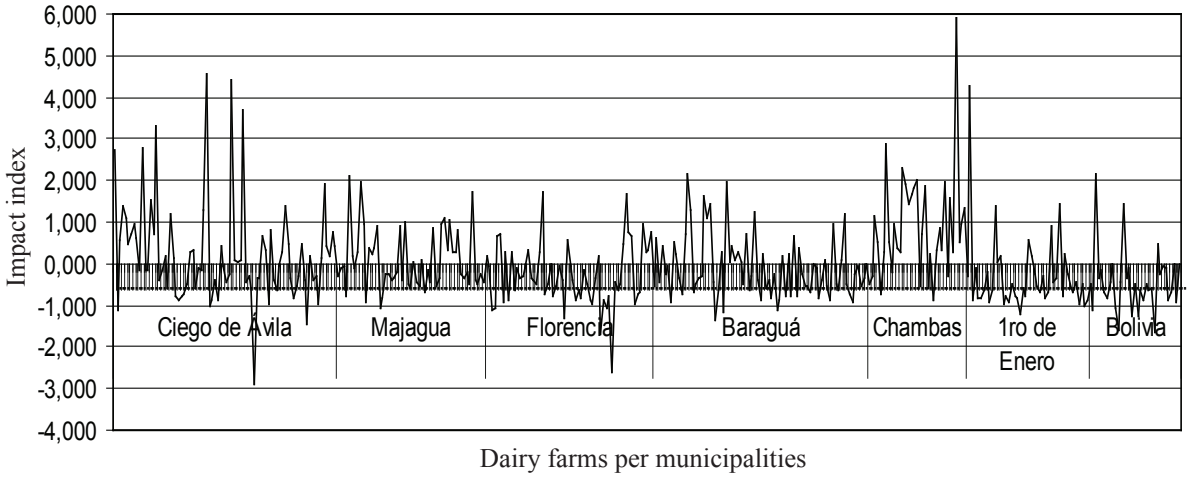

Figure 5. Impact index of mortality.

performance was less favorable in Ciego de Ávila and Chambas. In some farms the index was over 2. This indicates the importance of reducing the amount of deaths that acts as one of the factors affecting the herds' growth.

From the practical point of view, conducting this study in the CCS farm dairy units of the seven municipalities considered as milk producers was important. The calculation of the impact index strengthens the results of the multivariate analysis and contributes to interpret the level or performance of the studied indicators. The applied methodology may be the basis for designing a productive improvement strategy. Extending this study methodology to other provinces and productive ways is required.

The results of this study indicate that under the conditions of the dairy farms of Ciego de Ávila province, the efficiency of milk production is determined by five components that explain 72.1 % of the variance of these productive systems. They are related with the management, feeding basis, productive and reproductive component and mortality. Considering the factors affecting the productive efficiency of the farms to adjust these systems is necessary from the implementation of a technological management strategy and the control of main sustainability indexes.

The mathematical approach of this study, where the impact index of the variables of higher preponderance in the analysis of principal components was described contributes to explain the high variability existing in the performance of the factors affecting the milk production of these farms. Besides, it indicated the greater or less relative importance of the indicators in the farms of each municipality. Nevertheless, a classification of the farms considering these factors to interpret the weakness and strengths of each typology to address the plans of productive improvement is needed.

Acknowledgement

Thanks are given to the Editor and reviewers for their contribution to improve the quality of this study as well as to the Biomathematics Department for their help analyzing the data.

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Received: May 24, 2012