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Agricultural Technology Transfer Preferences of Smallholder Farmers in Tunisia's Arid Regions

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Abstract: The objective of this research study was to assess the sources of information on two improved agricultural and livestock technologies (barley variety and feed blocks) as well as the efficacy of numerous agricultural technology diffusion means introduced in the livestock–barley system in semi-arid Tunisia. The research used primary data collected from 671 smallholder farmers. A descriptive statistical analysis was conducted, and Kendall's W-test and the chi-squared distribution test were deployed to categorize and evaluate the efficacy of the different methods of technology diffusion used by the Tunisian extension system. To address farmers' perceived opinions and classify the changes from the use of the improved technologies, a qualitative approach based on the Stapel scale was used. Farmer training, demonstration, and farmer-to-farmer interactions were perceived as the most effective agricultural extension methods. The access to technology, know-how, adoption cost of that technology, and labor intensity for adoption influenced its adoption level. Farmers' opinions about the changes resulting from the adoption of both technologies revealed that yield and resistance to drought were the most important impacts of the two technologies. The study recommends empowering the national extension system through both conventional and non-conventional technologies (ICT, video, mobile phones, etc.), given the cost-effectiveness and their impact on the farmers' adoption decisions.

Keywords: agriculture technologies; extension methods; perception; Kendall's W-test; semi-arid Tunisia

1. Introduction

In Africa and beyond, the next 50 years will require changes to significantly increase agricultural production as well as increase labor productivity [1]. To meet the increasing demand for agriculture products, there will also be a need to reduce the proportion of the population engaged in agriculture, releasing labor from agriculture into other sectors of the economy, while also ensuring a large move out of rural areas to increase the amount of productive land [1]. In this sense, Collier and Dercon argue that development strategies need to shift emphasis and resources away from small farmer (and small trader) models and open up new forms of commercialization. It will require the creation of opportunities for serious, larger scale commercial investment in agriculture, and hybrid models in which smallholders interact with larger farmers, as well as implementing integrated enterprises within important value chains [1]. However, the main challenge for each individual country is to determine the precise balance between small-scale and large-scale farms. In most cases, the larger farms are likely to improve the agricultural productivity, while the smallholders will continue playing a key role of sustaining livelihoods for the rural communities. Most African countries have failed to meet the requirements for a successful agricultural revolution, with agricultural productivity lagging far behind the rest of the world [2]. Millions of smallholder farmers in developing countries remain in the dark regarding modern technologies, which are primarily based on the efficient use of inputs such as chemical fertilizer and pesticides, and best practices including strategic feeding protocols for livestock [3]. There is a dire need to educate farmers on the importance of improved farming practices, adaptation of proven and tested production technologies, and better utilization of land holdings through well-coordinated efforts of agricultural research and extension with allied developmental organizations [4]. This is particularly urgent in developing countries because agriculture remains a central element of the economy and innovation is the key to the agricultural growth needed to reduce poverty.

In developing countries, the agricultural sector is socially and economically important for its contribution to the achievement of national objectives such as food security, employment, and social cohesion [5]. In Tunisia, for example, agriculture is mainly extensive, limited by climatic conditions such as unreliable rainfall and very high temperatures [6]. It is also the main consumer of land and water, providing at least 20% of the national annual GDP and employing 22% of the total labor force, Agri-food exports also represent around 15% of total exports [5–7]. Key to the continued contribution of agriculture to Tunisia's economy and beyond, is the adoption of new management, communication, innovation, and production practices, which are expected to maintain long-term profitable agricultural operation [1]. To do this, farmers will require strategic management options or different crops to grow that can stabilize household income, a facilitative environment where prices and costs of production are stable, as well as innovations and information regarding which production options are cost effective and their potential impact on production levels.

The major challenge for policy makers to increase productivity in the agricultural sector is to improve the adoption rate of innovative related livestock technologies for farmers. For example, at the national level in Tunisia, the technology transfer system is essentially driven by public authorities through its various support structures, in particular the General Directorate of Agricultural Production (DGPA), the Regional Commissions for Agricultural Development (CRDA), the agricultural Training and Extension agency (AVFA), and the Office of Livestock and Pasture (OEP).The current system of technology transfer presents important deficiencies related to the lack of means in the extension institutions, such as the AVFA, to the lack of coordination between the various actors of the technology transfer system, particularly the profession and research, and the lack of a targeted transfer strategy that takes into account the specificity of regions and the sociodemographic and economic characteristics of farmers.

The main purpose of this study was to assess the effectiveness of technology transfer methods/sources as perceived by farmers in the Tunisian arid farming system. In particular, this study was designed to record the perceptions of farmers regarding the use and effectiveness of sources and approaches to technology transfer as used by agricultural extension/research; and to record the opinions of farmers regarding the technology transfer process.

The technology transfer model suggests a transfer of critical information from research and development, through extension personnel, to the person on the ground who utilizes such information—the farmer [8]. However, not all farmers are able and willing to adopt new technologies because of the challenges to adoption imposed by various socioeconomic, institutional, and environmental factors [9]. This study will contribute to the body of literature highlighting the effectiveness of different methods of information transfer to smallholder farmers, such as radio programs and information dissemination from neighboring farmers, SMS messages, field days, and technical, economic, and organizational training. In particular, this study examined the information sources of enhanced agricultural and livestock technologies to small-holder's farmers in addition to the effectiveness of the technology transfer methods.

2. Methodological Framework

2.1. Study Design and Study Area

The study focused on two governorates with similar agro-ecological conditions: Zaghouan and Kairouan (located in the north east and central west of Tunisia, respectively). The governorates were chosen due to the importance of their high barley/livestock-based production systems. In addition, the inhabitants are poor, socially disadvantaged, disfavored, scattered, and have limited political influence, in terms of infrastructural and institutional support. More than 70% of the population in Zaghouan and Kairouan are rural and involved in agricultural activities, with at least 51% of the labor force fully employed in the agricultural sector. A large number of the small farmers in the region derive most of their family income from barley/livestock-based systems, as barley is a flexible feed, food, and cash crop. Zaghouan is bordered by the governorates of Ben Arous, Ariana, and Manouba to the north; Sousse and Kairouan to the south; and Siliana and Beja to the east. It covers an area of 2820 km^2 and is characterized by a semi-arid climate with an average annual rainfall of 450 mm. Kairouan represents a crossroads between the north, south, east, and west of the country. It is bordered by the governorates of Zaghouan, Siliana, Kasserine, Sidi Bouzid, Sfax, Sousse, and Mahdia. It covers an area of 6712 km^2 and is characterized by an arid and a semi-arid climate in the south and north, respectively. Average rainfall ranges from 200 mm in the south to 350 mm in the north (Figure 1).

Figure 1. Research study sites in Tunisia.

2.2. Sampling Procedure and Sample Size Estimation

In 2016, the *Office de l'Elevageet des Pâturages (OEP)* in Tunisia provided a list of 700 smallholder farmer household heads (HHs) in the two governorates. The HHs were identified based on the following criteria: ownership of 0–5 ha of land and ownership of 1–50 small ruminants. Villages (*douars*) where at least 10 farm HHs fulfilled both criteria were selected. Ten HHs of the same village were put in one group, such that 70 villages each with 10 HHs were selected from the two governorates. Based on the selection criteria, the number of HH/village differed between the two governorates, resulting in 480 and 220 HH/village in Kairouan and Zaghouan, respectively. After selection of the 70 villages, farmers were divided into five treatment groups each comprising 140 HHs (or 14 villages). Both male and female HHs were included.

The "Mind the Gap" research project tested new and existing models of transferring innovative technology packages to smallholder farmers by using a randomized controlled trial (RCT) approach. The technology transfer models we tested comprised four model components: access to inputs, access to technical information, access to organizational and economics training, and female empowerment. These four model components were combined in various ways, and the combinations were implemented in different treatment groups to test and compare their individual and combined effects (Table 1).

Table 1. Distribution of project households according to treatment groups (T1–T4) in 2018.

T1 (*n* = 137)	T2 (*n* = 137)	T3 (*n* = 137)	T4 (*n* = 131)	Control (*n* = 129)
Technical training	Technical training, Economic/organizational training	Technical training, Economic/organizational training, Female empowerment	Technical training, Female empowerment	None

Notes: *n*: number of farmers involved in the treatment; Technical training included training 1 (presentation on feed blocks, presentation on Konouz variety, theoretical and practical training on melovine, field visits to see Kounouz at the ripening stage at a field station), follow-up training (demonstration of feeding with feed blocks, verbal refreshing of all technologies), field visits to a farmer who had planted Kounouz during the last season, field visits to a demonstration farm for Kounouz, and regular messages (on technical issues in livestock management and barley and on when, where, and for what price a farmer can purchase the promoted technologies). Economic/organizational training included organizational training (focus on benefits of farmer organizations), organizational training follow-up (creation process of farmer organizations and the administrative procedures), visits to cooperative/farmer group, economic/financial training (general theoretical lessons with a training sheet to determine cost of production), economic/financial training follow-up/coaching, and Farmer Business School. Female empowerment included training 1 (self-esteem and personal development), training 2 (develop specific business ideas for each participant, training 3 (sensibilization on credit), and a visit from a female cooperative/farmer group. Source: own elaboration from project data, 2019.

In total, we compared four different treatments with and without certain components included, and one control without any treatment (Table A1 in Appendix A). Two technologies were distributed to the project's farmers: Kounouz variety and feed blocks. The introduction of agricultural technologies into farmer production system brings numerous benefits. Feed blocks provide flexibility to livestock farmers, allowing them to choose the ingredients to be included in the feed block and providing a food supplement in drought and other harsh conditions. In addition, the blocks can be prepared when the cost of the ingredients is low and stored for later use. Additionally, the introduction of the improved barley Kounouz into farmer production systems increases production at the farm level, improves soil quality; especially nitrogen content, and provides a source of fodder for farmers. Compared to traditional crops, improved barley varieties significantly boost yields.

Data for the impact analysis were collected through a follow-up survey (after implementation of the treatment groups) conducted in December 2018. The questionnaire was divided into 17 modules covering all the variables that could influence the adoption of agricultural technologies by smallholder farmers (Table A2 in Appendix A). Modules 0, A, and B focused on identification of the HHs, with questions related to demographic data and the characteristics of the main household. Modules C and D focused on HH assets, and questions included land owned, land title possession, cost of renting land, and the access to communal pasture. Module E focused on crop management and questions included quantity, price, and source of inputs. Modules F, G, and H focused on livestock possession, marketing, technology, and nutrition, with questions including feed calendar, number of animals sold, and the number of communications with a veterinarian.

Modules I and J focused on technology perception and also on the awareness and uptake of HHs regarding adoption of technology. Module K focused on the social networks of HHs with questions including knowledge, number of contacts, and distance from neighbors. Modules L and M focused on the other sources of income, and transfer, and non-food expenditure. Module N focused on access of HHs to socioeconomic infrastructure, with questions centering on the distance to the nearest social facilities. Modules O and P focused on system vulnerability and dietary quality, with questions including shocks observed, coping strategies, and amount of food consumption. The findings of the survey are presented using descriptive statistics based on frequencies and percentages. Statistical analysis was performed with SPSS Version 22.0 statistical software. The analysis concerned a total sample of 671 HHs.

2.3. Analytical Framework

With the purpose to assess the efficacy of the different agricultural and livestock technology diffusion models used by the Tunisian extension system, the research used a mixed methods approach integrating both quantitative and qualitative approaches to collecting the data. Kendall's W-test and chi-squared (χ^2) distribution test have been deployed for the statistical descriptive analysis. The χ^2 test is used to test the hypothesis of no association between two or more groups, populations, or criteria. In our case, we used it for testing relationships between categorical variables. Such variables are characterized by a χ^2 distribution statistical test as soon as the null hypothesis is true. The null hypothesis of the χ^2 test was that no relationship exists on the categorical variables in the population.

The Kendall's W-test was used to classify, in ascending or descending order, selected agricultural and livestock technique diffusion models among farmers, from most to least significant. Kendall rank correlation was used to test the similarities in the ordering of data when it is ranked by quantities. This correlation was also used to assess the statistical associations based on the ranks of the data (such as our research case). Other types of correlation coefficients use the observations as the basis of the correlation, Kendall's correlation coefficient uses pairs of observations and determines the strength of association based on the patter on concordance and discordance between the pairs. It is a non-parametric statistic issued from a simple normalization of the Friedman test [9,10] and goes from 0 (disagreement) to 1 (whole agreement). This suggests that if W = 1, then each farmer assigned the same order to the list of concerns, given the unanimity of the respondents; if W = 0, there was no agreement among interviewees and consequently their responses were considered randomly.

The null hypothesis concerning this test suggests that there is no dependence of the classification revealed by all interviewed farmers. This is one-tailed, given that it only recognizes positive relations between vectors of classification. Kendall's statistical test was calculated using the following formula (Equation (1)):

$$S = \sum_{i=1}^{N} (Ri - R)^2 \tag{1}$$

where S is computed using the Kendall and Babington (1939) formula which is the sum of squares statistic over the row sums of ranks. In this sense, Kendall's W-statistical figure can be derived as follows:

$$W = \frac{12S}{p^2(n^3 - n) - PT} \tag{2}$$

where:

- n is defined as the number of concerns,
- p is quantified as the number of judges, and
- T is demarcated a correction factor for tied ranks.

The W-statistic is defined as an estimate of the variance of the row sums of ranks R_i divided by the maximum possible value the variance can take (R). This is could be possible when all respondents (small-holder's farmers, in this case) are in complete agreement; hence $0 \leq W \leq 1$.

Consequently, the above statistical test (Kendall's W-test) was used to classify the potential information sources on the two improved agricultural and livestock technologies to the smallholder farmers. We also employed this test to prioritize the potential transfer methods deployed by the agricultural extension delivery system in Tunisia.

The second objective of this research was focusing on assessment of the farmers' perceptions of the improved technologies introduced by the project in the examined sample. Data collection implemented during 2016–2018, contained the opinions of 671 farmers about the following technologies: barley variety Kounouz (hereon termed 'Kounouz') and feed blocks. The interviewed farmers were subdivided into three categories: those who had used some of these technologies for years (termed 'actual users'); those who knew about the technologies but had no interest in using them (termed 'non-users'); and those who planned to use the new technologies (termed 'potential users', because they may decide to use the technologies once constraints hindering their use are overcome). The reasoning behind this disaggregation was to define the level of change due to the adoption. The level of adoption depended, by hypothesis, on the nature of the technology (i.e., the level of change perceived by

Kounouz users, non-users, and potential users on yield, drought, marketability, market price, and appetence, good growth, and health of animals).

The questions asked placed emphasis on establishing the main factors influencing the adoption of the technologies in terms of access, knowledge need, adoption cost, and labor intensity for adoption.

The interviewed farmers provided their opinions on the influence of these technologies, their advantages and limitations on yield, drought resistance, and price from a list, which included a range of 1–7 possible changes (in function of the target technology). To assess the perceived opinions and classify the changes from the use of the corresponding technologies, the Stapel scale was used [11]. This is a unipolar (one adjective) rating scale designed to measure the respondent's attitude toward the object or event. The scale comprises 10 categories ranging from −5 to +5 without any neutral point (zero). In this case, if there are no changes or the change in insignificant compared to the existing conventional farming use of the technology, 0 is adopted. The negative numbers reveal a decrease; and the positive ones suggests an increase in the perception attitude [11]. An ANOVA was deployed to investigate the differences between average values of the groups of farmers (users, non-users, and potential users). Therefore, to establish the correlation between the adoption of the mentioned technologies and some important characteristics about the perceived potential performance of these technologies among smallholders, cross-table analyses using Cramer's V-values and their significance level were examined.

3. Results and Discussion

3.1. Socioeconomic Characteristics of Smallholder Farmers in the Examined Sample

The sample population was mainly composed of male HHs (93.6%) while female HHs represented about 6.4% (Table 2). Most study participants were married (91.3%), only 6% of the interviewees possessed an agricultural diploma, while about 94% were without any formal diploma. The average age of the HHs was quite high (56 years), with at least 74% of the surveyed farmers older than 46 years. It is also worth noting that only around five farmers were aged less than 25 years.

Table 2. Descriptive statistics of the survey.

Variables	Frequency	Percentage
Sex of household head (HH)		
Male	628	93.6
Female	43	6.4
Marital status of HH		
Married	609	91.3
Single	27	4.0
Divorced	4	0.6
Widow(er)	27	4.0
Agricultural diploma for HH		
Yes	40	6.0
No	631	94.0
Age of HH (years)		
26 or less	5	0.74
26–35	46	6.85
36–45	121	18.03
46–55	167	24.88
56–65	185	27.57
65 or above	147	21.90

Table 2. *Cont.*

Variables	Frequency	Percentage
Land holding (ha)		
Less than 6	454	67.66
6–10	132	19.70
11–20	59	8.81
More than 20	26	3.88
Years of HH schooling		
6 or less	548	81.72
7–12	88	13.09
13 or above	35	5.18
Household size		
2 or less	78	11.71
2–5	318	47.43
6–8	235	35.00
9 or above	39	5.85
Farm labor contribution of HH		
Part-time	297	44.39
Full-time	356	53.13
Does not work on farm	18	2.47
HH experience in agriculture (years)		
10 or less	42	6.22
11–20	95	14.18
21–30	159	23.73
31 or above	375	55.86
Off-farm income		
Yes	333	49.71
No	338	50.29

Source: Analysis of field data, 2019.

An overwhelming majority of respondents (67.66%) were smallholders (farm size 0–5 ha), with the mean farm size being 4.56 ha. From a total of 671surveyed individuals, at least 81.72% had less than 6 years of schooling, while 13.09% and 5.18% of them had attained secondary and university education levels, respectively (Table 2).

The average household size was five people and 47.43% of the respondents were in charge of about 2–5 persons. The results further indicate that 35% and 5.85% of the respondents were in charge of 6–8 members and nine members or above, respectively. About 53.13% of the sample were fully dedicated to farming activities, and 44.39% were dedicated to farming activities on a part-time basis. Of the interviewed farmers, 55.86% had 31 or more years of experience in farming and only 6.22% had less than 10 years of experience. About 49.71% of the farmers obtained a great portion of farm household income off the farm, including non-farm wages and salaries, pensions, and interest on income earned by farm families.

3.2. Sources of Information on Improved Agricultural Technologies

Several extension methods have been used to transfer agricultural and livestock technologies with varying strengths and weaknesses according to the technology characteristics [12]. For this study, two potential improved technologies were examined for their influence on the livelihood of farmers and their advantages in increasing smallholder farmer production capacities. Participants could choose their opinions about the effective information source for these technologies from a list, which included eight possible sources of information. Recent literature reviews and development projects suggest that mass media and information and communication technologies (ICT) are widely recommended for raising awareness, enhancing knowledge, and consequently contributing to the development of potential positive impact on farmers' livelihoods and wellbeing in a short period of time [13].

A high proportion of respondents (74.4%) received information on Kounouz from agricultural extension agents (Table 3). This was not surprising given the importance of the public extension system and its contribution to the diffusion of this new variety, among other interventions. In support of the current study's findings, Gaaya [14] argued that both individual and group extensions were more efficient methods for enhancing skills and learning information about agricultural approaches.

Table 3. Potential information sources of the two introduced agricultural and livestock technologies to smallholder farmers in Tunisia.

Source of Information [a]	Source Frequency (YES)	Percent
Crop technologies *Kounouz (n = 469)*		
Market (agrovet/stock agent)	24	5.11
Other farmers (neighbors/relatives)	30	6.39
SMS-extension (text message)	61	13.00
Extension staff/office	349	74.41
Other sources (e.g., NGOs [b], own experience, radio program/TV)	5	1.06
Feeding technologies *Feed blocks (n = 354)*		
Market (agrovet/stock agent)	33	9.32
Other farmers (neighbors/relatives)	44	12.43
SMS-extension (text message)	41	11.58
Extension staff/office	232	65.53
Other sources (e.g., NGOs, own experience, radio program/TV)	4	1.13

[a] This was multiple-response, so farmers were allowed to choose as many as applied to them. Source: Author's elaboration from analysis of field data, 2019. [b] NGO represents non-governmental organizations.

The national extension staff, in cooperation with researchers from the National Agronomic Research Institute of Tunisia (INRAT), used the potential lead-farmers (PLF) extension approach, where they are involved in maintaining and managing several experiments on the use of Kounouz, set out by researchers on their own farms. Field days were organized by the mentioned stakeholders for communicating information on this relevant technology. The national extension staff, other farmers, ICT, and input markets were observed to be the most reliable sources of information on feed block technology (Table 3). Of the respondents, 65.53%, 12.43%, and 11.58% considered these sources of information as critical regarding feed block technology (Table 3).

Empirical findings revealed an acceptable agreement strength (W) of 0.451, which was statistically significant at 1%, leading to a rejection of H_0 (null hypothesis) that there was no concordance among participants on the source of information. The national extension staff were ranked first (1.89) as the potential information source by the smallholder farmers in the project intervention area (Table 4). This was followed by information from agricultural input markets. Colleagues and neighboring farmers, and the farmer's own experience came third and fourth with mean ranks of 3.12 and 4.45, respectively.

Similar results were found by Al-Rimawi et al. [15] in Jordan, National Agriculture and Livestock Extension Policy (NALEP) [16] in Kenya, and Khan and Akram [17] in Pakistan. These previous studies report that farm visits, demonstrations, and field days hosted by extension workers received high ranking positions. Kingiri and Nderitu [18] argue that providing direct personal attention to farmers is a major advantage to adopting new technology as it tends to provide clear guidance to meet farmers' specific needs. Such face-to-face meetings facilitate a dialog in which extension agents learn from the farmers and share information, experiences, and knowledge [18]. These results confirm the importance and farmers' trust of the national extension system as a potential source of information for improved and new agricultural technologies. In this sense, the Tunisian Agricultural Extension System (TAES) has been in existence for decades and is elaborate in its contents and coverage. It covers a wide range of functions, regions and activities, using large quantities of both written and audiovisual extension material to convey messages to farmers. While elaborate in its administrative structure, the TAES is nevertheless elementary in its conceptual nature and has a number of limitations that are inherent to the nature of the agricultural activities themselves. Indeed, its level of efficiency was estimated at 36%. These limitations include: a lack of information on rainfall dependence, marketing channel functioning and power; the scattered nature of farms across different climatic regions; and the limited size of these farms.

Table 4. Kendall's W-test findings of potential information sources on the two introduced agricultural and livestock technologies to smallholder farmers in Tunisia.

Source of Information	Mean Rank	Standard Deviation	Minimum	Maximum	Ranking
Extension staff/office	1.89	0.95	1	4	1
Other farmers (neighbors/relatives)	3.12	0.88	1	4	3
Market (agrovet/stock agent)	2.89	0.97	1	4	2
Own experience	4.45	0.41	1	4	4
n			603		
Kendall's W [a]			0.451 ***		
Chi-square			1086.842		
df			4		

The ranking was 1–5, with 1, the most significant in terms of importance, and 5, the least significant. The mean was measured on a four-point scale. Rank 4 was the most effective information source for crops and livestock production and rank 1, the least effective. [a] Kendall's coefficient of concordance. Asterisks indicate significance at: *** 1%; ** 5%; and * 10%; Source: Author's elaboration from analysis of field data, 2019.

3.3. Results from Smallholder Farmers Attitudes toward the Potential Effective Technology Transfer Models

The study identified eight technology transfer methods: technical training on Kounouz, technical training on feed blocks, field visits to a barley farm, field visit to the INRAT demonstration farm, information sessions on Mutual Society of Agricultural Services (SMSA), visits to a SMSA, economic training, and farmer business schools.

The coefficient of concordance (W) was estimated at 0.208 and statistically significant at 1%, indicating no agreement among the farmers (Table 5). Hence, the null hypothesis was rejected in this instance.

Table 5. Kendall's W-test findings of the effectiveness of agricultural technology diffusion model on the two introduced agricultural and livestock technologies to smallholder farmers in Tunisia. National Agronomic Research Institute of Tunisia (INRAT), and Mutual Society of Agricultural Services (SMSA).

Technology Transfer Methods	Mean Rank	Standard Deviation	Minimum	Maximum	Ranking
Technical training on Kounouz	5.73	1.25	1	5	8
Technical training on feed blocks	3.19	1.59	1	5	1
Field visit at barley farm	4.99	1.25	1	5	7
Field visit to INRAT demonstration farm	4.57	1.42	1	5	5
Information session on SMSA groups	3.90	1.49	1	5	3
Visiting a SMSA	3.80	1.51	1	5	2
Economic training	5.34	1.37	1	5	6
Farmer business schools	4.48	1.50	1	5	4
N			603		
Kendall's W [a]			0.208 ***		
Chi-square			80.011		
Df			7		

The ranking was 1–8, with 1 the most efficient and 8 the least efficient ranking. The mean was measured on a five-point Likert scale. Rank 5 was most effective technology transfer method and rank 1 was the least effective. [a] Kendall's coefficient of concordance. Asterisks indicate significance at: *** 1%; ** 5%; and * 10%; Source: Author's elaboration from analysis of field data, 2019.

Technical training on feed blocks was ranked as the most reliable agricultural technology transfer method (3.19) within the assessed technology transfer methods. The second agriculture transfer method ranked by farmers was visiting a SMSA, with mean rank of 3.8. The information session on functioning of a SMSA was ranked at the third level with a mean of 3.9.

The farmer business schools came at the fourth level (mean rank = 4.48). By using this extension strategy, small-holder farmers received business information from the members of households who had used the technologies under consideration in this study. Anandajayasekeram et al. [19] indicated that farm field business schools are a useful transfer method for diffusion of new or improved agricultural technologies in Eastern and Southern Africa. Their use as an extension transfer method generated and produced decent results in terms of income improvement. Therefore, it should be considered as a complementary method to the existing extension system methods as some of its components and principles could be merged into agricultural extension. This is with the purpose of becoming more reliable at reaching marginalized small farm communities. Economic training, field visits to barley farms and technical training on Kounouz were the least ranked with sixth, seventh, and eighth positions, respectively. These results suggest that training on management of a new barley variety is not on a priority for these farmers. This could be explained by the fact that farmers are well experienced in management practices related to barley.

3.4. Efficacy of Agricultural and Livestock Technologies Diffusion Methods

The following section deals with results from the perceived evaluation of the efficacy on the diffusion methods deployed to project regarding the two introduced agricultural and livestock technologies from the small-holders perspective. To this effect, a five-point Likert scale method was used (5 being the most efficient and 1, the least efficient). The calculated mean values indicate the weight of the perception by farmers about a particular technology transfer method (Table 6).

Table 6. Perceived effectiveness of the agricultural technology transfer methods on improved agricultural and livestock technologies for smallholder farmers in Tunisia.

Technology Transfer Methods	*n*	Mean	Standard Deviation	Ranking
Technical training on Kounouz	306	3.49	1.34	4
Technical training on feed blocks	263	2.84	1.43	8
Field visit at barley farm	233	3.53	1.30	3
Field visit to the INRAT demonstration farm	152	3.54	1.41	2
Information session on SMSA groups	153	3.19	1.43	6
Visiting a SMSA	120	2.95	1.54	7
Economic training	149	3.65	1.35	1
Farmer business schools	134	3.47	1.40	5

n = 55. The mean figures are measured using a five-point Likert scale. The ranking was 1–8, with 1, the most important and 8, the least important. Source: Author's elaboration from analysis of field data, 2019.

The findings displayed in Table 6 reveal that all the extension methods used by the project had more than a 50% perception index in influencing smallholder farmers to adopt the two introduced technologies. It appears also from the analysis that the economic training extension method (with a mean value of 3.65) was perceived as the most effective method to enhancing adoption of the two technologies.

3.5. Adoption of Agricultural and Livestock Improved Technologies in the Examined Sample

To understand the adoption trend of the improved agricultural and livestock technologies, we divided the database into three subsamples taking into consideration the category of the technology used: users, non-users, and potential users. Kounouz was used by 40.8% of the interviewed farmers, and 29.1% were non-users. The use of this technology is promising in the future because about 53.1% of the interviewed farmers were potential users of Kounouz in their cropping systems (Table 7).

Table 7. Basic information about the adoption of improved agricultural and livestock technologies by smallholder farmers in Tunisian arid areas.

Agricultural and Livestock Technologies	Non-Users	Users	Potential Users
Kounouz	195 (29.1%)	274 (40.8%)	356 (53.1%)
Feed blocks	336 (50.1%)	18 (2.7%)	104 (15.5%)

Frequencies are in parentheses. Source: Author's elaboration from analysis of field data, 2019.

The feed block technology had a low proportion of users, with only 2.7% of interviewed farmers using this technology and almost 15.5% planning to apply it in the future. Feed blocks are currently used as an alternative feed supplement for small ruminants and can be used as replacements for costly imported concentrate feed. Therefore, potential adoption of this technology looks limited due to inaccessibility of the technology, its adoption cost, and limitations to its use.

Using cross-table analysis, the relationship between adoption of improved agricultural and livestock technologies by smallholder farmers and some important details about performance of the technologies was examined. Four factors were considered as potential drivers influencing the adoption of the target technologies: access to technology, necessity of having knowledge about technology, adoption cost of technology, and labor intensity for adoption. Empirical findings from the cross-table analysis are displayed in Table 8.

Table 8. The relationship between the adoption of improved agricultural and livestock technologies by smallholder farmers in Tunisia.

Factors Influencing Adoption of Agricultural and Livestock Technologies	Uncertainty Coefficient Value	Cramer V-Value	Strength of Relation
Technology 1: Kounouz			
Access to technology	0.419 ***	0.764 ***	Very large
Necessary knowledge about technology	0.405 ***	0.758 ***	Very large
Adoption cost	0.440 ***	0.757 ***	Very large
Labor intensity for adoption	0.395 ***	0.753 ***	Very large
Technology 2: Feed blocks			
Access to technology	0.491 ***	0.735 ***	Very large
Necessary knowledge about technology	0.485 ***	0.720 ***	Very large
Adoption cost	0.523 ***	0.732 ***	Very large
Labor intensity for adoption	0.486 ***	0.723 ***	Very large

Note: Asterisks indicate significance at: *** 1%; ** 5%; and * 10%; Source: Author's elaboration from analysis of field data, 2019.

The cross-table analysis showed that all four considered factors had significant effects on adoption of agricultural production and livestock farming technologies. The adoption of Kounouz and feed blocks depended on the four factors outlined above with moderate and significant uncertainty coefficient values, and significant and high Cramer V-values. Empirical findings suggest statistically significant correlations between the adoption of feed block technology and the four key influential factors. According to the survey of farmers, all target technologies were adopted by smallholder farmers but with different adoption degrees, depending on the magnitude of the indicated influencing factors.

3.6. Opinion of Farmers about Effects of Improved Agricultural Technologies

As based on the theoretical literature review, the advantages of using these improved technologies depend on the characteristics of the considered/improved technology. For Kounouz, the advantages are the following: higher yields, resistance to drought, marketability, good prices received in the market, acceptance by animals, and being good for animal growth and health. Thus, the interviewed farmers could voice their opinions about the positive or negative changes resulting from adoption of Kounouz using the Stapel scale. There were significant differences among opinions of the interviewed subsamples (users, non-users, and potential users) concerning only yield, resistance to drought, and appetence for this crop by animals (Table 9 and Figure 2).

Table 9. Results from the three subsample opinions on the changed results in smallholder farmers adopting the two improved agricultural and livestock technologies.

The Most Important Effects of Improved Technology	Users		Potential Users		Non-Users	
Technology 1: Kounouz	**Average (*n* = 274)**	**Rank**	**Average (*n* = 356)**	**Rank**	**Average (*n* = 195)**	**Rank**
Yield change ***	3.59	1	4.19	1	3.63	1
Drought resistance ***	3.27	2	3.96	2	3.77	2
Marketability/demand	−0.73	6	−0.97	6	−1.07	4
Price received at the market	−0.77	5	−1.00	5	−1.43	3
Appetence of animals *	1.36	3	1.62	3	0.92	5
Good growth of animals	1.10	4	1.22	4	0.31	7
Good animal health	0.39	7	0.42	7	−0.33	6
Technology 2: Feed blocks	**Average (*n* = 18)**	**Rank**	**Average (*n* = 104)**	**Rank**	**Average (*n* = 336)**	**Rank**
Appetence of animals ***	1.66	1	0.65	2	−1.04	1st
Good growth of animals *	−0.29	2	1.50	1	−0.139	3
Good animal health	−0.29	2	0.28	3	−0.45	2

Note 1: large-scale increase, +5; large-scale decrease, −5; maintaining conventional farming, 0. Note 2: The results between the different subsamples are statistically significant according to ANOVA. Asterisks indicate significance: *** 1%; ** 5%; and * 10%; Source: Author's elaboration from analysis of field data, 2019.

According to the results displayed in Figure 2, the main benefits of the Kounouz varietal are higher yields (66.7% of HH) and drought resistance (49.3% of HH). Nearly 5.1% of HH stated the appetence for animals and 5.1% declared the good growth of animals as benefits of the Kounouz varietal.

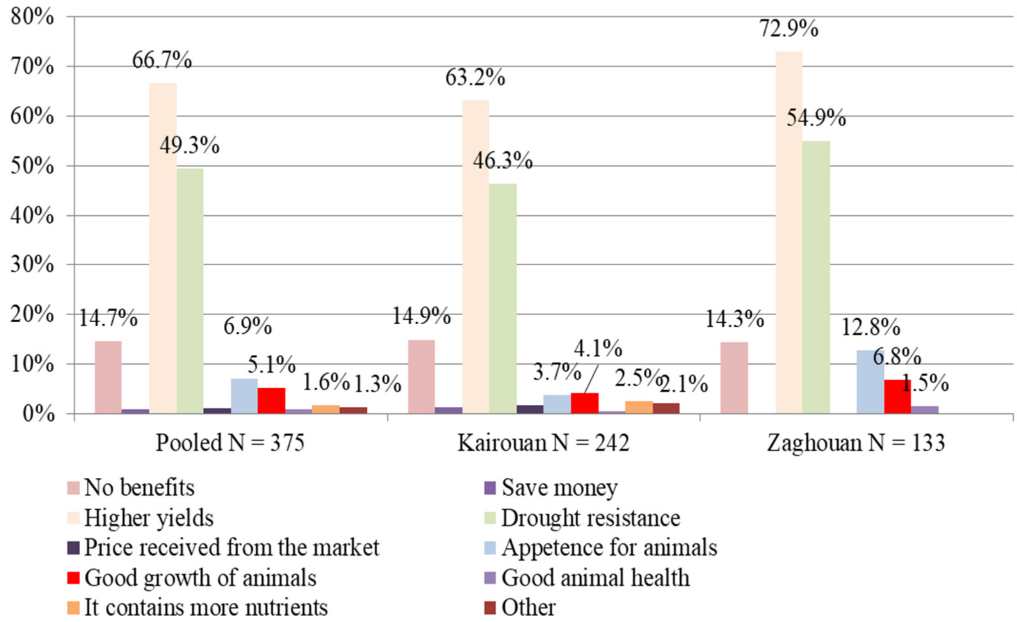

Figure 2. Benefits of Kounouz variety by governorate, %.

The ranking of the effects of introduction of Kounouz clearly showed that yield and resistance to drought were important limiting or non-limiting factors for the three categories (Table 9). Moreover, the most remarkable differences were in appetence and good growth of animals, according to the opinions of adopters of Kounouz. The ANOVA showed significant differences among opinions of the interviewed subsamples (Table 9). This is reasonable given the positive effect of the two technologies on increasing yield for smallholders.

For the feed block technology, three possible advantages were assessed: appetence of animals, good growth of animals, and being good for animal health (Table 9 and Figure 3). Figure 3 shows the benefits of the use of feed blocks. In Zaghouan, the majority of HH (79.8%) reported that they observed no benefits in the use of feed blocks. However, only 6.5% of HH mentioned that there was good growth of animals due to the nutrients provided by the feed blocks. In Kairouan, the major benefits of the use of feed blocks were; good growth of animals (19.6% of HH), the appetence by animals (10.6% of HH), more nutrients (7.3% of HH), saved money (5.6% of HH) and also saved labor (5% of HH).

The ANOVA statistical analysis showed significant differences among the opinions of users, non-users, and potential users of this technology regarding its appetence by animals and, with a lower level of significance, on its contribution to good growth of animals. In the survey, appetence by animals was ranked first by users and potential users of this technology. According to farming potential users, this advantage was in second place. The advantage of good growth of animals was placed second by users of feed block technology while non-users ranked good growth of animals in third place.

The results further highlight that the biggest problem with introduced technologies is that adoption of the technology greatly depends on the knowledge, perception, and attitude of the end users as well as the characteristics of the technology. This is why farmers sometimes think that investment in such technologies will not have the expected advantages, leading to them not adopting any introduced technologies, as was the case with the feed blocks.

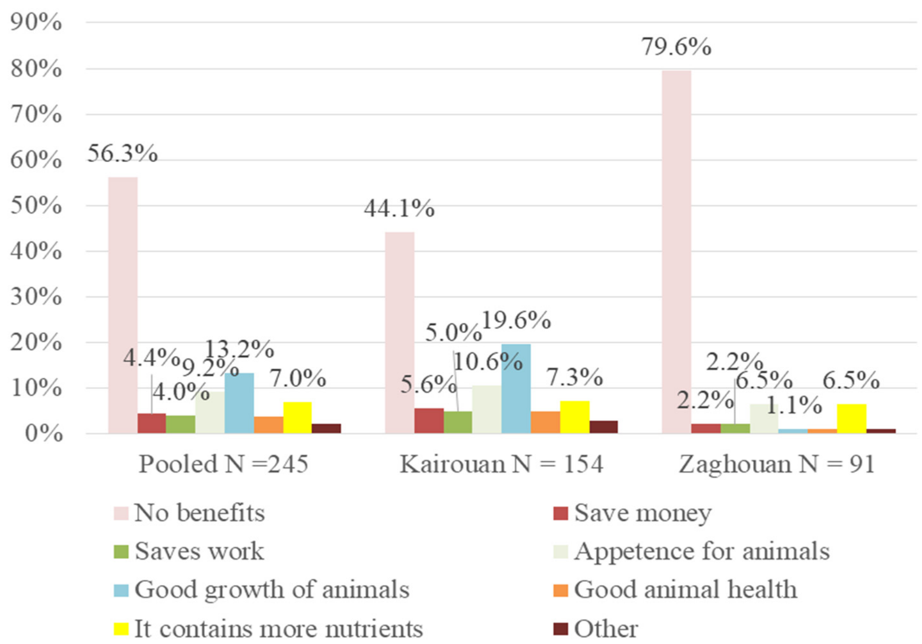

Figure 3. Benefits of the use of feed blocks by governorate, %.

4. Concluding Remarks and Practical Implications

In this study, we assessed the sources of information on two improved agricultural technologies (barely variety and feed blocks) as well as its potential diffusion methods in Tunisian semi-arid areas.

One of the biggest challenges facing smallholder farmers in dryland areas is not how to increase production overall but how to enable increased production within their limited resources, both financially and naturally. The "Mind the Gap" project in Tunisia set out to address this gap through introducing two technologies, Kounouz and feed blocks, and then testing various agricultural technology transfer methods aimed at enhancing adoption of these technologies.

Although information transfer strategies have been motivated to improve new technology adoption by smallholder farmers, the adoption rate of the two technologies remains significantly low, and consequently affects farm economic sustainability and performance. This is despite widespread evidence of economic and environmental benefits associated with these technologies and the cost-effectiveness of its diffusion models introduced by the project.

Furthermore, knowledge may be an important variable, but how farmers receive information from different sources has a more significant effect on adoption than just mere knowledge acquisition [20]. Agricultural extension (through different channels and methods) is the basis of the transfer of agricultural technologies to farmers [21] and, consequently, the persuasion of farmers to adopt agricultural techniques [22]. Therefore, combining the impact of different dissemination methods on adoption may sometimes be misleading since the actual impact and magnitude of each method may not be assessed clearly.

There is an urgent need to move away from the model of scientists largely determining research priorities, developing technologies in controlled conditions, and then handing them over to agricultural extension departments for transfer to farmers [23]. Such technology transfer approaches need to adopt more flexible and adaptable strategies which meet the needs of a high population of resource-poor smallholder farmers. Such strategies may be through, for example, regular extension programs, on-farm trials, and methods that encourage and enable smallholder farmers to directly identify what is ideal to improve their production base and resource accumulation. In addition, the recent rapid spread of ICT in developing countries, such as mobile phone coverage, offers a unique opportunity to transfer knowledge via private and public information systems [11,24].

Although new technologies and information transfer strategies have been motivated to improve smallholder farmer production levels, there is still a need for rigorous impact evaluations of such strategies to measure their impact on farmers' knowledge, adoption, and welfare, as well as the cost-effectiveness of such services [25]. This will be important in supplying information to farmers on a variety of topics and at various stages, before a new technology is assumed to be adopted [26].

With the purpose of satisfactorily meeting the demands and expectations of the different stakeholders and partners in an extension model, there is a need to review, address, and adapt extension approaches in response to changes that influence effective service delivery and policy priorities [27]. These changes include increasing pressure on government budgets, increased environmental and social concerns, the emergence of new communication technologies, and the strengthening of the private sector. To meet these challenges and to adapt, there will be a need for the following: building on existing extension structures and strengths in different locations within the country; establishing new programs in ways that explicitly recognize the experimental nature of the reform and change process; recognizing the value of diverse approaches to farming activities; and reforming strategies and arrangements with partnerships and different stakeholders.

In our case study, the technology-led extension approaches, particularly using text messages, were considered as complementary and not an alternative to the conventional face to face extension approaches. The text message is a technology newly introduced to farmers that requires more time for widespread adoption.

Finally, in order to improve adoption of Kounouz, as well as of other barley varieties, and feed blocks in the study area, and in similar agro-ecological contexts the following should be addressed:

- Government should understand what knowledge and attitude farmers have in relation to these technologies and how such technologies are introduced to them. Then, agricultural policy can redesign these technologies (i.e., feed blocks and substitute with pellets) to the preferences and specific conditions of farmers for better adoption and sustainability.
- It was clear that the effectiveness of a training program depends not only on the number of farmers that receive information, but also on how successful that approach is towards influencing farmers' decisions to adopt a given technology. This highlighted the need for empowerment of the Tunisian extension system in various ways First, by training farmers through both conventional (i.e., demonstration fields, economic training, and organizational training) and non-conventional (ICT, video, and mobile phone) methods. Second, strengthening local extension by strengthening the human and material resources of the national extension system and also by investing in new technologies considered to be cost effective with a clear impact on the adoption decisions of farmers. Thus, to enhance attendance of project farmers at training, some recommendations are proposed:
    - ○ Choosing the right training method and period (avoid the harvest period),
    - ○ Strengthening the material and human resources of extension agents to facilitate the methods for inviting farmers.

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Appendix A

Table A1. Trainings components applied under the differents randomized control trials (RCT) treatements.

		Trainings Components
Technical Training	1.1	1 day training:
		-Presentation on feedblocks by Office de l'Elevage et des Pâturages (OEP) and ICARDA
		-Presentation on Konouz by INRAT and OEP
		-Theoretical and practical training on Melovine by OEP
		-Field visit to see Kounouz at ripening stage at an INRAT field station
	1.2	1 day follow-up training:
		-Demonstration of feeding with feed blocks
		-Verbal refreshing of all three technologies (feed blocks, Kounouz, and Melovine)
	1.3	1 day field visit to farmer who has planted Kounouz during last season
	1.4	1 day field visit to INRAT demonstration farm for Kounouz
	1.5	Regular text messages:
		-On technical issues in livestock management and barley
		-On when, where and for what price a farmer can purchase the promoted technologies
Economic & Organizational Training	2.1	1 day organizational training:
		-Direction Générale du Financement des Investissements et des Organismes Professionnels (DGFIOP), Agence de la Vulgarisation et de la Formation Agricoles (AVFA), and ICARDA
		-Focus on benefits of farmer organizations (better input and output prices), examples from other countries given, supported technologies were presented as examples (e.g., cheaper access to seeds & marketing)
	2.2	1 day organizational training follow-up
		-Creation process of farmer organizations (Sociétés Mutuelles de Services Agricoles –SMSA) and Groupement de Développement Agricole (GDA) and the administrative procedures
	2.3	1 day visit to cooperative/farmer group
	2.4	1 day economic/financial training
		-General theoretical lesson (with training sheet to determine cost of production)
	2.5	1 day economic/financial training follow-up/coaching
	2.6	5 days Farmer Business Schools (FBSs)
Female Empowerment	3.1	3 days BUS 1 (Female Empowerment)
		-Implemented/supervised by AVFA
		-Self-esteem and personal development
	3.2	3 days BUS 2
		-Develop specific business ideas for each participant
		-In some cases, OEP staff mentioned how barley and feed blocks could be used to develop businesses (<30 min)
	3.3	1 day sensibilization on credit
		-Presentation by AVFA
		-Presentation of certified technical training options (provided by AVFA) which are required by the financial service providers to obtain credit
		-Obtaining credit and subsidies through the Agence de Promotion et des Investissements Agricoles (APIA) and the Banque Nationale Agricole (BNA), and NGOs
		-Identification of women's technical training interests
	3.4	1-day visit of female cooperative/farmer group

Table A2. Baseline Characterization.

Modules	Definition of the Module
Module O	Identification of the household
Module A	Household demographic data
Module B	Characteristics of the main house
Module C	Household assets
Module D	Land owned per hectare
Module E	Crop management and input use
Module F	Livestock possession and marketing
Module G	Livestock technology
Module H	Livestock alimentation
Module I	Technology awareness and uptake
Module J	Technology perception
Module K	Social networks
Module L	Other sources of income and transfer
Module M	Non-food expenditure
Module N	Access to socioeconomic infrastructure
Module O	Shocks
Module P	Day food recall

References

1. Collier, P.; Dercon, S. African agriculture in 50 years: Smallholders in a rapidly changing world? *World Dev.* **2014**, *63*, 92–101. [CrossRef]
2. Pretty, J.; Toulmin, C.; Williams, S. Sustainable intensification in African agriculture. *Int. J. Agric. Sustain.* **2011**, *9*, 5–24. [CrossRef]
3. Piesse, J.; Thirtle, C. Agricultural R&D, technology and productivity. *Philos. Trans. R. Soc. B* **2010**, *365*, 3035–3047.
4. Bozeman, B. Technology transfer and public policy: A review of research and theory. *Res. Policy* **2000**, *29*, 627–655. [CrossRef]
5. Chebbi, H.E. Agriculture and economic growth in Tunisia. *China Agric. Econ. Rev.* **2010**, *2*, 63–78. [CrossRef]
6. Chebbi, H.E.; Marcelo, O.; Habib, Z. Agricultural trade balance and exchange rate depreciation: The case of Tunisia. In *Economic Research Forum*; Working Papers; ERF: Tunis, Tunisia, 2011; No. 610.
7. Gil, J.M.; Ben Kaabia, M.; Chebbi, H.E. Macroeconomics and agriculture in Tunisia. *Appl. Econ.* **2009**, *41*, 105–124. [CrossRef]
8. Miller, R.L.; Cox, L. Technology transfer preferences of researchers and producers in sustainable agriculture. *J. Ext.* **2006**, *44*, 145–154.
9. Corder, G.W.; Foreman, D.I. *Nonparametric Statistics for Non-Statisticians: A Step-by-Step Approach*; John Wiley & Sons Inc.: Hoboken, NJ, USA, 2009.
10. Kendall, M.G.; Babington, B.S. The problem of m rankings. *Ann. Math. Stat.* **1939**, *10*, 275–287. [CrossRef]
11. Sajtos, L.; Mitev, A. *SPSS KutatásiésAdatelemzésiKézikönyv*; AlineaKiadó: Budapest, Hungary, 2007.
12. Aker, J.C. Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agric. Econ.* **2011**, *42*, 631–647. [CrossRef]
13. Azumah, S.B.; Donkoh, S.A.; Awuni, J.A. The perceived effectiveness of agricultural technology transfer methods: Evidence from rice farmers in Northern Ghana. *Cogent Food Agric.* **2018**, *4*, 1–11. [CrossRef]
14. Gaaya, A. Extension education in agricultural and rural development: Role of international organizations—The FAO experience. In *Cahiers Options Méditerranéennes*; Plaza, P., Ed.; Centre International de Hautes Etudes Agronomiques Méditerranéennes (CIHEAM): Montpellier, France, 1994; pp. 33–45.
15. Al-Rimawi, A.; Tabieh, M.; Al-Qudah, H. Assessing growers' perceptions of effective extension methods and information communication technologies for training vegetable growers in Jordan. *Int. J. Econ. Financ.* **2016**, *8*, 229–236. [CrossRef]
16. NALEP. *A Guide to Effective Extension Methods for Different Situations*; National Agriculture and Livestock Extension Program (NALEP), Government of South Sudan: Juba, Sudan, 2011.

17. Khan, A.; Akram, M. Farmers perception of extension methods used by extension personnel for dissemination of new agricultural technologies in Khyber Pakhtunkhwa Pakistan. *Sarhad J. Agric.* **2012**, *28*, 511–520.
18. Kingiri, A.; Nderitu, S. *Assessment of Extension and Advisory Methods and Approaches to Reach Rural Women (Examples from Kenya)*; USAID, Modernizing Extension and Advisory Services (MEAS): Nairobi, Kenya, 2014.
19. Buyinza, F.; Tibaingana, A.; Mutenyo, J. *Factors Affecting Access to Formal Credit by Micro and Small Enterprises in Uganda*; ICAE Working Paper Series; ICAE: Linz, Austria, 2018; Available online: https://www.jku.at/fileadmin/gruppen/108/ICAE_Working_Papers/wp83.pdf (accessed on 25 September 2019).
20. Anandajayasekeram, P.; Puskur, R.; Sindu, W.; Hoekstra, D. *Concepts and Practices in Agricultural Extension in Developing Countries: A Source Book*; IFPRI (International Food Policy Research Institute): Washington, DC, USA; ILRI (International Livestock Research Institute): Nairobi, Kenya, 2008.
21. Mauceri, M.; Alwang, J.; Norton, G.; Barrera, V. Adoption of integrated pest management technologies: A case study of potato farmers in Carchi, Ecuador. In Proceedings of the American Agricultural Economics Association Annual Meeting, Providence, RI, USA, 24–27 July 2005.
22. Thabet, B.; Dhehibi, B.; Kassam, S.; Aw-Hassan, A. Good intensions and hard realities: Achievements and challenges in agricultural extension systems in Tunisia. *Int. J. Agric. Ext.* **2015**, *3*, 209–216.
23. Chambers, R.; Jiggins, J. Agricultural research for resource-poor farmers Part I: Transfer-of-technology and farming systems research. *Agric. Adm. Ext.* **1987**, *27*, 35–52. [CrossRef]
24. Berger, T. Agent-based spatial models applied to agriculture: A simulation tool for technology diffusion, resource use changes and policy analysis. *Agric. Econ.* **2001**, *25*, 245–260. [CrossRef]
25. Nakasone, E.; Torero, M.; Minten, B. The power of information: The ICT revolution in agricultural development. *Annu. Rev. Resour. Econ.* **2014**, *6*, 533–550. [CrossRef]
26. Vanloqueren, G.; Baret, P.V. How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations. *Res. Policy* **2009**, *38*, 971–983. [CrossRef]
27. Elias, M.; Hensel, O.; Richter, U.; Hülsebusch, C.; Kaufmann, B.; Wasonga, O. Land conversion dynamics in the Borana Rangelands of southern Ethiopia: An integrated assessment using remote sensing techniques and Field Survey Data. *Environments* **2015**, *2*, 1–31. [CrossRef]