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Ibtissem Taghouti[1,*], Bouali Guesmi[2], Hichem Ben Salem[3], Sourour Laabidi[3], Salah Ben Youssef[3]

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 semi-arid 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 semi-arid 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

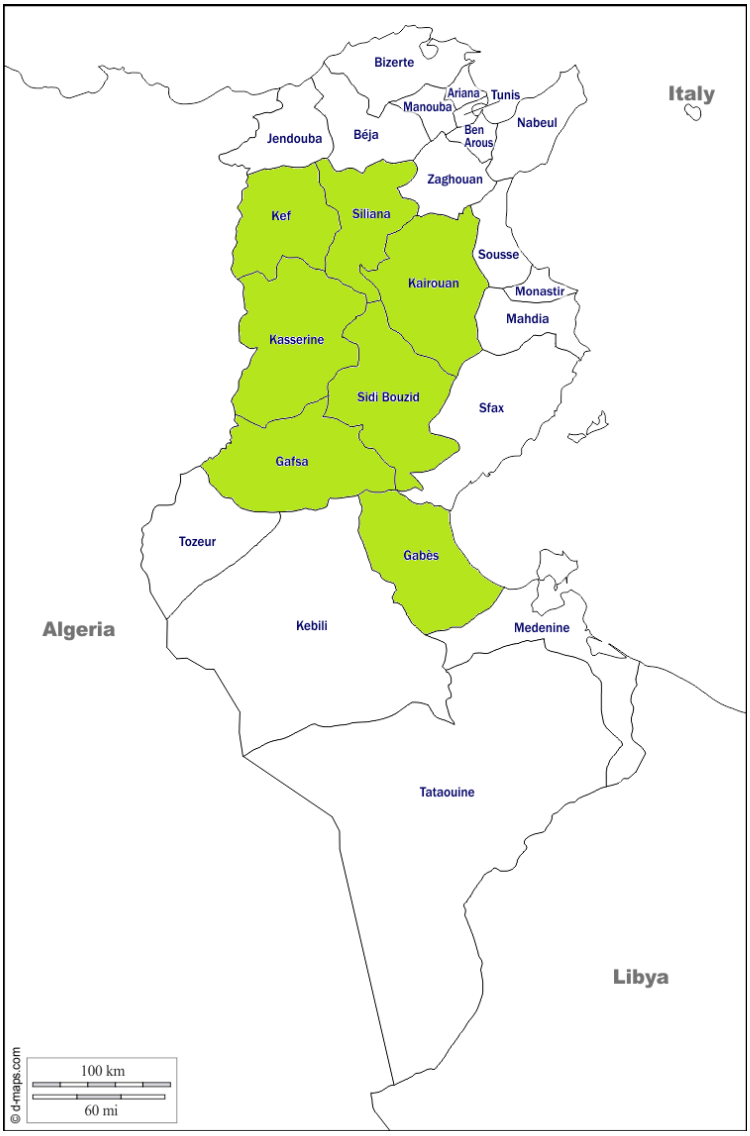
To carry out this research, seven provinces have been selected in the north, center and south of Tunisia. The study area represents 28% of the total area of Tunisia. These provinces were chosen to include all areas located in arid and semi-arid bioclimatic floors in the analysis and seen the importance 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.

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

Bioclimatic floor	Province	Number of surveyed farmers	Average rainfall (mm/year)	Surface area Km²
Superior semi-arid	Kef	59	521	5081
	Seliana	60	546	4642
	Kasserine	58	369	8066
Superior arid	Kairouan	63	315	6712
	Sidi Bouzid	64	233	7405
Lower arid	Gafsa	56	289	7808
	Gabes	54	181	7166
Total	7	414		46880

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.

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

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

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

X_i : 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.

Table 3: Description of variables used in the adoption model

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

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

Table 4. Descriptive analysis

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

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.

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

Component Nº	% variance explained (% variance accumulated)	Observed variables	Correlation of variables with the respective factor
1	21.265% (21.265%)	Gross margin cattle farming	0.897
		Total cost cattle farming	0.885
		Cattles (%, flock)	0.777
		Sheep (%, flock)	-0.724
		Goats (%, flock)	-0.241
2	12.625% (33.890%)	Gross margin sheep farming	0.840
		Gross margin goat farming	0.838
		Total cost of sheep farming	0.700
		Goats (% flock)	0.515
		Cost of livestock feeding (%, total cost of livestock farming)	-0.500
		Agriculture area	0.465
		Watering source	-0.477
3	12.093% (45,983%)	Irrigated agricultural area (%, total farm surface area)	-0.660
		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 livestock farming)	-0.363
4	11.090% (57.073%)	Area of olive trees (% , total farm surface area)	-0.805
		Cactus area (% , total farm surface area)	0.702
		Family size (persons)	0.523
		Irrigated agricultural area (%, total farm surface area)	0.320
		Cost of livestock feeding (%, total cost of livestock farming)	-0.372

		Sheep (%, flock)	0.326
5	10.197% (67.270%)	Available power on the farm (horses)	0.849
		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	1 (246)		2 (38)		3 (73)		4 (57)		p-value
Variables	average	Std. dev	Average	Std. dev	Average	Std. dev	Average	Std. dev	
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 farm area)	30.24	40.667	28.47	38.510	53.45	43.491	64.51	42.807	0.000
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 area)	23.28	34.589	7.11	7.894	7.99	15.494	5.68	11.627	0.000
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 (horses)	15.72	30.056	137.32	66.440	21.47	34.104	10.14	25.541	0.000
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 (TND)	16318.97	12006.228	20861.05	14221.151	40312.30	33805.114	8111.05	12403.487	0.000
Total costs of cattle farming (TND)	3190.56	4663.185	2544.37	3843.961	950.52	1895.020	26388.12	21229.104	0.000
Gross margin of cattle farming (TND)	2834.78	3959.708	2751.61	3242.251	1878.25	4072.744	21905.68	18943.845	0.000

Gross margin of sheep farming (TND)	19238.35	18575.632	34998.16	33691.997	66158.93	63317.401	12281.05	25834.862	0.000
Gross margin of goat farming (TND)	619.72	1086.084	2178.42	3566.320	8367.67	6652.592	906.14	2522.452	0.000
Cost of livestock feeding (%, total cost of livestock farming)	50.91	13.890	41.32	13.934	40.27	12.880	55.53	13.285	0.000
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

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

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	

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.

Table 8. Estimation of the logistic regression model

							Number of obs= 414
							LR chi2 (**11**) = 148.04
							Prob> 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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