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Cédric Gaillard, Pierre-Marie Bosc, Jalila El-Ati, Sandrine Dury. Pathways leading women in farming households to food security: an empirical study in Central Tunisia. *Review of Agricultural, Food and Environmental Studies*, 2022, 103 (1), pp.51-76. 10.1007/s41130-022-00167-1 . hal-04036778

HAL Id: hal-04036778

<https://hal.science/hal-04036778v1>

Submitted on 20 Mar 2023

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Pathways leading women in farming households to food security: an empirical study in Central Tunisia

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Received: 22 February 2021 / Accepted: 21 February 2022 / Published online: 17 March 2022
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Abstract

This paper examines the complex relations between farm, household and individual characteristics with the food insecurity of women living in the rural area of Sidi Bouzid, cradle of the 2010 Jasmine Revolution in Tunisia. According to the Individual Food Insecurity Index and based on a survey of 290 women living in farming households, more than 40% of women in the area reported experiencing some form of food insecurity. The results of econometric models have highlighted that an increase in farm production is essential but will not allow women to sufficiently reduce the food insecurity risks they face. Women's individual factors, describing their labour and income, play a fundamental role in this process. Women working and earning an income from agriculture, on and off the family farm, were more often food insecure than other women. Generating non-agricultural income reduced their exposure to food insecurity. Moderate and severe insecurity risks were also reduced by household-level factors, such as access to off-farm income by family members other than women.

Keywords Food security · Family farm · Tunisia · HFIAS · Women's empowerment

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Introduction

The persistence of hunger in the world means that ensuring adequate and nutritious food for the population will remain the principal challenge facing policy makers in many developing countries in the years to come. Public policy approaches to food security have evolved in recent years and now consider the availability of food, people's physical and economic access to food, the stability of food supplies and the use of food through adequate nutrition and food sanitation. Agriculture remains at the heart of this multidimensional approach. Farming households, which account for 63% of the world's 1.2 billion poor people (Olinto et al., 2013), are the first to be at risk of food insecurity while playing an essential role in the supply of food products (HLPE, 2013).

Several micro-economic studies on farm households have been conducted to characterise and assess the links between their resources, their strategies to mobilise these resources and their food and nutritional security. Studies examining the relationship between agricultural production and nutrition outcomes across countries in sub-Saharan Africa and South Asia (Carletto et al., 2015; Omotesho et al., 2016; Mitiku et al., 2012; Sidhu et al., 2008) support the hypothesis that agricultural production in a farming household has direct and important links with the dietary pattern and food security of each of its members. So, increases in production encourage the consumption of healthy food groups (Dillon et al., 2015) or lead to a better nutritional status (Slavchevska, 2015). Similarly, the role of farm production factors (capital and labour) in the improvement of food security has been highlighted in different African contexts where farming households with access to good quality agricultural land or livestock (Muhoyi et al., 2014), to an irrigation system (Nkhata, 2014) or motorised equipment (Sohoulande Djebou et al., 2017) or a greater labour force (Agidew & Singh, 2018), are more likely to be food secure than their counterparts. However, other results have shown that an increase in per capita aggregate production is not necessarily translated into food security at the household level (Feleke et al., 2005) and a review of the literature has underlined the fact that some agricultural interventions and higher production levels might have negative impacts on nutrition outcomes (Dury & Bocoum, 2012; Dury et al., 2015), for example by favouring a move from a diversified subsistence system to specialised cash crop farming.

Other non-agricultural factors describing household resources play a role in the pathway to food and nutrition security. Some authors have shown that food security strategies should consider the socio-economic characteristics of households (Maharjan & Khatri-Chhetri, 2006) and social capital (Dzanja et al., 2013). The diversification of livelihoods (Barrett et al., 2001) and particularly off-farm incomes also improve the food security of farming households (Dzanku, 2019).

However, all these relations become less clear when the situation is analysed at the intra-household level (Harris-Fry et al., 2017; Ruel et al., 2018). Understanding the importance of relationships and the distribution of tasks is therefore essential because stronger ties within families allow for more efficient

intra-household allocation of productive resources and consumption (Kazianga & Wahhaj, 2017). In contrast, when the head of the household does not use income uniformly to improve the nutrition of each household member, individual factors may improve individual food security. For women in particular, generating their own income (Hoddinott & Haddad, 1995) and empowerment factors associated with their rights and capacities to generate and manage their own income need to be considered to explore the different links that enable the improvement of their well-being (Malapit et al., 2015). While international institutions recognise the importance of empowerment for women's food insecurity, empirical evidence is scarce and incomplete (World Food Programme Gender Policy, 2015; Hajnalka et al., 2017). Many authors (Carr, 2005; Quisumbing & McClafferty, 2006; Quisumbing & Smith, 2007) questioned the relevance of relying on unitary models of households whose members share the same needs, resources, benefits and goals, and few studies have focused on both the collective (household and farm) and individual factors of women's food insecurity.

This paper, based on a survey of 290 farm households with at least one adult woman, aims to contribute to filling this gap and to explore the determinants of women's food insecurity, measured by an individual indicator derived from the Household Food Insecurity Access Scale (HFIAS) by considering factors of the family farm, other household livelihoods and women's individual factors. This survey took place on a territory located in west-central Tunisia, in the governorate of Sidi Bouzid, where the difficulties faced by the agricultural sector played an important role in fuelling the revolutionary dynamics of the Arab Spring (Gana, 2012). In these areas, women, often engaged in unpaid family work (Tabet et al., 2019), are particularly vulnerable to food insecurity and have low levels of empowerment (Kruse, 2019).

After a description of the context, we have detailed the methodology used and in particular the econometric strategy, designed considering the simultaneity of production and consumption decisions induced by the market failures and the incomplete markets that characterise poor areas in developing countries (De Janvry et al., 1991). The results of the econometric model were discussed in the light of various microeconomic works, the public policies implemented in Tunisia and the contextual elements of semi-arid zones and Sidi Bouzid in particular.

Background information

Tunisia is one of the Mediterranean countries most affected by changes in consumption patterns. The traditional Tunisian diet is characterised by high consumption levels of durum wheat and olive oil, with a moderate and uneven intake of animal products (mutton, eggs and milk), and is very diversified with regard to fruit and vegetables. This pattern is undergoing changes under the influence of economic development and the gradual urbanisation of households. A change that is clearly taking place is a steep increase in the consumption of imported soft wheat flour in the form of bakery bread, and other commodities such as sugar and blended oils (Périsse & Kamoun, 1987). This change has consequences on health, in particular

non-communicable diseases such as obesity and diabetes. As in other North African countries, Tunisian agricultural production only began to exceed individual nutritional needs in the early 1990s (Padilla et al., 2005). But the most vulnerable populations continue to face difficulties in meeting food needs and under-nutrition continues to exist in rural areas with economic difficulties. The weakness of employment opportunities for skilled workers has led to a growth in informal precarious employment, especially in agriculture (ILO, 2015), and a worsening of poverty rates, but also to a severe decline in the standard of living of the middle class, which was previously particularly developed in Tunisia (Ben Romdhane, 2011). A study conducted in 2017, led jointly by the Tunisian Institute of Strategic Studies and the World Food Programme, raised concerns about people's economic access to food. The same report underlined the difficulties of family farms in central regions of Tunisia, which produce olives, fruit and vegetables, in gaining access to finance, inputs and information, and in marketing their products.

This is particularly the case of the population of the governorate of Sidi Bouzid, located in the semi-arid zone in central Tunisia. Cradle of the Jasmine Revolution that took place in 2010, this territory faces both economic and social difficulties. The agricultural sector, which is the predominant economic activity, has undergone profound changes in recent years (Elloumi, 2015). The reduction in rangeland, together with the exploitation of groundwater resources, has transformed the region from a predominantly pastoral system to a system more focused on olive orchards and horticulture in irrigated areas. However, livestock farming, particularly sheep, has retained a leading position in the region. Recent public policies have also encouraged dairy farming, resulting in the increased presence of livestock on farms. But the modernisation of agriculture in Sidi Bouzid has faced both resource degradation and water scarcity in the soil and the deregulation of some agricultural sectors (Elloumi et al., 2006).

At present, a few entrepreneurial farms, well endowed with equipment, practice market-oriented intensive agriculture, alongside family farms which are beset by multiple financial, environmental and economic difficulties. This small-scale agriculture is suffering from rising input prices, uncertainty about selling prices and increased competition on the national market (Fautras, 2015). The high unemployment rate (17% in 2016 according to INS, Tunisia's national statistics institute) has made agriculture a refuge sector for many workers. Recently, a study in two rural villages (Dhraief et al., 2019) in the north of the governorate reported that nearly two-thirds of households can be considered vulnerable to food insecurity.

Despite gains in terms of protection and women's rights, gender imbalance in Tunisia still exists for household chores (Nazier & Ezzat, 2021) and integration into education (Harris & Koser, 2018). The position of Tunisian women in rural areas remains extremely problematic: 40% of women living in rural areas are illiterate while many rural women face numerous health problems due to a lack of access to free healthcare (Amroussia et al., 2016). In Sidi Bouzid, women, who account for 60% of the total workforce in the agricultural sector and have a higher unemployment rate than men (INS 2014), have been particularly affected by the area's economic difficulties. According to a report by the Overseas Development Institute (2014), women farm workers face informal and precarious working

conditions. Women in rural central Tunisia are obliged to work on the farm without obtaining their own remuneration and combine their agricultural tasks with domestic tasks. In addition, women are in charge of specific tasks (fetching water, harvesting, picking fruit and feeding animals) (Latreille, 2008) but generally have weak access to resources (Mellouli, 2007). The empowerment of rural Tunisian women is considered low compared to other African and Asian regions while women's decision-making is strongly correlated with nutritional security indicators (Kruse, 2019).

Data and methods

Sampling and data collection

The survey was conducted in December 2015 among farm households in Sidi Bouzid. The sample was selected to be representative of women of childbearing age (aged 20–49) in the governorate. The households were randomly selected from 36 governorate districts, which were themselves randomly selected (20 households per cluster to minimise design effects) (United Nations, 2010).

Among the 720 women surveyed for the purposes of a broader survey, 316 lived in an agricultural household. After data cleaning, 290 questionnaires were selected for analysis. The surveys were conducted face-to-face. Information on the farm (farm assets, family and hired labour, crop and livestock production, shares of production sold and self-consumption) was collected from the farm manager. Self-consumed production was valued using the farmer's selling price of the same product. If all the production of a given product was self-consumed by the household, it was valued using the product's average selling price in other households. A woman selected at random from the household was then interviewed about these activities and her food security (see the 'Measuring food insecurity using the Individual Food Insecurity Access Scale' section).

Farms were not selected as observation units in the sampling plan. Indeed, no exhaustive public data on the agricultural sector was available in Tunisia at the time of the survey. The most recent farm structure survey, conducted in 2004, was only available at a national aggregated level. According to this survey, 25% of Tunisian farms owned 10 ha of land or more compared to only 11% in our sample. Activities related to durum wheat production were under-represented. Two elements explained this difference: (i) our sample concerned only family farms on which women were present, which excluded entrepreneurial farms and (ii) over the past 20 years, the restructuring of public land, reform of land registration and privatisation of collective land have led to land fragmentation in all rural areas in Tunisia (Jouili et al., 2013). We assumed that this gap has been reduced since the 2004 survey. More methodological details about the survey's design and sampling can be found in a data paper (Gaillard et al., 2018). The metadata are available online at <https://doi.org/10.18167/DVN1/LWT7BG>.

Measuring food insecurity using the Individual Food Insecurity Access Scale

The HFIAS (Household Food Insecurity Access Scale) indicator estimates the prevalence of household food security (Coates et al., 2007). HFIAS is composed of a set of nine questions on the ‘occurrence of events with an increasing level of severity of food insecurity’ (access) and nine questions on the ‘frequency of occurrence’ that are asked after each question to determine the frequency of the event. Some of the nine questions on occurrences focus on respondents’ perceptions of their vulnerability or food stress, and others on their behaviour in the face of insecurity.

The methodology generally used has been slightly modified in this study. Food insecurity was measured based on women’s responses to their own experience of food insecurity in the two months preceding the survey. The indicator was renamed IFIAS (Individual Food Insecurity Access Scale) and has already been validated in some contexts with female populations (Natamba et al., 2015). HFIAS relies on the subjective report of food insecurity experiences. But food insecurity as measured by HFIAS has been shown to be positively associated with dietary adequacy (Becquey et al., 2010), dietary diversity (Faber, 2009) and lower odds of being underweight (Kadiyala & Rawat, 2013). In addition, the literature on HFIAS points to a cross-cutting indicator of food security (Desiere et al., 2015).

The indicator score ranges from 0 to 27. Based on the answers to each question and on the total scores, households can be classified in four categories (Coates et al., 2007): food security, mild food insecurity, moderate food insecurity and severe food insecurity. In the analyses, we made two types of grouping. In the first, we grouped the latter three categories to identify women who had some form of food insecurity. In the second, we grouped only the last two categories to identify women who had a moderate or severe form of food insecurity. These two dichotomous variables were the outcomes of our regression analyses.

Scoring of farm assets

To summarise the information from the farm assets, two scores were calculated from the different variables defining the assets. Firstly, the human asset score was calculated using the variables describing the number of workers (family and hired) according to their status (temporary or regular). Secondly, the physical and natural asset score was calculated with the variables corresponding to the amount of agricultural equipment, amount of irrigation equipment, presence of greenhouse equipment, farm size, number of small livestock and number of cattle.

Each variable has been normalised to be between 0 and 1. All dichotomous variables were recoded as 1 for presence and 0 for absence. The quantitative variables have been normalised as follows:

$$\tilde{X}_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad (1)$$

where i represents the family farms in our sample $i \in [1; 290]$. X_i is the value for the quantitative variable and individual i , X_{min} is the minimum value in the sample for

the quantitative variable and X_{max} is the maximum value in the sample for the quantitative variable. X_i is the new value of the variable between 0 and 1 for individual i .

The score of each asset was the average of the variables (transformed for quantitative variables and recoded for qualitative variables) defining this asset.

Empirical strategy

In many developing countries, production decisions may not be separable from consumption decisions due to market imperfections (De Janvry et al., 1991; Singh et al., 1986). In the Sidi Bouzid governorate, the hypothesis of imperfect markets, especially of the employment market, can be formulated. Faced with labour market failures, household decisions on the allocation of labour are aimed at maximising farm production and profit, simultaneously taking consumption into account, thereby making production and consumption decisions inseparable.

The empirical specification was motivated by a household model with a connection between agricultural production and household consumption. Drawing on presentations in the literature (Dillon & Barrett, 2017), we considered a household that derives its utility from consumption (C) and leisure (L), the household utility function can be specified as $U(C, L)$. Under non-separability, manifestations of consumption choice are directly influenced by production factors. The household is assumed to maximise utility subject to the constraints imposed by production, total household time endowment and household income. Consumption is the sum of consumption of a farm's own production and of purchased market goods. Leisure is dependent on family farm labour, off-farm labour and indirectly dependent on labour hired on-farm. Consumption is constrained by budget, which is the sum of farm profits, off-farm income and savings and can be modelled with the following equation:

$$C_w = f(G(L, K), I_{hh}, I_w, M, F_{hh}, F_w) \quad (2)$$

where C_w is consumption by women, G is farm profit which depends on L (quantity of labour), K (capital), I_{hh} represents household off-farm income, I_w represents women's income, M represents the market as a vector of food prices and input prices, F_{hh} stands for household characteristics and F_w for women's characteristics.

The IFIAS indicators of food insecurity were used to describe women's consumption with the previously exposed limits. The econometric models, based on the conceptual framework (Fig. 1), tested the relationship between farm assets, farm production, characteristics and income of households and women with women's food security. Prices, which are not observed in the data, are considered to be homogeneous across the territory, given the coverage of the food supply in the governorate (Jellali, 2016).

Econometric models and treatment of endogeneity

To address the issue of endogeneity, econometric estimation of a non-separable model requires the use of instrumental variables that are highly correlated with



Fig. 1 Relation between farm assets, household and individual characteristics and women's food security (Source: authors)

the production level and not linked to consumption. The instrumental variables should only impact consumption through their effect on production.

We chose the dichotomous variable indicating whether the head of the family farm has an agricultural background and their degree of agricultural experience (in years) as instruments of farm production. Farmers with more experience and a better background are associated with a greater ability to cope with shocks (climate, pests, prices etc.) through greater technical skills. These elements were a priori perfectly exogenous with consumption decisions and therefore not correlated with women's food insecurity. After the IV probit, the null hypothesis of exogeneity was tested with the Wald test (testing if the error covariances are null i.e. $\text{cov}(\epsilon, \mu) = 0$). The weak-instrument-robust test statistics were calculated using the 'weakiv' command (Finlay et al., 2014) in STATA as tests on the validity of the instruments used.

We estimated a model to explain women's food insecurity (as a dichotomous variable) by the value of farm production and a set of other variables. In one case (3), the variable was equal to 0 when women were food secure by IFIAS score, 1 when women were mildly to severely food insecure. In the second case (4), 0 encompasses food security or mild food insecurity and 1 equals moderate or severe food insecurity.

$$Y_{1i} = \begin{cases} 1 & \text{if } i \text{ is food in security (mild, moderate or severe), } Y_{1i}^* > A \\ 0 & \text{if } i \text{ is in food security, } Y_{1i}^* \leq A \end{cases} \quad (3)$$

$$Y_{2i} = \begin{cases} 1 & \text{if } i \text{ is important food insecurity (moderate or severe), } Y_{2i}^* > A \\ 0 & \text{if } i \text{ is in food security or in mild insecurity, } Y_{2i}^* \leq A \end{cases} \quad (4)$$

We assume there were unobserved variables Y_{1i}^* and Y_{2i}^* that generate the observed Y_1 and Y_2 . In the generation processes of Y_1 and Y_2 , the larger values of Y_{1i}^* and Y_{2i}^* were classified as $Y_1=1$ and $Y_2=1$, while those with smaller Y_{1i}^* and Y_{2i}^* are classified as $Y_1=0$ and $Y_2=0$. A is the cut-off point.

To simplify the writing of models that use the same procedure, we noted the endogenous variable by Y to evoke the variable Y_1 and the variable Y_2 .

The IV probit procedure in Stata attempts to fit models with dichotomous-dependent variables and endogenous regressors, and jointly estimates two equations via the maximum likelihood of Amemiya's generalised least square estimator (Amemiya, 1978; Newey, 1987).

The model can be written as:

$$\begin{cases} \ln(P) = \alpha_0 + \alpha_1 B + \alpha_2 C + \alpha_3 D + \alpha_4 E + \alpha_5 Z + \varepsilon \\ Y^* = \beta_0 + \beta_1 \ln(P) + \beta_2 B + \beta_3 C + \beta_4 D + \beta_5 E + \mu \end{cases} \quad (5)$$

where the explanatory variables on the B vector contain the two asset scores (human assets and physical and natural assets scores) described in the 'Scoring of farm assets' section and the categorical variable of the (market) orientation of production (self-consumption, mixed, sold). Household characteristics (size of family, presence of off-farm income) are captured in vector C . Vector D also included a household wealth index built using a principal component analysis (Traissac et al., 2016). Vector E includes women's characteristics (age, income, working time and empowerment). A woman's income was detailed in cash income from the farm they lived on, cash income from another farm and non-farm income. Working time was also broken down in one variable describing working time on the farm and another variable describing a woman's domestic working time. In addition to the variables of working time, woman's empowerment is partially measured by the responsibility for farm activities and the participation in decisions on the use of household income. In the Probit model, the variance of μ was normalised to one to identify the model.

The value of production P (log transformed) was estimated with the same set of covariates of the two instruments previously stated (experience in farming and background in agriculture). The estimates of the first stage, generally used as a tool to treat endogeneity, have also been interpreted in the results. Indeed, the effects of the scores of farm assets (human and physical assets) were deemed important to observe to consider their potential indirect effect, via the value of production, on women's food security.

For each estimation, the results were compared to the results of a Probit estimation of women's food insecurity without a prior treatment of endogeneity.

Results

Descriptive statistics

Food security

Among the 290 women living in agricultural households, the average IFIAS score was 2.31 (SD=4.22). Based on the answers to each question and on the total scores, we observed that 43.8% reported experiencing food insecurity in the two months preceding the survey [Fig. 2]. 18.7% reported moderate or severe insecurity.

Farm characteristics

Small-scale farmers accounted for most of our sample: the average farm size was 4.2 ha [Table 1] and 42% of the farms covered less than 2 ha. Significant heterogeneity was observed in the possession of physical assets (see the relatively high values of standard deviation compared to average values [Table 1] and in particular in the motorised equipment owned by two-thirds of the sample. Regarding human assets, a low level of recourse to external labour was observed, the majority of this being temporary labour (the latter concerning 30% of farms).

Some 66% of farms had at least two different sources of agricultural income, but this diversity remained relative with regards to land use. Olive trees were the main crop on two-thirds of agricultural land. Despite the reduction in rangeland in the region, livestock farming was also widely practiced by farmers. Sheep breeding concerned 61% of farms and 22% of farmers had dairy cows, an activity that has recently expanded in the region. The combination of growing olive trees and livestock farming was practiced by 53% of farmers. In farms combining these two sources of income, external seasonal labour was used more often than on other farms. In addition, 35% of farms had access to irrigation. Rainfall was low in 2015

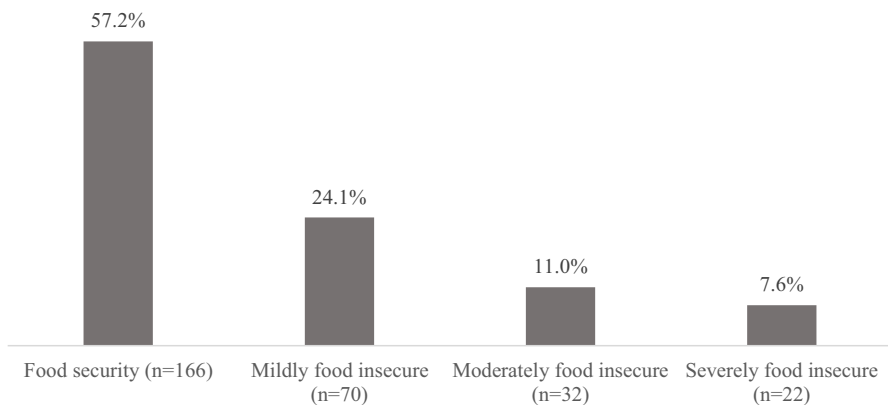


Fig. 2 Percentage distribution of respondents according to their level of food security measured by IFIAS ($n = 290$)

Table 1 Descriptive statistics of farm assets ($n=290$)

Variables	Mean (SD)	Frequency	Number of observations with value > 0	Mean score (SD)
Human assets				
Head of farm with education after age of 13		13.8%		
Number of permanent family workers	1.6 (1.4)		222	0.17 (0.23)
Number of temporary family workers	0.8 (1.1)		129	
Number of permanent hired workers	0.1 (0.8)		5	
Number of temporary hired workers	1.7 (3.6)		87	
Physical and natural assets				
Area (ha)	4.2 (6.7)		304	0.11 (0.14)
Irrigated area (ha)	1.1 (2.3)		107	
Presence of greenhouse cultivation		6.5%		
Value of motorised equipment (US dollars in 2015)	845.2 (3,708.5)		199	
Number of cattle	1.1 (2.7)		67	
Herd size	20.7 (33.3)		246	

and it was considered a difficult year, particularly for olive growers (68% considered themselves as victims of the poor economy in 2015).

The value of agricultural production was on average less than US\$5,000 per farm [Table 2]. The value did not even reach US\$2,200 for 45% of farms. Some 85% of farm households consumed at least some of the products they produced and 28% of households consumed more than half of their own production.

Labour and income

Farm households were composed of 2 to 11 individuals and just under two-thirds of them had off-farm income [Table 2]. Most of the women interviewed (70%) were the wives of the head of the household, 12% declared they were the daughter of the head of the household and 6% had another family relationship (most often the sister of the head of the household). Finally, 3% declared that they were the head of the household (they were single, widowed or divorced). While 80% of women declared that they participated in farm work, 25% said that they were the main person responsible for family farm tasks. Some 27% were engaged in off-farm activities [Table 2] and 5% of the women accumulated income from the family farm along with other income (mostly from agriculture). Farms with women in positions of responsibility were generally less endowed with physical assets (score of 0.07 versus 0.12 on average) and human capital (score of 0.09 versus 0.20).

The working time spent on the family farm by women depends on the family farm's activities (15.7 h on average when there are livestock activities versus 5.8 h for other farms) and the volume of workers on the farm (16.1 h for women living on farms with two or more workers versus 13 h for the others). The working times of women responsible for the family farm were obviously higher than those of other women (17 h versus 12.8 h). They combine this labour with domestic tasks (28 h on average). Women with activities on other farms also work on the family farm in equivalent proportions. In addition to this farm labour, they work an average of 24 h per week, almost as much as the other women (24.3 h). Only women with non-farm activities are spared from agricultural tasks on the family farm and spend less time on domestic work (22 h on average).

Econometric results

Determinants of women's food security

Table 3 provides the results of the regression models relating women's food insecurity among the level of food insecurity with farm production and other covariates. The first regression tested women's likelihood of having experienced some form of food insecurity. The results were very similar in terms of whether or not endogeneity was treated. In the IV estimation, an increase in the value of agricultural production was associated with a decrease in women's risk of food insecurity. Based on the marginal effects [Table 4], doubling agricultural production reduced the probability

Table 2 Descriptive statistics of the sample ($n = 290$)

	Mean (SD) or Frequency
Farm characteristics and farm performance	
Value of farm production (in US dollars)	4,603 (3260)
Value of self-consumed production (in US dollars)	498 (694)
Orientation of the farm production	
Market (self-consumption <20% of production)	48.3%
Mixed (20% < self-consumption < 80%)	31.4%
Self-consumption (self-consumption > 80%)	20.3%
IV determinants of farm performance	
Age of head of farm	44.4 (12.1)
Years of experience	26.8 (16.0)
Agricultural background	5.3%
Household characteristics	
Size of household	5.3 (1.8)
Wealth score	52.2 (12.6)
Households with off-farm income	62%

Table 2 (continued)

Women's characteristics	Mean (SD) or Frequency
Age of woman	45.9 (13.0)
Level of education	
No schooling	23.1%
Primary school	34.8%
Middle school	31.0%
High school and university	11.0%
Women married and main responsibility of farm activities	21.7%
Women not married (single, widowed, divorced) and main responsibility of farm activities	3.8%
Time spent on family farm activities (in hours per week)	13.9 (12.8)
Time spent on domestic tasks (in hours)	25.3 (10.2)
Women with own income from family farm	18.4%
Women with income from another farm	22.7%
Women with no farm income	9.5%
Time spent on family farm activities (in hours per week)	13.9 (12.8)
Time spent on domestic tasks (in hours)	25.3 (10.2)

Table 3 Coefficients of determinants of women's food insecurity

Variables	Women's food insecurity		Women's moderate and severe food insecurity	
	Probit	IV probit	Probit	IV probit
Value of farm production	-0.12**	-0.38***	-0.25***	-0.46***
Human assets	-0.91***	-1.00**	-0.64	-0.69
Physical assets	0.16	1.47	1.00	2.09
Orientation (mix sold & self-consumption/self-consumption)	0.04	0.29	0.68**	0.97**
Orientation (sold/self-consumption)	-0.23	0.07	0.26	0.53
Size of household	-0.01	-0.01	0.23***	0.24***
Household off-farm income (Y/N)	-0.03	-0.08	-0.33	-0.39*
Wealth score	-0.04***	-0.03***	-0.05***	-0.05***
Age of woman	0.00	0.01	0.01	0.01
Women married and main responsibility of farm activities (without responsibility)	0.11	0.14	0.84***	0.89***
Women not married and main responsibility of farm activities (without responsibility)	-0.37	-0.32	0.40	0.48
Time spent by the woman on household chores	0.01	0.01	0.01	0.01
Women's participation in decisions on the use of household income	0.08	0.09	0.18	0.19
Woman's income: non-farm (Y/N)	-0.61*	-0.67**	-1.07*	-1.18*
Woman's income: from other farm (Y/N)	0.31*	0.28*	-0.13	-0.15
Woman's income: on-farm (Y/N)	0.48**	0.57**	0.34	0.38*
On-farm women's working time (in hours)	0.01	0.01*	-0.01	-0.01
Constant	2.72***	4.03***	1.38**	3.03***
Wald test of exogeneity	$p=0.04$		$p=0.10$	
Lagrange multiplier K -test	$p=0.01$		$p=0.01$	
Hansen J test	$p=0.51$		$p=0.87$	
Observations		290		290

*** Significant at 1% level
 ** Significant at 5% level
 * Significant at 10% level

Table 4 Average marginal effects of determinants of women's food insecurity

	Average marginal effects IV probit	
	Women's food insecurity	Women's moderate and severe food insecurity
Log of production value	-0.036	-0.049
Woman's income: non-farm (Y/N)	-0.190	-0.200
Woman's income: from other farm (Y/N)	0.142	-0.024

of women being in food insecurity by 2.7 percentage points for an equivalent level of agricultural resources (assets) and the same level of household wealth.

Farm human assets (in particular farm family labour [Table 5]), household wealth and women's non-farm income were significantly associated with reduced food insecurity. In contrast, having income from the family farm, having income from another farm and working time on the farm were positively and significantly associated with an increased risk of women's food insecurity.

The equation was significant overall on a Wald chi-squared test at the 5% threshold. This suggests that calculations using IV techniques were more efficient. Diagnostic tests of weak instrumental variables validated the exogeneity of our instruments with the Hansen J statistic and their robustness (reject of Lagrange multiplier *K*-test).

Determinants of severe and moderate food insecurity among women

In the case where the variable to be explained was women's food insecurity restricted to moderate and severe cases, the results of the procedure were also found to be more efficient (Wald test where $p < 0.01$), the instruments robust (Lagrange multiplier *K*-test rejected) and exogenous (Hansen J-test not rejected). The results of this estimate also led us to identify a link between an increase in production and a reduction in moderate and severe food insecurity. Doubling agricultural production drove a reduction in the probability of women's food insecurity by 3.6% [Table 4].

Table 5 Coefficient of probit to measure the influence of variations in family labour on women's food security, adjusted by the size of household and number of family workforce

	Women's food insecurity
Number of family farm workers	-0.19***
Size of household	0.03
Number of family workforce	-0.06
Constant	0.38*

*** Significant at 1% level

** Significant at 5% level

* Significant at 10% level

In contrast to the previous estimate, variables characterising the household were significant. For example, an increase in household size was associated with increased severe food insecurity, while off-farm income from household members other than women reduces this risk. Production oriented towards a mix of self-consumption and off-farm sales was associated with an increase in risk compared to production mainly aimed at self-consumption. As in the previous model, while the effects of women's income affected their food insecurity in different ways, income from other farms was not associated with an increased risk of food insecurity. Married women with the main responsibility for the farm were associated with an over-risk of food insecurity compared to woman without farm responsibilities. These results were also very similar to those obtained with a Probit estimation without endogeneity treatment. As before, however, the influence of production was reduced compared to the IV estimation.

Determinants of farm production

The results of the first stage of the model explaining the log of the value of farm production [Table 6] showed that, apart from significant associations with the instrumental variables, the physical asset score was strongly associated with an increase in production. The value of production is also significantly related to the wealth index of the household. An orientation towards the sale of production versus an orientation towards self-consumption was associated with an increase in production. Women's labour on the family farm was also positively associated with farm production.

Discussion and policy implications

In this paper, we have examined the relationship between farm structure, agricultural production, household and individual incomes and perceived food insecurity among women living in farming households in Sidi Bouzid, Tunisia. The results confirmed that farm production plays a role in women's food security but the influence is weak. Among family farm assets, those characterising farm labour were associated with a reduction in women's food security, while those associated with physical and natural assets (equipment, land etc.) were only indirectly linked via production. Among the indicators for women, individual income from off-farm activities reduced their risk of food insecurity, while income derived from on-farm labour was associated with a greater probability of food insecurity. When moderate and severe food insecurity were observed, household level characteristics also played a protective role (household non-farm income) or aggravating role (family size).

Increase in production: necessary but not sufficient

As observed in empirical studies dealing with the linkages between agricultural production and food security at the household level, our results showed that an increase in agricultural production on the family farm, with equivalent wealth and farm

Table 6 First-stage: determinants of log of farm production value

	Log of farm production value
Variables	Coefficients
Agricultural education	1.61***
Age of farmer (head of farm)	0.02***
Experience in farming	0.03***
Human assets	-0.08
Physical assets	4.51***
Orientation (mix-sold & self-consumption/self-consumption)	1.04***
Orientation (sold/self-consumption)	1.01***
Size of household	0.02
Wealth score	0.03***
Household income off-farm (Y/N)	-0.05
Age of woman	-0.01
Women married with main responsibility of farm activities (/without responsibility)	0.34
Women not married with main responsibility of farm activities (/without responsibility)	0.21
Time spent by the woman on household chores	-0.01
Women's participation in decisions on the use of household income	-0.03
Woman's income: non-farm (Y/N)	-0.17*
Woman's income: from other farm (Y/N)	-0.05
Woman's income: on-farm (Y/N)	0.35*
On-farm women's working time (in hours)	0.01**
Constant	3.00

*** Significant at 1% level

** Significant at 5% level

* Significant at 10% level

assets, also reduces the risk of food insecurity for women living in these households. This weak link was slightly strengthened when it comes to moderate or severe food insecurity.

Our results showed that production orientation has no specific effect on women's food security. Income generation allows households in the governorate of Sidi Bouzid to have access to a large and diversified food supply on the market (Jellali, 2016). However, women were protected from moderate or severe food insecurity by strategies that tend to focus on self-consumption rather than a mixed strategy combining the sale and self-consumption of farm products. This effect was higher on livestock farms, given the economic access to certain animal products.

In small-scale agriculture, the predominant production system in Sidi Bouzid is a combination of olive crops and livestock. While livestock products are both consumed by household members and sold, olive production is essentially a cash crop. Regarding olive production, the sector faces competition from cheaper soyabean

oil and also suffers from important disfunctions along the value chain, in particular inadequate storage and transport methods (Salhab et al., 2020). Despite public policies designed to develop the dairy sector, livestock farmers report low margins, largely linked to difficulties in reducing the cost of animal feed due to the lack of local fodder production. In addition, the growth of the dairy sector is hampered by poor storage management and a lack of incentives for innovation (Chebbi et al., 2019). Even for market gardening producers in the sample, there were difficulties in generating income due to high irrigation costs in a region where pressure on land and water resources makes access to irrigation strategic. These difficulties in generating sufficient income through agriculture were particularly acute for those who are less endowed with physical and natural assets, which are the main determinants of the level of production. These elements also explain the weak influence of an increase of production on women's food security because this increase does not necessarily mean an increase in farm income.

In contrast, on-farm human assets were strongly associated with a reduction in women's risk of food insecurity. For an equivalent level of production and an equivalent household size, households where more family members are involved in farming activities were correlated with a reduction in food insecurity. This result underlines the importance of family organisation on the farm, which includes consumption strategies (Bosc et al., 2014) through a better division of labour to facilitate collective self-help and thereby reduce intra-household inequalities. A larger number of family workers gives women more choice in the organisation of their activities, whether domestic, particularly meal preparation, or in income-generating activities beyond the family farm. But the sharing of work is not only linked to the family labour available to carry out agricultural tasks. In livestock activities, which are more intensive in terms of labour, women were under greater pressure in terms of working time on the farm, combined with an equivalent time spend on domestic tasks.

For women who were responsible for on-farm decision-making, time spent on the farm increases even more. While there was no difference in the values of annual production between farms where women were the main decision-makers and farms where women had less responsibility, our results indicated an excess risk of food insecurity for women decision-makers, who are often overworked.

Collective resources of the household limit women's severe insecurity

When looking at models explaining moderate and severe forms of insecurity, collective resources outside the farm have played a major role in women's food insecurity. At the household level, household wealth and income level are essential determinants of food security in most contexts (Bashir & Schilizzi, 2013), including when income is generated off-farm (Dzanku, 2019). In our study, the protective role of household livelihood sources is exerted on women in the most vulnerable households. These results together argue for a high-income elasticity for food in the poorest households, as observed in macroeconomic studies (Colen et al., 2018). Off-farm collective income sources have a significant protective effect but only on women's

moderate or severe insecurity, showing resources are potentially not completely pooled but only partially pooled to meet basic needs. The difficulty of accurately assessing the distribution of these resources and its consequences on all members of the household is a limitation of the study.

In addition, in line with several empirical studies on the determinants of women's food insecurity (Harris-Fry et al., 2017; Kabir et al., 2014), household size is inversely correlated with improvements in women's food security. Regarding the control variables present in the equation, this result shows above all that a large number of dependents (children and elderly) in the household can lead women to reduce their own food consumption for the benefit of other people in the household.

Women's individual agricultural income as a means of subsistence, diversification with off-farm income as a means of empowerment?

Our results have shown a strong relationship between women's incomes and their own food security, but the effects were antagonistic depending on the source of income. Income from agriculture, whether from the family farm or another farm, is associated with increased food insecurity. In contrast, non-farm income is accompanied by higher food security and less severe or moderate food insecurity.

Labour in agriculture is often constrained by the lack of other opportunities or the substitution of hired labour in order to reduce costs. This workload, which is in addition to domestic work time, is practiced by women living in the most vulnerable households, less endowed in physical and human assets and in search of an additional source of income. In this regard, the time women spend working on the family farm, although positively correlated with an improvement in agricultural production (and thereby an indirect positive effect on food insecurity), is associated with an increased risk of food insecurity, but this direct effect disappears when it comes to estimating more severe insecurity. The ambiguity of the effects of women's agricultural work on their diet is also reflected in the literature with contradictory results that are positive (Schreinemachers et al., 2015) or negative (Malapit et al., 2015) depending on the context.

While personal income can be considered in the literature as an essential dimension of empowerment, it is important to distinguish the type of income in question and whether it comes from choice and emancipation or whether it is suffered. In our results, women's non-farm income is largely associated with a reduction in their food insecurity, echoing a review of data (Van den Bold et al., 2013) on the importance of women's income for their own food security, in particular when income comes from non-farm employment (Dzanku, 2019). Participation in the non-agricultural labour market, observed for less than 10% of the women in our sample, is strongly correlated with their level of education, itself often considered a factor in food security in Tunisia (Mellouli, 2007). While the 2018–2022 strategic nutrition plan (World Food Programme, 2017) in Tunisia has clearly identified the difficulties, women face in accessing non-agricultural employment, public policies are slow to take shape. However, our findings point to the importance of livelihood diversification in food security (Alobo Loison, 2015) and may also echo the work that

has highlighted differences in food strategies according to sources of income (Villa et al., 2011) in rural households.

In contrast, the other elements of empowerment (the measured participation in decisions on the use of income, main decision-making responsibility for farm activities) measured in this study did not provide empirical evidence that empowerment improves food security (Ramachandran, 2007; Clement et al., 2019). However, as observed in our results, the responsibility for farm tasks cannot be considered as an empowerment element since this responsibility generates additional working time. Despite the insights provided by our results, some dimensions of empowerment (such as leadership in the community) measured through benchmark indicators such as WEAI (Alkire et al., 2013) were not explored in our study.

Conclusion

The food insecurity reported by women living on farms remains quite significant, since it affected some 40% of women aged 20 to 49 in 2015 in the governorate of Sidi Bouzid. In this region, family farming faces many obstacles and struggles to ensure food security for women. Food insecurity is more severe among women living on less well endowed, less productive farms with larger families. In this case, livelihoods generated by other members of household play a protective role. Women who have an income from agriculture, often constrained by a lack of resources, are also the most food insecure. In contrast, non-agricultural income, received by 10% of women, is associated with a better level of women's education and better food security.

This study shows that interventions in the rural areas of Tunisia should be multi-dimensional. In order to revitalise family farming, farmers should benefit from better access to equipment and irrigation with water recovery technologies to cope with the growing depletion of resources. The region has a comparative advantage in the olive oil sector linked to climatic conditions and know-how but the organisation of the sector is also necessary for it to be competitive. Faced with more difficult access to collective grazing, an integrated crop-livestock system should be implemented to create added value for livestock products and ensure decent margins for farmers.

In addition to increased incomes, these agricultural interventions could also have positive consequences for improving agricultural diversity and the working conditions of women combining agricultural and domestic labour. However, putting the emphasis on agriculture is insufficient to enhance the living conditions and food security of women living in agricultural households. Public policies should focus on the broader access of women to education and, consequently, to non-agricultural employment opportunities.

Acknowledgments The MEDINA-Study Group: Marie-Josèphe Amiot-Carlin (Chair, INRA, France), Nawel Achir (CIRAD, France), Leila Alouane (INNTA, Tunisia), Jalila El-Ati (INNTA, Tunisia), Sihem Bellagha (INAT, Tunisia), Pierre-Marie Bosc (CIRAD, France and FAO, Italy), Mélanie Broin (Agropolis, France), Nicole Darmon (INRA, France), Claudie Dhuique Meyer (CIRAD, France), Marie-Claude Dop (IRD, France), Sophie Drogué (INRA, France), Sandrine Dury (CIRAD, France), Ahmed Ferchoui (INRA, France), Cédric Gaillard (CIRAD, France), Zeineb Ghrabi (INAT), Florence Jaquet (INRA,

France), Yves Kameli (IRD, France), Fayçal Kefi (CIHEAM, France/Italy), Faten Khamassi (INAT, Tunisia), Emmanuelle Kesse-Guyot (INRA, France), Denis Lairon (INSERM, France), Yves Martin-Prevel (IRD, France), Caroline Méjean (INRA, France), Claire Mouquet-Rivier (IRD, France), Sondos Njoumi (INAT, Tunisia), Martine Padilla (CIHEAM, France), Marlène Pérignon (INRA, France), Carole Sinford (SupAgro, France), Pierre Traissac (IRD, France), Eric Verger (IRD, France).

Author contribution Cedric Gaillard wrote the first draft of the manuscript; Pierre-Marie Bosc, Jalila-El-Ati and Sandrine Dury contributed to writing the manuscript and offered critical comments; and all authors read and approved the final manuscript.

Funding This work was supported by the Agence Nationale de la Recherche (France) as part of the MEDINA research project Promoting sustainable food systems in the Mediterranean for good nutrition and health (ANR-12-TMED-0004–01).

Data availability All the information on data collection is available in a datapaper already quoted in the article <https://doi.org/10.1051/cagri/2018005>.

Metadata and questionnaire are available on the CIRAD dataverse <https://doi.org/10.18167/DVN1/LWT7BG>.

Code availability Stata programming codes are not available.

Declarations

Ethics approval The study was approved by the Tunisian National Statistics Council (visa number: 08/2014).

Consent to participate The objective of the MEDINA study was explained to the participants prior to data collection and all participants included in the study gave their free and informed consent.

Consent for publication All participants included in the study gave their consent for publication of aggregate results.

Conflict of interest The authors declare no competing interests.

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