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Perspectives of adopting technological innovation in livestockbased production system

by Ibtissem Taghouti, Bouali Guesmi, Hichem Ben Salem, Sourour Laabidi, and Salah Ben Youssef

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Perspectives of adopting technological innovation

in livestock-based production system

Ibtissem Taghouti^{1,*}, Bouali Guesmi², Hichem Ben Salem³, Sourour Laabidi³, Salah Ben Youssef³

Abstract

Livestock farming is the main activity of rural population living in Tunisian arid areas. In this area, the situation has become challenging due to severe water scarcity, the chronic feed shortages and the high cost of forage. To overcome natural resources scarcity and upgrade forage production methods, an agriculture innovation represented in mechanized fodder processing was presented to farmers to valorize available resources on farm. A representative sample of livestock-based farms was analyzed and a set of variables were selected to perform the analysis. Principal Component Analysis and multivariate K-mean classification were performed to describe the livestock-based farming system in Tunisia. In addition, a logit regression was employed to analyze the adoption decision of Tunisian farmers. The cluster analysis generated four groups of production systems based on their farms structures, interest by mechanization and livestock farming system. The intensive sheep farming system found to be the most interested group by the chopper meanwhile farmers of the extensive mixed livestock-cereal production system are the less interested about the fodder chopper. It emerges from the logistic regression that the adoption decision is positively correlated with the presence of cactus on farm, the flock size, farm surface area (FSA) and input supply problem

Keywords : Technological innovation, adoption, principal components analysis, cluster analysis, Tunisia

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1. Introduction

The adoption of technological innovation and access to scientific and practical techniques are considered as a key element to improve farm productivity and socio-economic status of farmers. There is a growing interest about technology adoption to alleviate the impact of climate uncertainties and to face productivity losses. However, the adoption willingness of farmers depends on various legal, political and technical factors. Livestock farming is an important activity of the Tunisian agriculture. This sector has a relevant economic role contributing by 35 to 40% of the agricultural GDP and 4 to 5% of the national GDP (INS, 2004).

Recently, this activity is constrained by the high cost of forage especially in arid and semiarid areas. The situation has become alarming especially for smallholders due to the chronic feed shortages, both quantitative and qualitative, affecting their profitability and forcing them to reduce the flock size or to give up this activity. Besides, the employment of commercial feedstuffs such as maize, barely, etc to face this problem has conducted to high costs for farmers and imbalance of the national balance payments (Fezzani and Thabet, 1995). There is an immediate need to develop an alternative feed to face chronic forage shortages and climate change challenges. Indeed, livestock production can be developed by introducing new technologies to valorize available resources on farm such as cactus.

The use of cactus for animal feeding is very common especially in United States, Mexico and Brazil. Cactus is widely used as feed for beef, dairy cattle and small ruminants (De Waal., 2015). It was demonstrated that cactus is a source of water for animals raised in harsh environments (Nefzaoui and Ben Salem, 2001). Cactus is offering various opportunities to set up a sustainable livestock production system by improving fodder availability and presenting a cost-effective option for water provision to livestock in arid environments. A number of animal feeding studies demonstrated that fresh cactus with a protein-rich feedstuff can substitute barely grains or maize silage without having effect on body weight gains of the animals and milk production (De Waal, 2018). Ben Salem et al., (1996) demonstrated that adding cactus to poor forage leads to increase the digestibility of the animal and ameliorate the microbial activity. The cactus based diets can improve the protein nitrogen supply for lamb feeding and increase the daily weight gain (Ben Salem et al., 2002).

During the last decade, cultivation of cactus has been developed in Tunisia to prevent soil and water erosion especially in vulnerable areas. Cactus has become an abundant resource especially in Tunisian arid areas. To face water scarcity and to substitute expensive and conventional forage, this plant is used as an alternative feed resource. In addition, it is an important source of water for livestock especially in dry areas. In Tunisia, the cactus cladodes are manually chopped to feed the livestock. The idea of introducing a forage chopper is to present a labor-saving technology on the farm using the cut-and carry technique. The mechanized fodder processing has multiple benefits: economic, social and environmental. Indeed, the adoption of this agricultural technology helps to overcome feed shortage and to substitute traditional production method of forage in arid and semiarid areas in Tunisia. This machine is used to chop several types of fodder and livestock feed. However, the adoption of this machine is facing many constraints.

Within this framework, the specific objective of this paper is to present a typology of livestock-based production system in arid areas in Tunisia and to characterize which group is willing more to adopt the forage chopper. A logit model was performed also to identify the determinant factors of agricultural innovation adoption.

2. Theoretical framework

Understanding the reasons behind the level and pace of innovation adoption among farmers has been the concern of various sociologists and economists to identify the attributes of agricultural innovation adoption. Adoption is defined as the decision of complete use of an innovation or a technology as the best choice available. However, this decision starts to be difficult to made especially when the farmer is not sure about the profitability of the technology (Rogers, 2010). An agricultural innovation is defined as an innovative idea or practice perceived as new by beneficiaries and injected on the farm in packages (Toborn, 2011). Rogers et al, 2010 mentioned that an innovation to be acceptable to the farmers, it must be economically profitable, socially acceptable and technologically visible. Baumgart-Getz et al. (2012) suggested that the adoption decision is a result of an interaction of agronomic, social, economic and environmental factors. Otherwise, the purpose behind developing an innovative technology is to improve farmers' welfare and income, to increase farm yields and productivity and to ensure food security (Lee 2005, wright and shih 2010). Besides, the adoption decision depends on the farmers' preferences for environmental preservation.

During the last decade, an important number of studies evaluated the economic impact of adopting agricultural innovations in various countries considering the effect on farm productivity, crop yields and technical efficiency (Abate et al, 2014; Siziba et al. 2013; Sjakir et al. (2015) and Gonzalez et al. (2009)). Among others, Asfaw et al. (2012), Ndaghu et al. (2015) and Kuwurnu and Owusu (2012) have studied the impact of adopting agricultural innovations on household welfare. Literature retains the determining factors of the adoption process such as productivity, production level, price risk and land tenure (Feder et al., 1985; Fernadez-Cornejo et al., 1994). Others factors were identified also important to explain technological adoption, namely the farmer attitude toward credits

and loans and the farm size and its economic and commercial vocation (feder and O'Mara, 1981).. Summing up, these factors can be regrouped under five important elements influencing the adoption process: socio-economic characteristics and farmer perception toward the innovation, the complexity of the introduction process, Multiuse opportunity to employ the same innovation on different farm sizes, the visibility of the innovation impact (Van den Ban and Hawkins, 1988).

In the case of Tunisia, Ben Salem et al., (2006) analyzed the adoption of direct drilling technologies and identified the following attributes as the most relevant factors in the farmer choice of adoption: farmer off-farm income, the education level, the age of the farmer, farm size, and the importance of extension services. Another work dealing with the adoption of natural resource management technology in arid and semi-arid areas evaluated the impact of introducing spineless cactus in alley cropping system in central Tunisia (Alary et al., 2007). The adoption of direct drilling was analyzed also by Abdelhafidh et al., (2011) introducing the risk aversion attitude of farmer. Recently, Fouzai et al. (2018) analyzed the adoption of conservation agriculture technologies among smallholder farmers in the Tunisian semi-arid region presenting the most relevant adoption factors: education level and experience of farmer, quality of extension services, the importance of off-farm revenue, flock density and the land tenure.

3. Methodological framework

3.1. Study area

To carry out this research, seven provinces have been selected in the north, center and south of Tunisia. The study area represents 28% of the total area of Tunisia. These provinces were chosen to include all areas located in arid and semi-arid bioclimatic floors in the analysis and seen the importance of livestock production in these zones (figure 1). Besides, these areas are characterized by high rate of unemployment, water scarcity and the importance of rural population. 414 farmers were surveyed, around 60 farmers per province (table 1). This sample is composed of chopper adopters (73,43%) and non-adopters (26,57%). The sample was randomly constructed to give to all farmers the same probability of being selected. All statistical analysis was performed using the statistical software package IBM SPSS 20. The data was collected in 2019 using structured questionnaires including seven parts: farm identification and socio-economic characteristics, land use and cropping, livestock farming system, labor, farm equipment and mechanization, technology acceptance and adoption, access to extension services. In addition to the logit model, a principal components analysis and a cluster analysis were performed to characterize the adopter profile and to identify the determinants factors of adoption decision among farmers.

| Bioclimatic | Province | Number of | Average rainfall | Surface area |
|----------------|-----------|------------------|------------------|-----------------|
| floor | | surveyed farmers | (mm/year) | Km ² |
| Cunonion comi | Kef | 59 | 521 | 5081 |
| Superior semi- | Seliana | 60 | 546 | 4642 |
| anu | Kasserine | 58 | 369 | 8066 |
| | Kairouan | 63 | 315 | 6712 |
| Superior arid | Sidi | 64 | 233 | 7405 |
| | Bouzid | | | |
| L ouven emid | Gafsa | 56 | 289 | 7808 |
| Lower and | Gabes | 54 | 181 | 7166 |
| Total | 7 | 414 | | 46880 |

Table 1. Distribution of surveyed farmers by province and bioclimatic floor

Source: Ministry of Agriculture, Tunisia (2018)



Figure 1. Map of study area in Tunisia

2.1. Principal components analysis and cluster analysis

22 variables were considered relevant to characterize the livestock-based production system. These variables were regrouped into four categories: climatic and structural variables, economic variables, mechanization importance and flock size and composition (expressed as livestock unit (LU), 1 ewe=0.1 LU; 1 cow=0.7LU; 1 goat=0.1 LU; 1 camel =0.75 LU) (FAO, 2011). Additional variables were employed to characterize the production systems. These variables were selected to include the socio-economic profile

of the farmer and to reflect his interest about the chopper. Descriptive statistics of selected variables are reported in table 2.

| Variable category | Selected variable | Average | Std. dev |
|----------------------|--|----------|----------|
| | Agricultural area (ha) | 12.26 | 18.32 |
| | Irrigated agricultural area (%, total FSA) | 38.89 | 43.29 |
| 1 (1) | Cactus area (%, total FSA) | 46.66 | 32.59 |
| 1-Climatic | Area of olive trees (%, total FSA) | 16.68 | 28.98 |
| and structural | Cereal area (%, total FSA) | 24.29 | 23.64 |
| variables | Watering source | 2.65 | 1.24 |
| | Family size (persons) | 3.93 | 3.42 |
| | Rainfall (mm/year) | 324.30 | 131.46 |
| 2- Economic inc | licators | | |
| Crop | Gross margin arboriculture | 9545.77 | 35824.39 |
| production | Gross margin of fodder crops | 3355.87 | 19308.98 |
| (TND) | Gross margin of horticulture | 371.57 | 2963.75 |
| | Total cost of sheep farming | 19836.51 | 20597.71 |
| | Total cost of cattle farming | 5930.13 | 11984.54 |
| Livestock | Gross margin (sheep farming) | 28000.45 | 37914.62 |
| production | Gross margin (cattle farming) | 5284.18 | 10302.38 |
| (TND) | Gross margin (goat farming) | 2168.41 | 4342.67 |
| | Cost of livestock feeding (%, total cost of livestock farming) | 48.79 | 14.54 |
| 3- Importance | Value of small equipment (TND) | 3593.86 | 10844.32 |
| of | | 07.10 | 40.60 |
| mechanization | Available power on the farm (horses) | 27.13 | 49.62 |
| 4- Flock size | Sheep, % of the flock | 62.69 | 33.46 |
| and | Goats, % of the flock | 9.13 | 13.95 |
| composition | Cattles, % of the flock | 27.94 | 35.58 |

Table 2. Descriptive analysis of selected variables in the PCA analysis

Source: authors' elaboration

2.2. Logistic regression model: model for adoption behavior

The choice of adopting a technology is dichotomous. That is, the explained variable can only take two modalities (Montmarquette, 2008). This is because the farmer decides whether to adopt the forage chopper. In this paper, the analysis of determinant factors of adoption decision was carried out employing a regression model that makes it possible to predict the decision of a farmer to adopt or not the forage chopper proposed to him. The adopter is defined as the farmer who accepts and actively participated in the project. The decision to adopt is considered a dependent variable of a qualitative nature in a regression whose value is 0 (for the non-adopter) or 1 (for the adopter). By reviewing literature, there are four types commonly used to model the adoption decision. These are the linear regression models, the logit, the Probit and the Tobit model. In this study, we employed the Logit model to characterize the relationship between the probability of adopting forage chopper and the determinants variables. This model is commonly used to model the adoption decision (CIMMYT Economics Program, 1993). This logistic regression provides a quantitative analysis of the adoption process and maintains the estimated probability between 0 and 1.

The following equation presents the logistic probability function

$$E(Y_i) = P(Y_i) = \frac{e^{\alpha + \beta X_i}}{1 + e^{\alpha + \beta X_i}}$$

When the farmer does not adopt the machine, the probability for this purpose will be as the following:

$$P(no - adoption) = 1 - P(Y_i) = \frac{1}{1 + e^{\alpha + \beta X_i}}$$

Where the

P (Y): The probability for an individual i to adopt the machine

P(Yi) = 1 if the technology is adopted and 0 if the technology is not adopted.

e: The exponential function

Yi: the dependent variable; the adoption of fodder chopper

 β : The vector of the parameters to estimate whose sign allows the interpretation of the results

 α : The constant

Xi : characteristic of the individual i; it represents the vector of the explanatory variables

Data were collected on a range of variables covering the characteristics of both the farmers and farming systems used in the study area. The following table summarizes the employed variables in the logit regression. These variables were incorporated in the model taking into considerations the project context and the literature revision.

| Variables | Description | | | | | |
|-----------------------------|--|--|--|--|--|--|
| Dependent variable | | | | | | |
| Yi | Farmers adoption decision: 1 if adopted and 0, otherwise | | | | | |
| Explicative variables | | | | | | |
| Input supply problem | Inputs supply problem (fertilizers, seeds, concentrates, livestock feed, etc.); dummy variable (1 = yes; 0 = no) | | | | | |
| Cactus | Presence of cactus on the farm ($1 = yes; 0 = No$) | | | | | |
| Farm surface area | Expressed in hectares (ha) | | | | | |
| Irrigated agricultural area | Expressed in hectares (ha) | | | | | |
| Cereal area | Expressed in hectares (ha) | | | | | |
| Horticulture area | Expressed in hectares (ha) | | | | | |
| Flock size | Measured in Livestock Units (LU) | | | | | |
| Bioclimatic floor | Three bioclimatic floors were included in the analysis: | | | | | |
| | Superior arid (Sidi Bouzid and Kairouan) | | | | | |
| | Lower arid (Gafsa and Gabes) | | | | | |
| | Superior semi-arid (Kef, Seliana and Kasserine) | | | | | |
| Gender | Gender of the farmer $1 = men$, $0 = women$ | | | | | |
| Family size | Number of persons living on the farm | | | | | |

Table 3: Description of variables used in the adoption model

Source: authors' elaboration

Descriptive statistics are reported in table 4 showing that the studied farms were of medium size with and average area of 12.25 ha and 17 LU. The average irrigated area is 2.7 ha and the average horticulture area is 8.6ha. Among these variables, others socio-economic variables were considered: The family size and the farmer gender

| Variables | Average | Standard Deviation | Minimum | Maximum |
|-----------------------------|---------|--------------------|---------|---------|
| Farmers adoption decision | 0.73 | 0.44 | 0 | 1 |
| Input supply problem | 0.84 | 0.35 | 0 | 1 |
| Cactus | 0.61 | 0.48 | 0 | 1 |
| Farm surface area | 12.25 | 18.32 | 0 | 180 |
| Irrigated agricultural area | 2.76 | 4.67 | 0 | 30 |
| Cereal area | 0.13 | 0.76 | 0 | 10 |
| Horticulture area | 8.66 | 17.26 | 0 | 180 |
| Flock size | 17.07 | 15.98 | 0.7 | 111.60 |
| Superior arid | 0.30 | 0.46 | 0 | 1 |
| Lower arid | 0.26 | 0.44 | 0 | 1 |
| Gender | 0.94 | 0.22 | 0 | 1 |
| Family size | 3.92 | 3.42 | 0 | 7 |

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Source: authors' elaboration

4. Results and Discussion

Before starting the ACP, we excluded all variables with a coefficient of variation less than 60% (Frija et al., 2016). Moreover, variables highly correlated among each other or totally uncorrelated were eliminated based on the correlation matrix. The Kaiser-Meyer-Olkin index (KMO =0.67) was considered as well as to check sample adequacy (Toro-Mujica et al., 2012). After the preliminary verification of mentioned conditions above, the remaining standardized variables were subjected to a factor analysis using principal components analysis (PCA). Results of the PCA analysis provided five categories of factors explaining 67.27% of the total sample variance (table 5). After selecting the factors, an orthogonal Varimax rotation was used to identify most correspondent variables with extracted factors (Toro-Mujica et al., 2015). Considering the size of the sample and the selected number of variables, a K-mean cluster analysis is presented to cluster farmers into separate groups (Keenan et al., 2012; Goyeneche et al., 2014; Ibidhi et al., 2018).

Based on these factors, the K-mean cluster analysis generated four production systems that are described in table 6. Table 7 presents the one-way ANOVA test of additional variables used in the clusters descriptions. Each of these clusters is characterized by a specific set of variables allowing the following interpretation of clusters:

Extensive mixed livestock-cereal production system: the first group accounted for 59.4% of surveyed farmers, which are in majority located in semi-arid regions of Northern and Central Tunisia. The average size of these farms is 11.07 ha mostly allocated to cereal cropping. This system integrated sheep and cattle husbandry with high presence of cactus on the farm. The average family size of this group is 3.54 persons. Small equipment is almost absent with a production system mostly rainfed (table 7). This group is the less interested cluster about the chopper in comparison with other groups. Extensive mixed sheep-cereal production system: The second groups (9.17%) is a mixed farming system with the dominance of sheep farming. Crops production has a significant importance (in terms of gross margin) and seems more important than livestock farming. This group includes mainly large farms located in superior semi-arid area. These farms are endowed with an important presence of mechanization and small equipment. The production system of the second group is predominantly in rainfed system. The farmers of this group are very interested about the forage chopper. Intensive Sheep farming system: The third group, in which sheep-goat farming are intensively managed, represents 17.63% of the studied sample. This group includes mainly medium farms with high presence of cactus on the farm and high endowment of small mechanization. The family size is very important in comparison with other groups. These farmers are located mostly in Kasserine and Sidi Bouzid provinces (superior arid). This cluster is the most interested about adopting the forage chopper. **Intensive cattle farming system**: The last group refers to cattle-olive tree production system. The cost of livestock feeding is very high in the case of this group, which explains the interest about the proposed machine. The cluster is composed of small farms located in lower arid area with access to collective and private watering system.

| Component | % variance | Observed variables | Correlation |
|-----------|--------------|---|-------------|
| N° | explained (% | | of |
| | variance | | variables |
| | accumulated) | | with the |
| | | | respective |
| | | | factor |
| 1 | 21.265% | Gross margin cattle farming | 0.897 |
| | (21.265%) | Total cost cattle farming | 0.885 |
| | | Cattles (%, flock) | 0.777 |
| | | Sheep (%, flock) | -0.724 |
| | | Goats (%, flock) | -0.241 |
| 2 | 12.625% | Gross margin sheep farming | 0.840 |
| | (33.890%) | Gross margin goat farming | 0.838 |
| | | Total cost of sheep farming | 0.700 |
| | | Goats (% flock) | 0.515 |
| | | Cost of livestock feeding (%, total cost of | -0.500 |
| | | livestock farming) | |
| | | Agriculture area | 0.465 |
| | | Watering source | -0.477 |
| 3 | 12.093% | Irrigated agricultural area (%, total farm | -0.660 |
| | (45,983%) | surface area) | |
| | | Cereal area (%, total farm area) | 0.651 |
| | | Rainfall (mm/year) | 0.599 |
| | | Agriculture area | 0.598 |
| | | Drinking source | 0.595 |
| | | Sheep (%, flock) | 0.344 |
| | | Cost of livestock feeding (%, total cost of | -0.363 |
| | | livestock farming) | |
| 4 | 11.090% | Area of olive trees (%, total farm surface | -0.805 |
| | (57.073%) | area) | |
| | | Cactus area (%, total farm surface area) | 0.702 |
| | | Family size (persons) | 0.523 |
| | | Irrigated agricultural area (%, total farm | 0.320 |
| | | surface area) | |
| | | Cost of livestock feeding (%, total cost of | -0.372 |
| | | livestock farming) | |

 Table 5. Factors generated through PC analysis, variance explained and accumulated, and correlation coefficients

| | | Sheep (%, flock) | 0.326 |
|---|-----------|--------------------------------------|-------|
| 5 | 10.197% | Available power on the farm (horses) | 0.849 |
| | (67.270%) | Value of small equipment (TND) | 0.791 |
| | | Gross margin of cereal crops | 0.543 |
| | | Gross margin of arboriculture | 0.430 |

Source: authors' elaboration

Table 6. Characteristics of identified clusters of farms and p-value of one-way analysis of variance (equality of group mean) for production

systems clustering variables.

| Groups | $C_{\text{rowns}} = 1.(246)$ | | 2 (28) | | 2 (72) | | 4 (57) | | n |
|-------------------------------------|------------------------------|-----------|----------|-----------|----------|-----------|----------|-----------|-------|
| Variables | 1 (. | 240) | <u> </u> | (30) | | (73) | 4 | | P- |
| Variables | average | Std. dev | Average | Sta. dev | Average | Std. dev | Average | Std. dev | value |
| Cattle (% of the flock) | 24.3817 | 31.98549 | 15.6033 | 21.83956 | 3.2708 | 6.08539 | 83.1182 | 21.19926 | 0.000 |
| Sheep (% of the flock) | 70.41 | 30.887 | 76.50 | 21.582 | 67.71 | 20.524 | 13.72 | 19.222 | 0.000 |
| Goat (% of the flock) | 5.22 | 8.491 | 7.84 | 7.948 | 27.73 | 19.427 | 3.00 | 6.062 | 0.000 |
| Agriculture surface area (ha) | 11.07 | 14.597 | 21.53 | 23.940 | 14.38 | 23.381 | 8.46 | 19.429 | 0.002 |
| Irrigated agriculture area (% Total | 30.24 | 40.667 | 28.47 | 38.510 | 53.45 | 43.491 | 64.51 | 42.807 | 0.000 |
| farm area) | | | | | | | | | |
| Cereal area (% of total farm area) | 26.76 | 25.870 | 35.26 | 18.868 | 17.08 | 17.422 | 15.54 | 17.751 | 0.000 |
| Cactus area (% of total farm area) | 41.21 | 32.014 | 48.37 | 24.507 | 63.63 | 31.787 | 47.30 | 33.842 | 0.000 |
| Olive trees area (% of total farm | 23.28 | 34.589 | 7.11 | 7.894 | 7.99 | 15.494 | 5.68 | 11.627 | 0.000 |
| area) | | | | | | | | | |
| Value of small equipment (TND) | 947.40 | 2821.368 | 26452.63 | 23773.318 | 3250.68 | 6861.975 | 215.79 | 1187.252 | 0.000 |
| Available power on the farm | 15.72 | 30.056 | 137.32 | 66.440 | 21.47 | 34.104 | 10.14 | 25.541 | 0.000 |
| (horses) | | | | | | | | | |
| rainfall (mm/year) | 341.71 | 125.788 | 435.76 | 110.504 | 266.92 | 97.983 | 248.33 | 133.815 | 0.000 |
| Family labor (persons) | 2.94 | 2.077 | 3.45 | 3.294 | 4.56 | 3.131 | 2.47 | 2.261 | 0.000 |
| Family size (persons) | 3.54 | 3.411 | 4.61 | 3.184 | 5.18 | 3.776 | 3.54 | 2.726 | 0.000 |
| Total costs of sheep farming | 16318.97 | 12006.228 | 20861.05 | 14221.151 | 40312.30 | 33805.114 | 8111.05 | 12403.487 | 0.000 |
| (TND) | | | | | | | | | |
| Total costs of cattle farming | 3190.56 | 4663.185 | 2544.37 | 3843.961 | 950.52 | 1895.020 | 26388.12 | 21229.104 | 0.000 |
| (TND) | | | | | | | | | |
| Gross margin of cattle farming | 2834.78 | 3959.708 | 2751.61 | 3242.251 | 1878.25 | 4072.744 | 21905.68 | 18943.845 | 0.000 |
| (TND) | | | | | | | | | |

| Gross margin of sheep farming | 19238.35 | 18575.632 | 34998.16 | 33691.997 | 66158.93 | 63317.401 | 12281.05 | 25834.862 | 0.000 |
|-------------------------------------|----------|-----------|----------|------------|----------|-----------|----------|-----------|-------|
| (TND) | | | | | | | | | |
| Gross margin of goat farming | 619.72 | 1086.084 | 2178.42 | 3566.320 | 8367.67 | 6652.592 | 906.14 | 2522.452 | 0.000 |
| (TND) | | | | | | | | | |
| Cost of livestock feeding (%, total | 50.91 | 13.890 | 41.32 | 13.934 | 40.27 | 12.880 | 55.53 | 13.285 | 0.000 |
| cost of livestock farming) | | | | | | | | | |
| Gross margin of arboriculture | 5215.55 | 12344.671 | 42626.45 | 102665.330 | 9787.37 | 20436.621 | 5870.84 | 21411.899 | 0.000 |
| Gross margin of fodder crops | 887.45 | 4698.505 | 187.66 | 634.387 | 4550.08 | 11302.421 | 14591.74 | 48214.565 | 0.000 |
| Gross margin of horticulture | 211.28 | 1150.547 | 322.53 | 1836.511 | 508.22 | 2488.125 | 921.05 | 6953.795 | 0.000 |

| Groups | 1 | 2 | 3 | 4 | p-value |
|-----------------------------------|-------|------|------|------|---------|
| Farmers adoption decision | 0.000 | | | | |
| Yes | 65.4 | 76.3 | 87.7 | 73.4 | |
| No | 34.6 | 23.7 | 12.3 | 26.6 | |
| Watering source ⁴ | | | | | 0.000 |
| Collective | 19.1 | 15.8 | 26 | 50.9 | |
| private | 26.8 | 28.9 | 39.7 | 19.3 | |
| Mixte | 4.1 | 5.3 | 8.2 | 7 | |
| Rainfall | 50 | 50 | 26 | 22.8 | |
| Bioclimatic floor | | | | | 0.000 |
| Superior semi-arid | 46.7 | 78.9 | 26 | 22.8 | |
| Superior arid | 38.2 | 18.4 | 34.2 | 1.8 | |
| Lower arid | 15 | 2.6 | 39.7 | 75.4 | |
| Use of cactus in livestock feed (| 0.000 | | | | |
| Oui | 57.3 | 47.4 | 60.3 | 15.8 | |
| Non | 42.7 | 52.6 | 39.7 | 84.2 | |

Table 7. Characterization across the identified livestock-based production systems in

Tunisia

Source : authors' elaboration

After characterizing existing production systems, we proceed with the logistic regression. The results indicated that the model overall is statistically significant. The finding of this study are in line and consistent with a number of theoretical and empirical studies revealing that the adoption decision is determined by farm characteristic and socio-economic attributes of the farmer. Table 8 presents the results of the performed regression and the marginal effect (dx/dy) of each variable on the probability of adoption. Findings indicate that the adoption decision is positively correlated with the farm surface area, the flock size, the presence of cactus and the existence of input supply problem. Results shown that the adoption decision

⁴ Watering source : (1) private (well, Majel (traditional technique for the collection and storage of rainwater. It is a small underground tank with a small capacity of a few cubic meters in the community), Fesguia (traditional technique for the collection and storage of rainwater in big capacity underground tank); Collective : dam, lake...; Mixte : access to private and collective watering sources

is negatively correlated with gender. Findings indicate that input supply problem and the presence of cactus on the farm are relevant for adoption decision.

In the study areas, Men and women are partly engaged in all related activities to livestock farming. However, the task of feed preparation and cactus cutting are especially considered female activities. Indeed, our findings suggest that male farmers are less likely to adopt the chopper. The family size is positively correlated with the dependent variable but statistically insignificant. Regarding the farm characteristics, our findings suggest that the presence of cactus on the farm in an important determinant of the adoption decision. However, farmers with an important cereal and horticulture area are less interested by adopting this machine. Another relevant variable found is the bioclimatic floor of the studied area: results suggest that in comparison with farmers of the superior semi-arid, producers of the lower arid area is more interested about adopting the proposed machine.

| $T_{-1} = 0$ | E at inc at | · · · · · · · · · · · · · · · · · · · | - 1 ! - 4! - | | |
|--------------|-------------|---------------------------------------|--------------|------------|-------|
| Table 8 | Estimat | 101 01 110 | -1001stic | regression | model |
| I doite o | . Louinau | ion or un | e logibule | regression | mouci |
| | | | <u> </u> | 0 | |

| | | | | | | Number | r of obs= 414 | |
|---|--------|---------|-------|--------------|---------------|-----------|-----------------|--|
| | | | | | | LR chi2 (| (11) = 148.04 | |
| | | | | | | Prob> c | chi2 = 0.0000 | |
| Log likelihood = -165.66169 Pseudo R ² =0.3088 | | | | | | | | |
| | Coef. | Std.Err | Z | P> z | [95% Conf. | interval] | Dy/Dx | |
| Input supply problem | 1.031 | 0.391 | 2.63 | 0.008^{**} | 0.264 | 1.799 | 0.111* | |
| Cactus | 0.720 | 0.338 | 2.13 | 0.033** | 0.058 | 1.383 | 0.624* | |
| Farm surface area | 0.882 | 0.043 | 2.03 | 0.042** | 0.003 | 0.173 | 0.007** | |
| Irrigated agricultural area | -0.046 | 0.042 | -1.11 | 0.268 | -0.129 | 0.036 | -0.003 | |
| Cereal area | -0.835 | 0.045 | -1.83 | 0.068^{*} | -0.173 | 0.006 | -0.006* | |
| Horticulture area | -0.790 | 0.193 | -4.09 | 0.000*** | -1.168 | -0.411 | -0.063*** | |
| Flock size | 0.212 | 0.031 | 6.83 | 0.000*** | 0.151 | 0.274 | 0.017*** | |

| Superior arid | -0.160 | 0.375 | -0.43 | 0.668 | -0.896 | 0.575 | -0.013 |
|---------------|--------|-------|-------|---------|--------|--------|----------|
| Lower arid | 0.776 | 0.390 | 1.99 | 0.047** | 0.011 | 1.541 | 0.054** |
| Gender | -1.047 | 0.630 | -1.66 | 0.097* | -2.282 | 0.188 | -0.057** |
| Family size | 0.0493 | 0.050 | 0.97 | 0.330 | -0.049 | 0.148 | 0.003 |
| Constant | -2.097 | 0.805 | -2.61 | 0.009** | -3.675 | -0.519 | |

*= Significant at 10%, **= Significant at 5%, ***= Significant at 1%.

Source: authors' elaboration

Conclusions

Data on production systems and livestock feeding in Africa is scare. This paper addressed this gap based on global survey reflecting a wide range of livestock-based production systems in Tunisia. A multivariate statistical analysis allowed the identification of four different groups of livestock-based production systems. In addition, a logistic regression was performed to identify determinant variables of the adoption decision. It emerges from this study that the adoption of the forage chopper is positively correlated with various variables related to the farm structure such as the flock size, the farm surface area, the presence of cactus on the farm and the existence of input supply problem. Meanwhile, the adoption decision is negatively correlated with the surface of cereals and horticulture. The connections between the production system and adoption decision represent an essential step to set up improved strategies to develop a sustainable livestock production in Tunisia taking into account the specific characteristics of the production systems before the initialization of innovation insertion among farmers.

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