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Analysis of the determinants influencing the choice of local market garden crops: tomato, chili, onion, krinkrin and okra in Southern Benin

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Abstract

For more than two decades, Benin has witnessed a steady increase in market gardening production. However, his growth has not led to self-sufficiency, as the country still relies on imports from neighboring countries during lean periods. Analyzing the choice of local market garden crops will undoubtedly help find solutions to address the problem. Thus, the study used a multivariate probit model to identify the determinants of the adoption of market garden crops, particularly tomato, pepper, onions, krinkrin and okra, on farms in southern Benin. It was conducted on a sample of 474 randomly selected market gardeners. The results revealed the existence of interdependence and complementarity in the adoption of the various local market garden crops studied. Also, it is observed that the majority of producers surveyed prefer to adopt a combination of two crops at a time (27.43%) or four crops at a time (25.74%). Furthermore, the existence of a market in the village, the level of education, the existence of a telephone network, the type of area in relation to the proximity or not of the water table and the security of the sites are the main factors determining the adoption of local market gardening crops by producers in southern Benin.

Keywords: Determinants, Southern Benin, Market Gardening, Multivariate Probit

Introduction

Market gardening is practiced in all regions of Benin. It represents a varied food source that supplements the population's basic food needs (Adjatini et al., 2019; Bognini, 2011). They contribute significantly to food security, job creation and income for many producers in peri-urban and rural areas of Benin (Sikirou *et al.*, 2001), hence their importance in reducing household poverty (Babah-Daouda and Yabi, 2021). These crops are also essential to human health due to their contribution of trace elements, particularly vitamins and mineral salts (Shiundu, 2002; Stevels, 1990).

In Benin, market garden production experienced a real boom between 2003 and 2013, rising from 241,399 tons to 549,310 tons of market garden produce per year (Babah-Daouda and Yabi, 2021). According to DSA/MAEP (2024), the total market garden production during the 2023-2024 season is estimated at 717,365 tons compared to 675,188 tons in the 2022-2023 season. Despite the upward trend, the distribution of market garden products remains poorly regulated across markets. This very often leads to periods of overabundance causing price drops in certain markets and numerous post-harvest losses, especially in a context where processing remains rudimentary and underdeveloped. Moreover, during periods of shortage, we generally observe imports from neighboring countries such as Niger, Burkina Faso and Nigeria (Allogni *et al*., 2015).

This is why this study focuses on analyzing the determinants influencing the choice of local market garden crops including tomato, pepper, onions, krinkrin and okra in southern Benin, in order to identify appropriate solutions to improve local crop adoption. By exploring the interactions between the socio-economic characteristics of farmers, the specificities of the study region and market dynamics, this analysis will be able to provide crucial information to support the development of more efficient and sustainable agricultural strategies.

Methodology

Rogers' theory of adoption of agricultural practices or innovations states that adoption remains an individual decision (Rogers, 2003). According to Varian (2008), the adoption decision is generally based on the principle of rationality as defined by neoclassical economic theory.. Thus, the producer adopts a new technology or makes a choice if and only if it allows him to maximize his utility. In the same vein, a producer will adopt a vegetable crop, if the expected utility, represented by U1 (π), is higher than that which he would obtain if he had not adopted it, represented by U0 (π), i.e. U1 (π) > U0 (π). However, the utility that the producer obtains from the adoption of one or the other of the vegetable crops is not observable. It nevertheless depends on the socioeconomic, demographic, institutional and

environmental characteristics of the said producer noted (Xi) and can be represented by the following latent variable: $Ui = Xi\beta + \varepsilon i$, $i = 1,2, \ldots, N$ (1); where β is the vector of coefficients and εi is the random disturbance term.

In this case, the analytical approaches most often used in decision studies on the choice of a crop to estimate equation 1 are Probit and Logit. When the decision involves a single crop making the dependent variable dichotomous a univariate Logit or Probit model is generally applied (Lansink *et al.*, 2003). On the other hand, when the choice must be made between several possible alternative market garden crops, the literature recommends using either multinomial or multivariate Logit or Probit models.

Multinomial models are based on the independence of irrelevant alternatives, i.e. the error terms of the choice equations of the alternatives are mutually exclusive (Greene and Hensher, 2003). However, choices among market garden crops in southern Benin are not mutually exclusive; the producer could adopt a given market garden crop and consider adopting another. Therefore, the random error terms of the different market garden crop adoption equations may be correlated. In such circumstances, the estimation of multinomial Logit or Probit models would lead to biased estimators (Greene, 2008).

Vegetable crops are classified into local or traditional crops and exotic crops through literature (Simeni et al., 2009; Traoré, 2022). Moreover, leafy vegetables also stand out due to their usefulness (Shiundu, 2002; Stevels, 1990). For this reason, this study will focus on the choice of market garden crops by homogeneous group for greater consistency and tangible results. Therefore, this first phase of our work focuses on tomato, pepper, onions, krinkrin and okra.

As mentioned earlier, producers tend to adopt several vegetable crops at once in order to maximize their profits. Therefore, and based on the empirical literature on adoption, (Kassie *et al.*, 2015), all complementary innovations in terms of utilities that they allow the producer to gain and maximize will be adopted by the latter. This stipulates an interdependence of the producer's decisions to adopt each of these vegetable crops. In other words, the decision to adopt vegetable crop j by producer I would depend on the decision to adopt vegetable crop k, and so on. When interdependence in agricultural technology adoption decisions is suspected, the literature advises the use of a multivariate probit regression model for unbiased estimation of the estimators (Timu et al., 2014; Wu and Babcock, 1998). Multivariate probit is an extension of the bivariate probit model that uses Monte Carlo simulation techniques to simultaneously estimate the system of multivariate probit regression equations (Greene, 2008). To achieve this, the simultaneous

adoption of tomato[1], pepper[2], onion[3], krinkrin[4,] and okra[5]can be modeled by a system of dichotomous adoption equations (2) as follows:

$$\{Y_1 = 1\ si\ U_{1*}^{*} > U_{0*}^{*}\ Y_1 = 0\ if\ not\ Y_2 = 1\ si\ U_{2*}^{*} > U_{0*}^{*}\ Y_2 = 0\ if\ not\ Y_3 = 1\ si\ U_{3*}^{*} > U_{0*}^{*}\ Y_3 = 0\ if\ not\ Y_4 = 1\ si\ U_{4*}^{*} > U_{0*}^{*}\ Y_4 = 0\ if\ not\ Y_5 = 1\ si\ U_{5*}^{*} > U_{0*}^{*}\ Y_5 = 0\ if\ not \quad (2)$$

The multivariate probit regression model was adopted to estimate the probability of adoption of market garden crops (equation 2) in order to take into account possible correlation between the error terms of the different binary adoption equations (Greene, 2008). The multivariate probit model has already been used in a number of empirical studies assessing the factors influencing the simultaneous adoption of several agricultural technologies (Adekambi et al., 2021; Dassoundo-Assogba et al., 2019). The empirical model estimated with the variables included in the estimations is presented as follows:

$$CULTj = \alpha 1\beta i + \alpha 2\beta i + \alpha 3\beta i + \ldots + \alpha n\beta i + \varepsilon i \quad (3)$$

With CULTj the set of dependent variables that are tomato, chili, onion, krinkrin, and okra. Each dependent variable in equation (3) is a binary variable that takes the value 1 if producer i adopts vegetable crop j (with j = tomato, chili, onion, krinkrin and okra) and 0 if not. The different independent variables used in the estimation of the multivariate probit model are described in Table 1.

Table 1: Description of independent variables included in the estimated models

Variables	Description	Terms and conditions
Gender	Gender	Binary variable (0=Female, 1=Male)
Age range	Age group	Binary variable (0=Young, 1=Adult)
Mb_coop	Cooperative member	Binary variable (0=no, 1=yes)
Nv_instruction	Educational level	Categorical variable (0=None, 1=Primary, 2=Secondary 1, 3=Secondary 2, 4=Higher)
Market gardening experience	Experience in market gardening	Categorical variable (0=Beginner, 1=Junior, 2=Confirmed, 4=Senior)
Form_prof	Vocational training	Binary variable (0=no, 1=yes)
Exist_struct	Existence of a market gardening promotion structure	Binary variable (0=no, 1=yes)

[1]Solanum lycopersicum
[2]Capsicum annuum
[3]Allium cepa
[4]Corchorus olitorius
[5]Abelmoschus esculentus

Variables	Description	Terms and conditions
Exist_support	Existence of market gardening support advice	Binary variable (0=no, 1=yes)
Exist_electri	Existence of electricity	Binary variable (0=no, 1=yes)
Exist_teleph	Existence of the telephone	Binary variable (0=no, 1=yes)
Access_site	Site accessibility	Categorical variable (0=Road in poor condition and not accessible, 1=Road in poor condition and accessible, 2=Road in good condition but not accessible, 3=Road in good condition and accessible)
Exist_march	Existence of a nearby market	Binary variable (0=no, 1=yes)
Exist_secure	Existence of a secure site	Binary variable (0=no, 1=yes)
Type_tablecloth	Type of water table	Categorical variable (0=Lowland zone, 1=Coastal barrier zone, 2=Intermediate water table zone, 3=Deep water table zone)

This study was carried out in the southern part of Benin, between 6°10 and 6°45 North latitude, and 1°34 and 2°48 East longitude. This region covers the departments of Atlantique, Littoral, Mono, Couffo, Oueme, Plateau and Zou. It is characterized by an equatorial climate with high humidity and a seasonal cycle marked by alternating dry and rainy periods. In this region, market gardening is practiced both in the rainy season and during the dry season; with cultivation techniques adapted to each climatic condition.

In this study, the basic unit of analysis is the market gardeners. For the survey, they were targeted at sites in southern Benin from the coast to the commune of Djidja, approximately 150 kilometers from Cotonou. The choice of these sites in Benin is explained by their importance in market gardening production and the diversity of market garden crops. The market gardeners surveyed were randomly selected to obtain a representative sample of the study population and to ensure the reliability of the results. A total of 474 market gardeners were surveyed.

Table 2 : Sample size

PDA	Investigated	Percentage (%)	Cumulative (%)
4	17	3.59	3.59
5	125	26.37	29.96
6	47	9.92	39.87
7	285	60.13	100.00
Total	**474**	**100.00**	

As part of this study, the primary, quantitative and qualitative data deemed necessary were collected from November to December 2024. Initially, an exploratory phase allowed contact with the resource persons in the study area in order to better plan the survey. It also allowed us to become familiar with local realities and to readjust certain details of the questionnaire. In a second phase, the actual data collection was carried out through direct interviews using a structured questionnaire, administered individually to market gardeners using the KoboCollect tool. Unstructured interviews were also conducted in order to obtain as much information as possible. The data collected relate to the socioeconomic and demographic traits of market gardeners, the adoption of market gardening crops, experience, the working environment of market gardeners, the management tools used, and quantitative data (area available and used, etc.).

Stata 14.0 software was used to analyze the data through the multivariate probit regression model (Greene, 2008) applied to market garden crops including tomato, pepper, onion, horseradish and okra. The multivariate probit model has already been used in a number of empirical studies evaluating the factors that influence the simultaneous adoption of several agricultural technologies (Adekambi et al., 2021; Dassoundo-Assogba et al., 2019).

Results

Table 3 presents the sociodemographic and economic characteristics of the market gardeners surveyed according to their membership in an agricultural development cluster. Variables such as gender, age group, participation in a cooperative, level of education, level of experience, security of production sites, etc. were analyzed in relation to the agricultural development clusters.

Table 3: Descriptive statistics of variables according to the agricultural development pole

Variables	Terms and conditions	Agricultural Development Poles (PDA)				Total	Comparison test
		PDA 4	PDA 5	PDA 6	PDA 7		
Gender	Women	7.1%	30.7%	10.2%	52.0%	100.0%	Pearson chi2(3) = 9.1016 Pr = 0.028
	Man	2.3%	24.8%	9.8%	63.1%	100.0%	
Age group	Young	1.1%	25.4%	11.8%	61.8%	100.0%	Pearson chi2(3) = 13.7063 Pr = 0.003
	Adult	6.9%	27.7%	7.4%	57.9%	100.0%	
Cooperative member	No	4.4%	46.7%	28.9%	20.0%	100.0%	Pearson chi2(3) = 39.2336 Pr = 0.000
	Yes	3.5%	24.2%	7.9%	64.3%	100.0%	
Educational level	None	11.7%	45.0%	0.0%	43.3%	100.0%	Pearson chi2(12) = 46.2159 Pr = 0.000
	Primary	5.8%	34.6%	7.7%	51.9%	100.0%	
	Secondary 1	2.8%	28.4%	9.2%	59.6%	100.0%	
	Secondary 2	2.5%	21.5%	15.7%	60.3%	100.0%	

Variables	Terms and conditions	Agricultural Development Poles (PDA)				Total	Comparison test
		PDA 4	PDA 5	PDA 6	PDA 7		
	Superior	0.8%	17.4%	10.6%	71.2%	100.0%	
Experience in market gardening	Beginner	0.0%	50.0%	0.0%	50.0%	100.0%	Pearson chi2(9) = 20.1447 Pr = 0.017
	Junior	1.8%	36.4%	8.2%	53.6%	100.0%	
	Confirmed	3.9%	26.0%	14.9%	55.2%	100.0%	
	Senior	4.4%	20.4%	6.1%	69.1%	100.0%	
Vocational training	No	4.1%	27.2%	8.9%	59.8%	100.0%	Pearson chi2(3) = 2.6451 Pr = 0.450
	Yes	2.2%	24.3%	12.5%	61.0%	100.0%	
Existence of a market gardening promotion structure	No	7.7%	37.0%	6.1%	49.2%	100.0%	Pearson chi2(3) = 36.8274 Pr = 0.000
	Yes	1.0%	19.8%	12.3%	66.9%	100.0%	
Existence of market gardening support advice	No	0.0%	51.4%	16.2%	32.4%	100.0%	Pearson chi2(3) = 17.6616 Pr = 0.001
	Yes	3.9%	24.3%	9.4%	62.5%	100.0%	
Existence of electricity	No	4.7%	28.4%	12.8%	54.0%	100.0%	Pearson chi2(3) = 7.5583 Pr = 0.056
	Yes	2.7%	24.7%	7.6%	65.0%	100.0%	
Existence of the telephone	No	0.0%	36.7%	15.2%	48.1%	100.0%	Pearson chi2(3) = 12.1812 Pr = 0.007
	Yes	4.3%	24.3%	8.9%	62.5%	100.0%	
Site accessibility	Road in poor condition and not accessible	5.9%	5.9%	0.0%	88.2%	100.0%	Pearson chi2(9) = 108.5081 Pr = 0.000
	Road in poor condition and accessible	10.7%	27.3%	16.5%	45.5%	100.0%	
	Road in good condition but not accessible	0.0%	6.5%	5.7%	87.8%	100.0%	
	Road in good condition and accessible	1.0%	41.8%	10.2%	46.9%	100.0%	
Existence of a nearby market	No	5.1%	34.8%	12.9%	47.3%	100.0%	Pearson chi2(3) = 38.6070 Pr = 0.000
	Yes	1.8%	16.5%	6.4%	75.2%	100.0%	
Existence of a secure site	No	0.9%	21.5%	14.0%	63.6%	100.0%	Pearson chi2(3) = 6.5717 Pr = 0.087
	Yes	4.4%	27.8%	8.7%	59.1%	100.0%	
Type of water table	Lowland area	0.0%	19.8%	4.1%	76.2%	100.0%	Pearson chi2(9) = 116.8136 Pr = 0.000
	Coastal barrier area	0.0%	9.8%	2.4%	87.8%	100.0%	
	Intermediate water table zone	3.0%	45.0%	18.0%	34.0%	100.0%	
	Deep water table zone	11.7%	31.7%	16.7%	40.0%	100.0%	

Variables such as vocational technical training, the availability of electricity and the availability of a secure site do not vary significantly depending on the PDA.

On the other hand, gender, age group, membership of a cooperative, level of education, experience in market gardening, existence of market gardening promotion structure, existence of market gardening advisory support, existence of a telephone network, accessibility of the site, existence of a market close to the site, type of water table very significantly from one PDA to another.

Table 4 presents the adoption rates of the different local market garden crops adopted by producers. The results reveal that pepper is the most adopted market garden crop in the study area (78.48%); followed respectively by tomato (49.58%), okra (39.87%), krinkrin (31.43%) and finally onion (17.93%) in the category of these local crops studied.

The analysis of the combined adoption of different market garden crops reveals that the majority of producers opt for two crops at a time, i.e. 27.43% of the producers interviewed. Also, 25.74% of the producers surveyed practiced four crops at a time compared to 18.99% for the three crops, 10.13% for one crop and 3.80% for none of these five crops studied.

Table 4: Adoption rate of market gardening crops

Adopted cultures	Adopters	Percentage (%)
Capsicum annuum (Pepper)	372	78.48
Solanum lycopersicum (Tomato)	235	49.58
Okra (Abelmoschus esculentus)	189	39.87
Krinkrin (Corchorus olitorius)	149	31.43
Onion (Allium cepa)	149	17.93
Number of cultures adopted at a time		
No culture	48	3.80
A culture	130	10.13
Five cultures	18	13.92
Three cultures	122	18.99
Four cultures	66	25.74
Two cultures	90	27.43

The analysis of the determinants of the choice of market garden crops was approached by assuming the different possible market gardening systems. To this end, it is noted through the literature that Traoré (2022) proposes a categorization of market garden crops, namely local or traditional species such as okra, tomato, leafy vegetables, etc., then exotic species such as lettuce, cabbage, carrot, etc. Going practically in the same direction, Simeni et al. (2009). He mentioned the existence of three main market gardening systems, namely the traditional crop system, the exotic crop system and the mixed crop system.

Furthermore, within the local or traditional culture system, based on the work of Yao et al. (2015) exclusively dedicated to leafy vegetables, we believe that there are still possible subdivisions to further refine the research into the determinants of the choice of market garden crops. Indeed, the

literature grants almost vital importance to leafy vegetables because they provide the majority of medicinal constituents and micronutrients essential to human health (Shiundu, 2002; Stevels, 1990). This precisely pushes us to single them out in our analyses, which allows us to run the first multivariate probit model dedicated to tomato, pepper, onions, krinkrin and okra.
Table 5 presents the estimation results of the first multivariate probit model relating to local crops: tomato, chili, onion, krinkrin and okra.

Table 5: Estimation of the multivariate probit model

	Tomato Coef (Z Test)	Pepper Coef (Z Test)	Onion Coef (Z Test)	Krinkrin Coef (Z Test)	Okra Coef (Z Test)
Location of the agricultural development center	0.132 (1.68*)	0.184 (2.05**)	0.255 (2.70***)	-0.0009 (-0.01)	-0.078 (-1.07)
Membership in a cooperative	-0.599 (-2.27**)	-0.536 (-1.88*)	0.157 (0.47)	-0.275 (-1.08)	0.242 (0.95)
Gender	0.0402 (0.25)	0.408 (2.46**)	-0.034 (-0.18)	-0.428 (-2.80***)	-0.121 (-0.81)
Educational level	0.249 (4.24***)	0.052 (0.90)	0.144 (2.12**)	0.151 (2.59***)	0.112 (2.09**)
Accessibility of the village	0.026 (0.38)	-0.369 (-4.48***)	0.174 (2.24**)	-0.114 (-1.69*)	-0.071 (-1.11)
Existence of electrical energy	-0.333 (-2.31**)	0.217 (1.41)	0.215 (1.32)	0.180 (1.28)	-0.041 (-0.32)
Existence of telephone network	0.90 (54.68***)	-0.024 (-0.12)	0.765 (3.07***)	0.592 (3.02***)	0.537 (3.06***)
Existence of a market in the village	-0.640 (-4.40***)	-0.519 (-3.22***)	-0.499 (-3.05***)	-0.480 (-3.40***)	-0.423 (-3.14***)
Existence of a market gardening promotion structure	0.006 (0.05)	0.019 (0.12)	0.466 (2.65***)	0.185 (1.28)	0.049 (0.36)
Use of farm management tools	-0.581 (-3.06***)	-0.261 (-1.25)	0.023 (0.11)	-0.665 (-3.59***)	-0.048 (-0.27)
Site security	0.280 (1.59)	1.10 (6.08***)	0.445 (2.29**)	0.391 (2.19**)	0.398 (2.32**)
Type of area related to the proximity or not of the water table	0.420 (7.27***)	-0.041 (-0.67)	0.150 (2.14**)	-0.027 (-0.50)	0.138 (2.59**)
Age group	0.161 (1.06)	0.109 (0.66)	0.239 (1.41)	0.095 (0.64)	0.077 (0.54)
Level of professional experience in market gardening	-0.033 (-0.35)	-0.070 (-0.68)	0.352 (3.08***)	-0.297 (-3.24***)	-0.084 (-0.95)
Number of observations = 474 Wald chi2(70) = 316.66 Prob > chi2 = 0.0000 Log likelihood = -1139.5858					
	Coefficient (z test)			Coefficient (z test)	
rho21	0.541 (7.92***)		**rho42**	0.3745418 (4.61***)	
rho31	0.465 (5.87***)		**rho52**	0.2266077 (2.93***)	
rho41	0.269 (3.68***)		**rho43**	-0.0231471 (-0.26)	
rho51	0.235 (3.26***)		**rho53**	0.0908882 (1.08)	
rho32	0.197211 (2.08**)		**rho54**	0.358327 (5.20***)	
Log likelihood: rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho > 54 = 0: chi2(10) = 127.548 Prob > chi2 = 0.0000					

The likelihood ratio test for the overall correlation of error terms in the different models (chi2 (10) = 127.548; p < 0.001) is significantly different from zero at the 1% level and therefore allows us to reject the hypothesis of the independence of the choices of the different crops analyzed. The decision to adopt a market garden crop between tomato, chili, onion, krinkrin and okra is therefore determined by that of another and vice versa.

On the other hand, the correlation between the decision to adopt krinkrin and onion is negative and not significant at the 1% level (rho = -0.023; p > 0.01). This is also the case with the correlation between the decision to adopt okra and onion which was found to be positive and not significant at the 1% level (rho = 0.908; p > 0.01).

The correlations between the decisions to adopt pepper and tomato, onion and tomato, krinkrin and tomato, okra and tomato, onion and pepper, krinkrin and pepper, okra and pepper, okra and krinkrin are all positive and significant at the 1% level (rho21=0.541; rho31=0.465; rho41=0.2692; rho51=0.235; rho32=0.197 rho42=0.3745; rho52=0.226 and rho54=0.358; p < 0.001).

Also, from this table, it appears that the variables that significantly influence the adoption of at least one of the five market gardening crops are: the level of education (positively), the existence of a telephone network (positively), the existence of a market in the village (negatively), the use of farm management tools (negatively), the type of area in relation to the proximity or not of the water table (positively), the accessibility of the village, the security of the site (positively), the location of the agricultural development center, the existence of a market gardening promotion structure (positively), the level of professional experience in market gardening (positively for onions and negatively for krinkrin) and gender (positively for pepper and negatively for krinkrin).

Only one variable among the fourteen (14) tested variables has the merit of significantly influencing the adoption of the five market garden crops simultaneously; it is the existence of a market in the village, that has a negative effect. This means that the producers interviewed adopt tomato, pepper, onions, krinkrin and okra when there is no physical market close to their villages.

Discussion

The market gardening production increase in southern Benin is now reality, thanks to projects and programs, and strong support from grassroots stakeholders, in addition to political will. However, this increase does not yet rhyme with year-round self-sufficiency. To this end, we thought that

analyzing the choice of local market garden crops would undoubtedly help find solutions to the problem.

Thus, the results reveal that in southern Benin, pepper is the most widely adopted market garden crop, followed by tomato. This result relating to adoption is not entirely in line with the national production data from the Directorate of Agricultural Statistics of the Ministry of Agriculture, Livestock and Fisheries, which specifies that over the last five years, the average production of tomato is 299,075 tons, while that of pepper is 117,080 tons (DSA/MAEP, 2024). This qualifies our results to some extent in the sense that even if pepper is widely adopted in the south of Benin, the effect of this adoption is not sufficient to give a production of pepper higher than that of tomato. Our results do not deviate too much from those of Allogni *et al.* (2015), which demonstrated through a financial analysis that all chili production systems are profitable in southern Benin compared to others, which can clearly justify its adoption. In the same vein, Alinsato and Yagbedo (2018), recall the production areas in the south of Benin, notably the Adja plateau in the South-west, the South-east region and the peri-urban areas of Cotonou, Abomey-Calavi and Porto-Novo, as well as their characteristics confirm our conclusions.

On another level, the results show that the existence of a market in the village is the only factor that simultaneously determines the choice of all the crops studied with a negative effect. Clearly, the producers interviewed adopt more tomato, pepper, onions, krinkrin and okra when there is no physical market close to their villages. This result may seem paradoxical, especially since it deviates from the conclusions of certain authors such as Fayolle *et al.* (2008); and Robast *et al.* (2006). Indeed, the latter are unanimous on the fact that the existence of physical markets contributes to the integration of market gardeners into formal distribution channels, thus improving the quality and traceability of products. However, the results we have reached must be qualified because the context in southern Benin is marked by relatively short distances to reach the sales markets, the largest of which is Dantokpa market in Cotonou. Under these conditions, not having a market close to one's village is no longer necessarily a problem for market gardeners, especially since they specifically seek out urban markets, which are generally more profitable. The Dantokpa market in Cotonou is a prime example of the importance of physical markets in the marketing of market garden products. It constitutes a nerve center hub for the sale of local agricultural products, where market garden produce is sold directly, contributing to the food supply of major cities such as Abomey-Calavi, Cotonou, Porto-Novo, and surrounding areas.

Our work also shows that the education level positively influences the adoption of at least one of the five market garden crops. This is perfectly

in line with the results of other studies that have found that the level of education of producers has a direct impact on their ability to adopt improved production techniques. According to Tchouamo *et al*. (2005), producers with higher levels of education are more likely to use modern farming methods, which improves the productivity and sustainability of their vegetable farms. Similarly, educated farmers tend to have a better understanding of market issues and are better able to manage risks associated with vegetable production (Fofana *et al.*, 2010).

Our results also confirm that the existence of a telephone network positively influences the adoption of at least one of the five market garden crops. According to the literature, the availability of an efficient telephone network greatly facilitates agricultural production by improving communication between producers, suppliers and potential markets. According to Sassi and Goaied (2013), farmers with access to a telephone network can obtain information on market prices, weather and new farming techniques more quickly, which optimizes their decision-making. In addition, Duflo et al. (2012) emphasize that access to mobile telephony allows producers to reduce risks related to market uncertainty and improve the profitability of their market gardening production by optimizing supply chains. The same effect and the same interpretation are valid for the existence of a market gardening promotion structure near producers.

Through our collected data, our analyses also reveal that the use of farm management tools negatively influences the adoption of at least one of the five market garden crops. This postulate may seem implausible at first glance. However, given the context marked by the recent nature of the introduction of management tools in market gardening, this observation is easily justified. Indeed, in this same logic, Gathigi (2011) demonstrates that the introduction of complex management tools can hinder the adoption of new agricultural practices, due to the difficulty of integrating these tools into traditional agricultural systems and the lack of appropriate training for producers. Along the same lines, Tchouamo et al. (2005) point out that the use of farm management technologies can sometimes lead to an overload of information and administrative tasks, which could discourage some producers.

Another dimension of the research is that the type of area in relation to the proximity or not of the water table positively affects the adoption of at least one of the five market garden crops. Indeed, the proximity of the water table positively influences the adoption of market garden crops, because easy access to groundwater allows producers to guarantee stable and continuous irrigation, which is crucial for market garden production. For Duflo e*t al.* (2012), areas close to water tables offer a considerable advantage for market gardeners, as they allow good water availability and reduce dependence on

climatic conditions, which favors the adoption of market gardening crops. Similarly, Tallet (1983) argues that irrigation facilitated by proximity to the water table is a key factor for the adoption of market gardening, particularly in semi-arid areas where access to groundwater makes it possible to maintain stable and regular production.

The results also demonstrate that site security positively influences the adoption of at least one of the five market garden crops. According to Wanyama *et al*. (2019), securing farm sites is a key factor in the adoption of market gardening, as it allows producers to reduce land tenure risks and focus on medium- and long-term investments in agricultural infrastructure such as irrigation and fertilization. *Kouadio et al.* (2014) indicate that securing sites, particularly through clear land policies and sustainable land management systems, plays a key role in stimulating the adoption of market gardening crops, as it provides producers with a stable environment to cultivate and increase their productivity. Clearly, securing land tenure is a central element that positively influences adoption, by guaranteeing producers sustainable access to land, which encourages them to invest in modern agricultural practices and adopt intensive crops (Bationo *et al.*, 2010).

If there is one result that seems ambiguous in the context of our present work, it is the fact that the level of professional experience in market gardening positively influences the adoption of onions and at the same time negatively the adoption of krinkrin. In the same logic, gender positively influences the adoption of pepper and negatively the adoption of krinkrin. In the present case and for both onions and pepper, the constant is that experienced producers better identify favorable conditions for growing onions and also better apply more efficient irrigation and fertilization methods, which improves their profitability (Duteurtre, 2006). To go further, Koffi and Oura (2019) believe that professional experience positively influences the adoption of innovative agricultural practices. For example, strengthening the technical and organizational capacities of onion producers is a particularly important issue given the demands of this crop (David-Benz and Seck, 2018). Thus, the negative influence of krinkrin compared to the professional experience on the one hand and gender on the other hand, can be justified by the fact that experienced producers generally prefer to focus on more profitable and proven crops such as onion and chili, to the detriment of lesser-known crops such as krinkrin, perceived as less lucrative or riskier. In summary, experienced producers, having already mastered more popular and profitable crops such as chili and onion, are very hesitant to diversify their production with less conventional crops (Sassi and Goaied, 2013; Tchouamo *et al.*, 2005).

Conclusion

This study used a multivariate probit model to analyze the factors that determine the adoption of local crops, including tomato, pepper, onions, krinkrin and okra in southern Benin, in order to contribute to the scientific debate on the determinants of adoption. The results revealed adoption rates of 78.48% for pepper, 49.58% for tomato, 39.87% for okra, 31.43% for krinkrin and 17.93% for onions. The results also revealed the existence of interdependence in the adoption of the different local vegetable crops studied. The decision to adopt a local vegetable crop is determined by the adoption of another local vegetable crop and vice versa. Overall, the majority of producers surveyed prefer to adopt a combination of two crops at a time (27.43%) or four crops at a time (25.74%). The results of the study also revealed that the existence of a market in the village, the level of education, the existence of a telephone network, the type of area in relation to the proximity or not of the water table and the security of the sites are the main factors determining the adoption of local market gardening crops. Based on these empirical results, the study proposes that agricultural policies aimed at promoting market gardening crops should be oriented towards supporting the creation of inter-professional organizations, the harmonious organization of market gardening production according to agricultural development centers and then the creation of infrastructure and equipment to make fresh market garden produce available in all seasons.

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