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TECHNICAL PAPER

THE TECHNOLOGICAL LEVEL OF AGRICULTURAL MECHANIZATION IN THE STATE OF CEARÁ, BRAZIL

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KEYWORDS

Agricultural mechanization, technological level, technical efficiency, economic development.

ABSTRACT

Agricultural mechanization is a significant factor of agricultural modernization, but there are few data on the technological levels of this mechanization in the State of Ceará, Brazil. To study this topic, we designed a structured questionnaire, and interviews were conducted across the state. The survey data made it possible to calculate an index of agricultural mechanization technology and study hypotheses specific to farms of Ceará. The results indicate that the technology levels are different between farms of different sizes: large and medium farms are level I-M5 (automation), while small farms ranged from level IV-M1/M2 (primary/animal) to III-M3 (preliminary). We conclude that public policy for training should be directed at small farms. There is a need to show new production alternatives to small farmers, which leads to savings, and increases the profitability of the activity.

INTRODUCTION

Agricultural mechanization is one of the main factors of agricultural modernization and provides large amounts of energy for agricultural activities, which increases the working capacity and efficiency of farm systems. However, the misuse of agricultural mechanization can directly cause soil degradation (Guerra & Jorge, 2014), particularly when inadequate soil preparation practices are employed.

There are few data on the technological level of agricultural mechanization and the effectiveness of machines in the field in Brazil. This topic is important because assessing the economic development of a farm and diagnosing the influence of technological change in these farms are essential aspects of understanding the agricultural mechanization setting (Nogueira, 2001; Vieira & Silveira, 2013).

If the crop produced by the property is extensive (grain and forage), the area of a farm can be directly related to the purchasing power of the owner, more extensive areas, more significant gains and dilution of costs, thereby facilitating investments and the acquisition of more technology compared to small farms or properties. On the other hand, if the crop is intensive (e.g., fruits, horticultural and flowers), this parameter (area) is not suitable because great value added of the product is obtained in tiny areas for these intensive crops.

This study aims to examine the technological level of agricultural mechanization in the State of Ceará and examine the hypothesis that there is stratification between farms of different sizes. After the technology indexes were analyzed, specific hypotheses were identified (Saavedra et al., 2012), by using contingency tables and the $\chi 2$ test. According to Arriola et al. (2015) this research should focus on finding patterns among the variables that express the resource allocation with the intensity of production.

MATERIAL AND METHODS

For the purpose of this study, the farms were divided into three segments: small farms, medium farms and large farms. This categorization followed the normative of Law No. 8.629 / 93 (EMBRAPA, 2012), which determines the size (area) of farms: large farms (area high than 15 fiscal modules), medium farms (area high than 4 modules and lower modules than 15) and small farms (area less than 4 fiscal modules). This article did not consider the class of minifundium, and the farms in this range were grouped in the small farm category.

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However, the size of the fiscal module ranges from 5-110 ha, depending on the type of exploitation, obtained income and the concept of family farming. In Ceará, the size of the fiscal module varies from 5 to 80 ha (EMBRAPA, 2012). Considering the types of exploration of the different regions studied, the area of the rural module was adopted of 5 ha as criterion.

The following areas were chosen for this study: small farms (areas smaller than 2 rural modules (10 ha)); medium farms (larger area than 2 rural modules (10 ha) and less than 36 rural modules (180 ha)), large farms (larger areas of 36 rural modules (180 ha)). This stratification was chosen according to the configuration of the properties of Ceará, where average small properties include up to 10 ha and large farms include over 180 ha.

A questionnaire was designed with specific questions about agricultural machines, maintenance, and energy use. The questions were structured to make it possible to use the method described in the dissertation of Lima (2010), and the questionnaire was sent to]small, medium and large farms. The grid of technological responses was defined according to the possible answers that can be quantified according to the methodologies and research of Silveira (2001), Witney (1998) and Lima (2010).

This method makes use of assigning scores to quantitative and qualitative variables related to the techniques used in production. The questionnaire with their respective scores is presented in Table 1.

TABLE 1. Survey of technological level and technical relative score.

.Question	Technology	Score
1-What mechanized system is used on the property?	1a) human or animal power 1b) simple or stationary machines, primary or no training 1c) tractors and their implements, electronics, GPS, advanced training	1a) Score 1 1b) Score 2 1c) Score 3
2-What mechanization step has the farm reached?	2a) Soil tillage 2b) Seeding 2c) Crop conduction/cultivation 2d) Harvest	2a) Score 1 2b) Score 3 2c) Score 2 2d) Score 4
3-Do you rent Agricultural Machinery?	3a) Yes 3b) No	3a) Score 3 3b) Score 0
4-What kind of maintenance is performed on the machines?	4a) Predictive 4b) Preventive 4c) Corrective	4a) Score 3 4b) Score 1 4c) Score 0
5-Have you been trained to use the machines?	5a) Yes 5b) No	5a) Score 3 5b) Score 0
6-Do you read the instruction manuals?	6a) Yes 6b) No	6a) Score 3 6b) Score 0
7- How many machines are there on the farm?	7a) 0 7b) 1 7c) 2-5 7d) 6-11 7e) >11	7a) Score 0 7b) Score 1 7c) Score 2 7d) Score 3 7e) Score 4

In Lima (2010) a number index was used to assess the technological level of the farm. First, the technology index is calculated as the [eq. (1)]:

$$I_{bj} = \sum_{r=g}^{k} \frac{E_r}{Vme_b} \quad (1)$$

Where,

I_{bj} is the technology index b in farm j;

E_r is the score value of the r^{th} variable of technology b,

Vme_b is the maximum score value of technology b.

From the determination of diverse technology indexes, it is possible to calculate the mean technology index by the following [eq. (2)]:

$$I_b = \frac{1}{n} \cdot \sum_{j=1}^{n} I_{bj} \quad (2)$$

Where:

I_b is the mean of technologies index in set of farms j,

n is the number of farms.

According to Lima (2010), this index can be used to assign a different technological standard for all the farms that can be defined as follows: Technological Standard I, Ib values ranging between 0.75 and 1.00; technological standard II, Ib values ranging between 0.50 and 0.75; Standard technology III, Ib values ranging between 0.25 and 0.50; IV technological standard, Ib values ranging between 0.00 and 0.25.

This Study adopted the following relationships between the terminology of technological levels defined by Silveira (2001) and the technological standards set by Lima (2010): Technological Standard IV = M1 levels (human) and M2 (animal); technological standard III = M3 level (primary); technological standard II = M4 level (engine); technological standard I = M5 level (automation).

According to the IBGE (2006), the State of Ceará has 381,017 rural properties, with 67.57% being properties with less than 10 ha, 17.98% between 10 and 100 ha, 3.89% between 100 and 1,000 ha and 0.18% over 1,000 ha. The number of questionnaires by macro-region was defined by the minimum sample size method through uni caudal operating characteristic curves (Montgomery, 2000). After evaluating articles in the literature, we found means and standard deviations that were used to find the standard error estimated from this value, and we considered a 10% beta error to be the minimum sample number for small, medium and large farms (12, 4 and 4 for each macro-region, respectively). Therefore, for large farms, 32 questionnaires were completed, 32 for medium farms, and 96 questionnaires for small farms, totaling 160 questionnaires. The experimental design was completely randomized.

With this total number of questionnaires, the surveys were conducted with randomly distributed interviews in the farms of the municipalities for each macro-region; this configuration attained a coverage of approximately 80% of municipalities. Contingency tables were produced for specific issues in terms of technological level. These data were evaluated using the Chi-square method to determine whether there was an association between variables at the 5% significance level and the contingency coefficient to assess the level of relationship between these variables (Martins & Domingues, 2011). The correlation indicator chosen was the Pearson contingency coefficient, which measures the degree of correlation between two nominal or ordinal variables that are submitted to the chi-square test and applied to the contingency tables. When there is no association between the variables, the value is zero, and the highest value is dependent on the size of the table, tending toward 1 for very large tables. The contingency coefficient is determined by the following [eq. (3)]:

$$C = \sqrt{\frac{\chi^2}{\chi^2 + N}} \tag{3}$$

Where:

C is the contingency coefficient;

χ^2 is the chi-square statistic for the sample,

N is the sample size.

To cover the entire state of Ceará, teams of researchers were sent to collect the responses from questionnaires in farms of all categories in each macro-region of the state. Municipalities were chosen to be the focal point of each macro-region; these municipalities were the base of support for the travel of the respective teams and were chosen by researchers that live in these cities (Table 2).

TABLE 2. Focal municipality for the base of support in the State of Ceará.

Macro-region	Focal Municipalities
West Coast	Acaraú
East Coast/Jaguaribe	Icapuí
Ibiapaba	S. Benedito
Central Hinterland	Quixadá
Baturité	Aratuba
Inhamuns	Crateús
Cariri	Assaré
Metropolitan Zone of Fortaleza	Aquiraz

RESULTS AND DISCUSSION

The results for the technological standards of farms of Ceará are presented in Table 3, divided by size category and by macro-region.

TABLE 3. Technological standards of agricultural mechanization in the state of Ceará.

Macro-region	I_b Small	Technological Standard Small	I_b Medium	Technological Standard Medium	I_b Large	Technological Standard Large
West Coast	0,252	III	1,00	I	1,000	I
East Coast/Jaguaribe	0,170	IV	0.833	I	1,000	I
Ibiapaba	0,253	III	0,840	I	1,000	I
Central Hinterland	0,250	III	1,000	I	1,000	I
Baturité	0,251	III	0,885	I	0,875	I
Inhamuns	0.236	IV	0,947	I	1,000	I
Cariri	0,163	IV	0,826	I	1,000	I
MZ- Fortaleza	0,129	IV	0,859	I	1,000	I

An analysis of Table 3 shows that there is a clear stratification among small, medium and large farms; according to Arriola et al. (2015), there is a distinction between the production scale and intensity of production, and this distinction can be used to create a typology of farms.

The results show that large and medium-sized farms hold the greatest possible technological standard (level I), and small farms are distributed between standard III and IV. Large farms have unrestricted access and they use all available technologies, from large and medium-sized tractors to GPS systems and automation of irrigation. Notably, the technology index of the large farms of the macro-region of Baturité is lower than the other macro-regions.

One hypothesis to explain this difference may be the spatial characteristic of the macro-region, since the large farms of this region are very close to the size of the lower limit of large farms and next to medium farm sizes; according to Barath & Ferto (2015), statistical models suggest that the size of the farms is likely to influence the technological differences between them.

This time, in the macro-region of Baturité, technological characteristics are closest to the pattern of medium farms than the larger farms. However, the values still fall within the standard I, M5 level of mechanization.

Regarding the medium farms, the geographical regions of the coast East and Central Hinterland have the same indices of large farms. A possibility for this difference is that the Central Hinterland is a dairy region. Like large dairy farms, the medium farms use automated technologies such as milking and animal tracking, which substantially raises the technological level and follows the trend set by Winsten et al. (2011).

For the east coast, the explanation may be that large farms producing fruits, as well as the irrigated areas in this region, have greater technological support. A clarification must be made for small farms: the delimitation of the farm size as less than 4 rural modules caused a problem regarding heterogeneity among farms. These farms were not considered minifundiums (areas up to 1 ha), and the presence of these small farms influenced the data.

Where there was a greater amount of minifundium accompanied by great technology (fruit-growing and horticulture), as opposed to regions with small farms and low-technology (rain-fed agriculture), small farms are vulnerable to the availability of labor and initial soil fertility (Chenoune, et al., 2016) and drought in the semi-arid region (Guerreiro et al., 2013).

This inaccuracy has generated a sub-stratification within the class that can be explained both regarding area and technology. It can be seen that in the regions where horticulture and irrigated horticulture is prevalent, there is a higher technology index (Baturité, Ibiapaba and West Coast) as well as in dairy production (Hinterland Central).

In regions with grain or fruit occurred in large areas (Cariri and East Coast) small farms have deficient technology indexes representing technological standard IV. The Inhamuns region has technological standard IV, but the technology index is close to transitioning to standard III. This fact can be explained by this region having a much higher production of small animals, especially goat and sheep breeding that use technological support (Mujica et al., 2015), but this is diluted due to subsistence agriculture in the region based on rain-fed agriculture.

The Metropolitan Region of Fortaleza is basically a supplier of fresh produce to the metropolis and has a low technology content due to the influence of the service sector and tourism that are more attractive to small farmers.

Dupraz & Latruffe (2015) state, “this situation reinforces the fact that members of the families of small farmers are involved increasingly with work "out the farm" and are therefore less available for work in the field.”

After analyzing the technological levels, we developed specific hypotheses for a better picture of the technological levels of Ceará. Hypotheses, statistical analysis, and χ2 contingency coefficient are shown in Table 4.

TABLE 4. Statistical analysis of the hypothesis of technological level.

Hypothesis	**χ^2 Calc.**	**Value p**	**Hypothesis Accepted?***	**Contingency Coefficient**
Is the use of animal traction related to the type of mechanized operation?	52,560	0,000	YES	0,788
Is the use of simple machines related to the type of mechanized operation?	35,151	0,000	YES	0,683
Is the use of tractors related to the type of mechanized operation?	36,762	0,000	YES	0,777
Is the use of mechanical systems related to the rental of machinery for the small farm?	5,955	0,015	YES	0,570
Is the use of mechanical systems related to the rental of machinery for the medium farm?	1,814	0,178	NO	-
Is the use of mechanical systems related to the rental of machinery for the large farm?	-	Large farms do not rent machines		-
Do operators of small farms who had training read the instructions manual of machines?	11,323	0,001	YES	0,699
Do operators of medium farms who had training read the instructions manual of machines?	0,4041	0,525	NO	-
Do operators of large farms who had training read the instructions manual of machines?	39,612	0,047	YES	0,705
Is the number of machines on the farms related to the type of maintenance?	13,132	0,011	YES	0,788

* at 5% de significance level (p= 0,05).

From Table 4, we concluded that there is an association between the mechanical system and the type of mechanized operation, with a correlation defined by a contingency factor of 78.8%, 68.3% and 77.7% for animal traction, simple machines and tractors, respectively.

According to Nogueira (2001), the trend of agricultural modernization has been like the main elements of mechanization, but there are huge contrasts. Some intensely use technology and achieve high productivity, while others do not have access to technology, credit, and technical assistance, which generates low productivity. Quantitatively, the farms that use animal traction 93.7% only make soil tillage.

Of those using simple machines, 77.5% use simple machines in the soil tillage, 12.5% use simple machines for seeding, and 10% use simple machines for cultivation. Of those using tractors, 100% use tractors for soil tillage, 50% for cultivation and 50% for sowing. Only one farm of the 160 evaluated used harvesters, and this farm is classified like large farm used the machine for harvesting seeds.

The macro-region of the East Coast/Jaguaribe is well served by harvesters of grains and foragers, since it is a region producing seeds and milk and is mainly irrigated by central pivots. The obtained result is representative of this macro-region, since it represents 25% of the whole sample of large farms, noting that for each macro-region only four large properties were chosen randomly.

An important observation is that there was a climatic interference in the modus operandi of the rural properties on the East Coast/Jaguaribe. During the period that this research was carried out (2016/2017), the State of Ceará was undergoing its sixth consecutive year of severe drought.

Therefore, the government manager of the main water supply dam for the irrigated perimeters of the East Coast/Jaguaribe (Castanhão) decreased (almost cut) the volume of water for agriculture, which had a substantial impact on the seed production and dairy sector. In this research, the large and medium farms that were interviewed used a harvester (forage or grain) that was owned or rented. However, with the substantial impact of drought at these properties, at the time of the interview, those who usually rented were not renting anymore, and many owners of the machines had sold their equipment.

According to Ortega et al (2009), machine rental has taken place both by the emergence of outsourcing companies and by farmers who underuse their equipment and rent out to other producers. In this context, the large farms do not rent equipment for their operations, because 100% own their machines, and do not rent out their machines to other farms because the fleets are sized just for their operations.

With small farms that rent machines for mechanized operations, there was an association between the rental of machines and the type of mechanized system with a 57% contingency coefficient, 100% of farms rent machines when they use animal traction, 61% rent when they use tractors, and 70% rent when using simple machines.

There was no association between the rental of machinery and mechanized systems for medium-sized farms, but it was found that these farms rent their idle machines to small farms.

Regarding the machine operators who had training and that read the instruction manual, there was an association between small and large farms, with 69.9% and 70.5% respectively for a contingency factor. Eighty percent of small farm operators and 95% of large farm operators who had training read the manual. For the medium farms' operators, there was no association. According to Vieira & Silveira (2013), the technology adoption influences the conditions of dissemination of new knowledge.

This paper comes to the following deduction about operators of mechanization: small farms are lacking in technical assistance, so when they receive any kind of training, operators – usually the owners – are very interested in technological advances, follow the recommendations, and read the manual of the machines. Also large operators usually hire employees who have to follow orders from superiors, and after training, these employees are required to read the manual or be fired.

In the case of the medium farms, there is an intermediate situation where operators may or may not be the owners. In this case, if the operator is the owner, there is the possibility of him not being interested in reading the manual for reasons of socio-educational (self-sufficiency), or if an employee is also not interested because there is no charge or burden if not read.

Thus, 87.5% of medium-sized farm operators who have training have not read the instruction manual. According to Vieria & Silveira (2013), the farmer's ability to exploit external knowledge and the absorption capacity may influence not only the assimilation of knowledge but also in reducing the final cost of production.

In this context, the type of maintenance and the number of machines the farms have were associated with a contingency coefficient of 78.8%. One hundred percent of small farms, 71% of medium farms and 14% of large farms only perform corrective maintenance; 44% of large farms and 19% of medium farms only perform preventive maintenance; and 42% of large farms and 10% of medium farms perform predictive maintenance.

According to Reis et al. (2005), the costs of maintenance are the highest operating costs of mechanization, and lower maintenance also has costs; thus, it is noteworthy that most medium farms, which have a relatively high number of machines (2-5 machines per farm), perform more costly and inefficient maintenance.

CONCLUSIONS

1-The technological levels were determined for farms in Ceará: large and medium-sized farms are level I-M5 (automation), and small farms range from level IV-M1 (initial) / M2 (animal) to III-M3 (preliminary).

2-Based on the confirmation of the specific hypothesis showed in technological column of Table 4, it was concluded that a public training policy should be directed towards small farms because larger farms already have training, and medium farms have no interest.

3- There is a need to show new production alternatives to small farmers, which leads to savings, and increases the profitability of the activity.

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