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Research Article
Agricultural Mechanization Statue in the North West Regions of Tunisia According to Farmers' Agricultural Mechanization Competencies

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Abstract

Background and Objective: During the pre-industrialization phase in developing countries, one of the strategies for the intensification of agricultural production is the evaluation of agricultural mechanization. The study aimed to assess the status of agricultural mechanization in two governorates of North-Western Tunisia according to farmers' competencies. **Materials and Methods:** Agricultural mechanization statue of two governorates of Northwestern Tunisia was analyzed according to farmers' skills. The factor analysis methods (MCA and PCA) were used to analyze correspondences and the effect of farmers' skills on agricultural mechanization indices. **Results:** The MCA analysis allowed to provide two factorial axes with a low contribution of the variables related to farmer's competence (2.39%) and the indices of mechanization (less than 30%) for axis 1. Axis 2 explained 40% of the variance and was supported by crop and cropping operations with strong contributions to its construction (>80%). The PCA and MCA results revealed that the average level of mechanization efficiency was low (about 7.36%) with a power gap of 9.33 hp ha^{-1} between smallholders and large farms with a predominance of mechanization for large crops. **Conclusion:** The farmers of the two governorates are generally poorly educated and have limited knowledge of mechanization, which does not exceed 3.2%.

Key words: Farmers' competencies, mechanization index, productivity index, power index tractorisation index, education level, mechanization knowledge

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Since its independence, Tunisia has continued to develop its agriculture by various means, in particular technical and technological, to access self-sufficiency in food for an increasing and demanding population. The agricultural policy concerning agricultural mechanization has evolved in an anarchic way from one decade to the next. The beginning of the motorization during the period 1960-1970 was typically manifested by an organizational framework and creation of Cooperative Units of Production[1]. These institutions are engaged in the modernization of agriculture and its mechanization. The period 1970-1980 was marked by the creation of various regional and central motor crop cooperatives (RCMCC). The end of this period of development of mechanization regulated and organized by the government, marked the beginning of its disengagement and the first attempt was characterized by the marginalization of the machinery sector and its abandonment of private initiatives. The main structured study on mechanization was done in 2003-2004 "Study of the current situation and prospects of the sector of agricultural machinery in Tunisia" (ESAPASMAT, 2004). This study attempted to analyze the machinery sector in the country by tackling its different components and to propose trend scenarios for the development of the sector. The Agricultural Mechanization Master Plan (2005) and the "Study of the current situation and prospects of the agricultural machinery sector in Tunisia" (ESAPASMAT, 2004) constitute the most important databases on agricultural machinery in Tunisia, especially since they cover the entire Tunisian territory and had a multiple dimension. However, they do not offer appropriate mechanization indexes to allow identifying actions to allow professionals to develop this sector. Indeed, agricultural machinery is a typical input for agriculture. Mechanization is defined as a description of how these inputs are applied. The choice and mode of use of agricultural tools reflect the production intensity, agricultural profitability and farmer's life quality. Agricultural production is positively correlated with energy input[2-5]. Mechanization technologies continue to evolve in Tunisia with the industrial growth and socio-economic progress of Tunisian farmers. While the decline between available mechanization inputs and real inputs is growing steadily due to the mismatch between farm mechanization and farm size. Indeed, the almost total selection, on import, of agricultural equipment by the concessionaires and the gradual decrease over years of farm sizes is among factors of increasing agricultural machinery operating cost and reducing agricultural profitability. Now-a-days, the cost of mechanized inputs occupies the largest share of agricultural production costs so an assessment of the level of mechanization becomes an urgent need for Tunisian farmer[6]. Even after the (ESAPASMAT, 2004)[1] study, the mechanization of Tunisian agriculture is not managed as a part of profitability parameters and agricultural productivities, despite the availability of modern agricultural machinery. The problem of agricultural mechanization in Tunisia does not only arise in terms of intensification (quantitative aspects) but also in terms of the adequacy of mechanization to the economic, environmental and social objectives of agriculture (qualitative aspects). Agricultural research and development are focusing on other production parameters (variety, climatic conditions, soil type, complementary irrigation, fertilization, an adaptation of crops to climate change, etc.). Up to now, the Tunisian farmer is not able to define his genuine needs in terms of agricultural mechanization. Often, the carried studies on agricultural mechanization were a census or an inventory of equipment and did not solve the problems that were highlighted by the last survey on farm structures of 2004-2005[5]. Like so, the study of the agricultural mechanization component is one of the priorities of the agricultural sector to demystify the machine tool adequacy approach and provide guidelines for the development of small mechanization in design and use. Furthermore, with the continuous decrease of farm sizes and the continuous changes in production parameters, the diagnosis and analysis of the state of mechanization will help to evaluate constraints and needs of small mechanization. Negrete[7] defines the state of mechanization by the level of growth of agricultural mechanical equipment to means using human and animal power. Indexes of mechanization are indeed means of measuring mechanical assistance to human work and its efficiency. They can be expressed in various ways[2-5]. Abbas *et al.*[8] reviewed the methodology[9] adopted by several authors to express an index of mechanization. The Gana and Khaldi[1] cites an index called "equipment rate" expressed in horses per ha. It is also mentioned another index which is a rate expressed in the number of tractors per 100 ha. Olaoye and Rotimi[9] defines a mechanization index as the ratio between (LM) spent mechanical work expressed in kwh ha^{-1} and the sum of mechanical and human work (LT) spent in kwh ha^{-1}. This index informs on the proportion of mechanical work compared to the total work (mechanical and human work only). It can apply to different speculations to inform on the degree of their mechanization. Özpinar[10] cited by Olaoye and Rotimi[9] quantifies the mechanization level by the dissipated power per unit area (kw h^{-1}), the number of tractors available per 100 ha (tractor/100 ha) and the percentage of

mechanical power used compared to the total power dissipated to characterize the state of mechanization of one country. Ramirez *et al.*[11] used a model to predict two mechanization indexes MI (Mechanization Index relative to a crop and an area) and MER (mechanization index relative to the machine energy ratio).

An agricultural mechanization policy to be established in Tunisia must respond to the problem of access to efficient mechanization. Analysis of the current state of mechanization must highlight the influences of the various variables. In the first phase, The objective of this study is to study the effect of farmer's competencies (level of education, knowledge and mastery of agricultural tools and their uses) on the status of agricultural mechanization and the effect of the availability of skilled, unskilled labour and agricultural equipment on the productivity and efficiency index. In this study, the Mechanization status is quantified by mechanization index, productivity index, power index and tractorisation index.

MATERIALS AND METHODS

Study area: The present study about the state of mechanization in Northwestern Tunisia concerned the governorates of Jendouba and Beja. The national contribution of local agricultural production of the governorate of Beja is about 20% in cereals, 20% in legumes, 12.5% in milk and 10% in red meat. The national contribution of local agricultural production of the governorate of Jendouba is about 10% in cereals, 12% in milk, 20% in potatoes, 90% in cork and 10% in red meat[5]. The study was carried out at the Department of Mechanical Engineering and Agro-Industrial, Tunisia from August 2019 to March, 2020.

Data collection techniques: The data is carried out through a survey using a questionnaire and interviews. The most important data on which this study is based are from the questionnaire survey. Data are also used from ESAPASMAT (2005)[1] studies, which remain presently the references for any mechanization work in Tunisia, such as farm structure surveys, which set aside a chapter for mechanization. Other information is drawn from the statistical data of the INS (National Institute of Statistics).

The selected questionnaire has two parts, which are general information on the farm and the farmer such as identification of the land area, the holding, the operator, characteristics of the farm and planted areas, dominant crops, labour and machinery, steering and management. Specific data on mechanization by crop and cropping operation described by tillage: tractors, power, tools, time, surface, animal traction, manual labour, labour, costs. The developed questionnaire includes 83 independent variables including 27 categorical qualitative and 56 quantitative measures from which we calculated new variables for the specific needs of the study.

Sampling: Using data from the farm structure survey (2004-2005) and cross-referenced with data from the ESAPASMAT study[1]. The number of farms in the governorate of Jendouba and Beja is estimated respectively at 25,000 and 21,000 farms. The determination of the sample size is based on the usual statistics, with the assumptions related to the normal law and the normal centred reduced law, the size of the sample can be calculated using the Eq. 1:

$$n = \frac{\frac{z^2(1-p)p}{e^2}}{1+\frac{z^2(1-p)p}{Ne^2}} \quad (1)$$

where, z is the centred variable (for a 95% confidence interval z = 1.96), e is the margin error (e = 5%) and p is the standard deviation (p = 0.5) and N is the number of farms. Using equation 1, the number of structured questionnaires was estimated at 340 for Beja governorate and 378 for Jendouba governorate. This choice is translated statistically by the representability of the sample with a degree of confidence of 95% and an error of 5.27% for Beja and 5% for Jendouba. So that all classes of agricultural holdings are represented in sufficient numbers and inhomogeneous groups, the stratified sampling method has been typically used. The areas considered by stratified sampling are S_1 from 0-10 ha, S_2 between 10 and 50 ha and S_3 greater than 50 ha (Table 1).

Data processing: Accurately quantifying the status of mechanization involves identifying the effects of qualitative variables such as mechanized inputs, the socio-economic conditions of farmers and the characteristics of the holdings of Beja and Jendouba governorates. In this study, among the 27 qualitative variables, 10 most relevant variables (Table 2) are associated with Mechanization Index (MI) (Eq. 2), Productivity Index P_V (Eq. 3), Power Index (Eq. 4) and tractoristion index (Eq. 5). The information contained in Table 2 has been evaluated by the MCA (multiple correspondence analysis) methods:

Table 1: Distribution of farms by size

City	Strat	Frequency	Percentage	Cumulative percentage
Jendouba	S_1	295	78.0	78.0
	S_2	68	18.0	96.0
	S_3	15	4.0	100.0
	Total	378	100.0	
Beja	S_1	265	77.9	77.9
	S_2	61	17.9	95.9
	S_3	14	4.1	100.0
	Total	340	100.0	

Table 2: List of quantitative variables

Variables	Modality
Farmer education	Yes, No
Farm ranking	S_1, S_2, S_3
Farm category	AS[1], Ff[2]
Main crops	Cc[3], Fc[4], Le[6], Ft[7]
Irrigation	Irrigated, not irrigated
Soil tillage	Mechanized, not mechanized
Agricultural training	Yes, No
Mechanization training	Yes, No
Mechanization knowledge	Yes, No
Harvesting	Mechanized, not mechanized

AS[1]: Agricultural society, Ff[2]: Family farm, Cc[3]: Cereal crops, Fc[4]: Forage crops, Le[6]: legumes, Ft[7]: Fruit trees

$$MI = \sum_{(i=1)}^{n}\left[\left(\frac{M_{e(a,i)}}{M_{av}}\right)\left(\frac{L_{(a,i)}}{TL_a}\right)\right] \quad (2)$$

where, $M_e(a,i)$ is the mechanical energy expended for a crop i in the plot a, M_{av} is the regional average of the mechanical energy expended, L(a,i) is the area of crop i in the plot a and T is the total area the owned plot a:

$$P_v = \left(\frac{P_i}{S_t}\right) \quad (3)$$

where, P_i is the total mechanical power available in hp and S_t is the total area cultivated in ha:

$$P_i = \left(\frac{P_t}{S_t}\right) \quad (4)$$

where, Pt is the total mechanical power expended in hp and St is the total area cultivated in ha:

$$TI = \left(\frac{100N_t}{S_t}\right) \quad (5)$$

where, N_t is the number of tractors per 100 ha.

A large number of measurable quantitative variables has the advantage of covering many studies on agricultural systems in the northwest regions of Tunis. However, the analysis of 56 quantitative variables is accompanied by a significant loss of information on mechanization. To not lose the representatively of quantitative variables, which retain a significant proportion of information related to mechanization, the Pearson correlation coefficient was used to select the most relevant variables. In this study, 14 independent quantitative variables and 08 dependent quantitative variables were selected based on the Pearson coefficient ($R^2 \geq 0.4$). The Principal Component Analysis (PCA) method was used for evaluation the mechanization level of the two governorates (Beja and Jendouba).

RESULTS AND DISCUSSION

Qualitative analysis: Before starting the analysis of dependencies between mechanization indicators and qualitative variables (Table 2), a reliability analysis was carried out for 04 combinations between qualitative variables and one of 04 mechanization indicators. Table 3 shows Cronbach's alpha for the four combinations. The coefficients of different combinations are greater than the minimum threshold of 0.7[12].

It can be concluded that there is satisfactory internal coherence between the variables. Multiple Correspondence Analysis reduces a matrix of 11 columns (10 variables and mechanization level indicators) and 335 observations for Beja and Jendouba governorates. For four combinations, two axes have been selected (Table 3) where Axis 1 and 2 explain 40 and 39% of the variance, respectively. Analysis of discrimination shows that axis 1 is supported by the inertia of variables reflecting category of exploitation, level of education, knowledge and control of mechanization settings (Table 4 and 5).

For all combinations, the knowledge and mastery of mechanization do not reflect the status of mechanization. Indeed, no correlation is evident between mechanization indicators and farmer qualification (Table 4 and 5).

Mechanization and the qualification of farmers can be justified by the low level of education of farmers or the unavailability or lack of mastery of mechanized inputs. To support these two explicit statements, a descriptive analysis of farmers' level of appropriate education associated with mechanical efficiency (Eq. 6) was carried out:

$$E_m = \frac{P_t}{P_d} \quad (6)$$

where, P_d is total available power (kwh ha^{-1}) and P_t is a total power dissipated (kwh ha^{-1}).

Table 5 shows that farmers in the northwest regions of Tunisia are unable to set the required needs when adopting mechanization. Indeed, there is a relatively elevated rate of illiterates in farm operators (38.5% for Beja and 23% for Jendouba) and a very low rate of them have followed mechanization training or who know mechanizations. The low level of mechanical efficiency can be reflected by the low level of farmer's qualification and shows inadequate management of mechanized inputs. Indeed, the weakness of mechanical efficiency reflects the availability of untapped power. The decline between available power and dissipated power on the farm (7.34% for Beja and 7.39 for Jendouba) reflects the inappropriate choice of agricultural tools. This fact can be explained by the low level of education of farmers (24.4% for Beja and 21.4% for Jendouba have a level of primary school) and the limited knowledge in agricultural machinery on the one hand. A lot of insane purchases of agricultural equipment subsidized by the government can happen without demonstrating the real need for efficient agricultural mechanization.

Table 6 shows a too high tractorisation index, especially for the groups of farmers in strata S_1 and S_2. The higher tractorisation indexes of those two strata are explained by the government subsidies in the purchase of agricultural machinery (subsidies of up to 80% of the total price of the tractor). However, these incentives for tractors acquisition have been largely directed by farmers to use in public works services.

Table 3: Cronbach's alpha between qualitative variables and mechanization indicators

Combinations	Cronbach's alpha
Qualitative variables and mechanization index	0.863
Qualitative variables and productivity index	0.830
Qualitative variables and power index	0.814
Qualitative variables and tractoristion index	0.821

Table 4: Correlation coefficient between qualitative variables and mechanization indicators

Combination 1	Axes 1	Axes 2	Combination 2	Axes 1	Axes 2
Farmer education	0.755	0.118	Farmer education	0.780	0.105
Farm ranking	0.174	0.008	Farm ranking	0.177	0.011
Farm category	0.676	0.040	Farm category	0.702	0.015
Main crops	0.252	0.900	Main crops	0.220	0.919
Irrigation	0.052	0.593	Irrigation	0.019	0.604
Soil tillage	0.053	0.806	Soil tillage	0.018	0.836
Agricultural training	0.744	0.033	Agricultural training	0.768	0.006
Mechanization training	0.701	0.027	Mechanization training	0.722	0.006
Mechanization knowledge	0.758	0.060	Mechanization knowledge	0.794	0.019
Harvesting	0.099	0.700	Harvesting	0.093	0.709
Mechanization index	0.073	0.703	Productivity Index	0.044	0.583
Combination 3	Axes 1	Axes 2	Combination 4	Axes 1	Axes 2
Farmer education	0.781	0.103	Farmer education	0.747	0.100
Farm ranking	0.191	0.014	Farm ranking	0.253	0.018
Farm category	0.704	0.009	Farm category	0.712	0.009
Main crops	0.203	0.937	Main crops	0.214	0.939
Irrigation	0.008	0.682	Irrigation	0.008	0.678
Soil tillage	0.008	0.841	Soil tillage	0.009	0.844
Agricultural training	0.762	0.001	Agricultural training	0.726	0.001
Mechanization training	0.730	0.003	Mechanization training	0.719	0.002
Mechanization knowledge	0.805	0.008	Mechanization knowledge	0.769	0.007
Harvesting	0.098	0.703	Harvesting	0.087	0.707
Power index	0.075	0.039	Tractorisation index	0.304	0.024

Table 5: Level of education and knowledge in the mechanization of farmers in Beja and Jendouba cites

City	Illiterate	Primary school (%)	Mechanization training (%)	Mechanization knowledge (%)	Average mechanical efficiency (%)
Beja	38.5	24.4	7.6	3.2	7.34
Jendouba	23.0	21.4	15.6	3.2	7.39

Table 6: Power index and tractorisation index per stratum

	Stratum					
	S_1		S_2		S_3	
Governorate	Beja	Jendouba	Beja	Jendouba	Beja	Jendouba
P_i (ch ha^{-1})	14.48	18.19	8.43	6.97	1.61	3.28
T_I (tractors/100 ha)	16.106	18.30	6.442	6.56	1.432	2.28

Table 7: Distribution of field crops

	Hard wheat (%)	Forage crops (%)	Total (%)
Beja	54.7	19.1	73.8
Jendouba	60.6	2.6	63.2

Table 8: KMO index and Bartlett test

Kaiser-Meyer-Olkin index for measurement of sampling quality		0.878
Bartlett sphericity test	Khi-deux approx.	6809.027
	ddl	153
	Signification	0.000

Table 9: Component matrix and presentation quality

	Components		Representation qualities	
Variables	1	2	Initial	Extraction
Dominant crops area	0.656	0.721	1.000	0.950
Dominant crops yield	0.744	0.571	1.000	0.880
Number of technicians			1.000	0.024
Number of permanent workers	0.409	0.522	1.000	0.439
Number of casual workers	0.548	0.499	1.000	0.550
Number of tractors		0.797	1.000	0.790
Number of combine harvesters	0.901		1.000	0.843

For combination 1 and combination 2, axis 2 is supported by main crops, irrigation, soil tillage and harvesting variables, which explains that the mechanization and productivity indexes vary in a similar direction as qualitative variables already cited.

The main crops and soil tillage method explain the mechanization (90% of the modalities for the variable main crops and 80.3% for the soil tillage were used for the construction of axis 2).

The descriptive analysis (Table 7) shows that the dominant crop for those governorates is cereals and forage crops. These crops occupy more than 73 and 63% of farms of Beja and Jendouba governorates, respectively.

Quantitative analysis: Before starting the factor analysis, it is necessary to measure the sampling adequacy by the Kaiser-Meyer-Olkin coefficient (KMO) and Bartlett's sphericity test to assess the extent of the psychometric relationship of the items. The KMO index of 0.878 can be typically qualified as excellent or meritorious. It informs us that the correlations between the items are of good quality. Then, the result of Bartlett's sphericity test is significant ($p<0.0005$) (Table 8).

Principal Component Analysis (PCA) allows the extraction of two axes. Axis 1 explains 50% of variance and Axis 2 explains 14.64% of the variance. The Principal Component Analysis (PCA) shows that the number of machines available on the farm, the classification of farm and dominant crops mainly support Axis 1. However, Axis 2 is supported by the variables characterizing the availability of labour (technician, worker....) and the number of tractors available on the farm.

Table 9 shows a contribution of 1.4% of the production index to the construction of axis 2 with a moderate correlation (less than 40%). The productivity index is slightly affected by variables supporting this axis. Indeed, the availability of labour and tractors do not reflect the productivity improvement. Examining the exploitation rate of the available power (efficiency index) notes that there is no coherence between the availability of agricultural equipment and genuine need for machinery (a correlation of 47%).

This is explained by the size of farms in stratum 1 (Table 1). Indeed, the mechanization of the stratum S_1 holdings is based on the rental of agricultural equipment. The use of leased equipment is at the origin of the inconsistency between the real needs in mechanization and the mechanization practised at random by the group of farmers of a stratum S_1. Indeed, small farms consume almost nine times more power per ha than larger ones (Table 9). This is explained by the absence of small mechanization machinery and tools which adapts well to the farm area and to the nature of speculation.

The state of mechanization in the two governorates can be characterized by the low level of farmer's education and the almost absence of training in agriculture or mechanization.

This study shows the significant effect of farmers' mechanization skills on mechanization and production indicators. Indeed, the total power available for farmers in stratum S_1 was 6.56 greater than the mechanical power available for stratum S_3 and a tractorization index is multiplied by 5.5 compared to the tractorization index of stratum S_3. This is explained by the predominance of family work in this stratum[13,14], the majority of which have a limited educational level and skills in mechanization (Table 5). Also, many agricultural speculations in the northern regions are based on (relatively) large tractors[15]. Indeed, access to mechanical inputs for stratum S_1 is based on the allocation of targeted equipment for farmers in stratum S_1, which leads to the amplification of mechanization and production indicators. The inverse relationship between farmer skill and mechanical efficiency found in this study (Table 5) suggests that appropriate mechanization, based on determining actual mechanized input needs and using small machinery[16], should also be considered for farms in stratum S_1.

The predominance of field crops for those governorates naturally favours the orientation of farmers, researchers and agricultural development services to develop agronomic properties (variety, soil) and mechanized inputs, which explains the correlation between mechanized inputs, the mechanization index and the production index.

The significance of mechanization indicator's gaps to farmer skill, which is strongly correlated with farm size, calls into question the potential impact of land fragmentation over the years on agricultural efficiency in the region. Baudron *et al.*[16]. Indeed, the intensification of mechanized inputs does not reflect the improvement of mechanization, productivity and efficiency indicators due to the random use of mechanized inputs. The policies of decision-makers, equipment suppliers and agricultural associations concerning the encouragement and support of mechanized inputs for the northern regions of Tunisia must be reformulated taking into account the skills of farmers and the socioeconomic characteristics of smallholders[17].

The results obtained in this work will be important to generate information that will help to understand the state of mechanization in Tunisia, the constraints and the opportunities of existing agricultural mechanization. It will also help guide the research agenda for agricultural mechanization, improving existing technologies and formulating technical and policy recommendations for policymakers. However, this work is focused on the qualifications of mechanization to the aspects related to the skills of the farmer without taking into account the production costs. A study of the status of mechanization to production costs remains an urgent need for Tunisian farmers.

CONCLUSION

An assessment of the level of agricultural mechanization in two governorates in the North West of Tunisia was carried out. The farmers of the two governorates are generally poorly educated and have limited knowledge of mechanization, which does not exceed 3.2%. However, farms in stratum S_1 are too mechanized. Less than 8% of the available power is exploited by farmers in this stratum with a high tractor index, which exceeds 16 tractors per 100 ha for the two governorates. This is explained by the random purchase of agricultural equipment influenced by government subsidies. To optimize the use of mechanized inputs and improve productivity and integration study of small mechanization remains an urgent need for the North West regions of Tunisia.

SIGNIFICANCE STATEMENT

This study uncovers the decline between mechanized inputs and human resource skills for the northern regions of Tunisia. The results found can be beneficial for policymakers, agricultural implement suppliers and support and extension associations as a basic tool for the development of agricultural reform strategies. This study will help the researcher to discover the critical impact of the couple mechanized input and farmer's skills and pave the way for the development of smart and small mechanization as a typical research axis.

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