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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

Olouhitin Mouléro Franck Ronald Adjobo
Laboratoire d'Analyse et de Recherches sur les Dynamiques Économiques et Sociales (LARDES) de l'Université de Parakou, Bénin

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Abstract

For over two decades, Benin has experienced a steady rise in market gardening production. However, this growth has not translated into self-sufficiency, as the country continues to rely on imports from neighboring nations during lean seasons. Analyzing the factors influencing the choice of local market garden crops could provide valuable insights for addressing this issue. This study employed a multivariate probit model to identify the determinants influencing the adoption of specific market garden crops, namely tomato, pepper, onion, krinkrin, and okra, on farms in southern Benin. The research was conducted using a randomly selected sample of 474 market gardeners. Findings revealed interdependence and complementarity in the adoption of the various crops studied. Notably, most surveyed producers preferred adopting combinations of either two (27.43%) or four (25.74%) crops at a time. Moreover, key factors influencing crop adoption included the presence of a local market, the farmers' level of education, access to a telephone network, the nature of the area, particularly its proximity to the water table, and the security of farming sites.

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

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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 $U1(\pi)$, is higher than that which he would obtain if he had not adopted it, represented by $U0(\pi)$, i.e., $U1(\pi) > U0(\pi)$. 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

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characteristics of the said producer noted (X_i) and can be represented by the following latent variable: $U_i = X_i\beta + \varepsilon_i$, $i = 1,2, \ldots, N$ (1); where β is the vector of coefficients and ε_i 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 maximum likelihood estimation. 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 groups 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

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

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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 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,

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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 relates 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 analyzes the sociodemographic and economic characteristics of the surveyed market gardeners based on their membership in agricultural development clusters. The analysis considered factors such as gender, age group, cooperative involvement, education level, experience, and security of production sites.

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%	
	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%	

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Variables	Terms and conditions	Agricultural Development Poles (PDA)				Total	Comparison test
		PDA 4	PDA 5	PDA 6	PDA 7		
	Yes	2.2%	24.3%	12.5%	61.0%	100.0%	Pearson chi2(3) = 2.6451 Pr = 0.450
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

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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 local market garden crops among producers. Pepper shows the highest adoption rate (78.48%), followed by tomato (49.58%), okra (39.87%), krinkrin (31.43%) and onion (17.93%).
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

	Adopters	Percentage (%)
Agricultural crop adoption rate		
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 crops adopted at a time		
No crop	48	3.80
One crop	130	10.13
Two crops	90	27.43
Three crops	122	18.99
Four crops	66	25.74
Five crops	18	13.92

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.

Drawing from Yao et al. (2015) study on leafy vegetables in local or traditional agriculture, we propose further subdivisions to better understand market garden crop choice. Given the literature's emphasis on leafy vegetables as key sources of medicinal compounds and micronutrients (Shiundu, 2002; Stevels, 1990), we single them out for analysis. This leads to our first multivariate probit model, focusing on tomato, pepper, onions, krinkrin, and okra.

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Table 5 presents the estimation results of the first multivariate probit model, which analyzes the adoption of 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

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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).

From this same 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 of the fourteen tested variables significantly influences the simultaneous adoption of the five market garden crops: the presence of a village market, which has a negative effect. This implies that interviewed producers are more likely to adopt tomato, pepper, onions, krinkrin, and okra when there is no physical market near their villages.

Discussion

Increased market gardening production in southern Benin is now a reality, driven by projects, programs, strong grassroots support, and political will. However, this growth has not yet translated to year-round self-sufficiency. To address this, we believe that analyzing the choice of local market garden crops will be crucial in finding solutions.

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

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(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.

The results indicate that pepper is the most widely adopted market garden crop in southern Benin, followed by tomato. This adoption pattern contrasts with national production data (DSA/MAEP, 2024) showing an average tomato production of 299,075 tons over the last five years, compared to 117,080 tons for pepper. This suggests that while pepper adoption is high in the south, its impact on overall production is not yet greater than that of tomato. Our findings align with Allogni et al. (2015), whose financial analysis demonstrated the profitability of all chili production systems in southern Benin, potentially explaining its adoption rate. Similarly, Alinsato and Yagbedo (2018) identified key production areas in southern Benin (Adja plateau, South-east, and peri-urban Cotonou-Abomey-Calavi-Porto-Novo) and their characteristics support our conclusions.

Furthermore, the presence of a village market is the sole factor negatively influencing the simultaneous adoption of all studied crops. Specifically, interviewed producers tend to adopt more tomato, pepper, onions, krinkrin, and okra when a physical market is not located near their villages. This seemingly paradoxical finding contrasts with Fayolle et al. (2008) and Robast et al. (2006), who emphasize the role of physical markets in integrating market gardeners into formal distribution channels, thereby improving product quality and traceability. However, our results are qualified by the context of southern Benin, characterized by relatively short distances to sales markets, notably the large Dantokpa market in Cotonou. In this context, the absence of a local market may not be a significant impediment, especially as producers often target more profitable urban markets. The Dantokpa market exemplifies the importance of physical markets as central hubs for local agricultural product sales, directly contributing to the food supply of major cities like Abomey-Calavi, Cotonou, and Porto-Novo.

Moreover, our findings indicate that education level positively influences the adoption of at least one of the five market garden crops. This aligns with previous research showing a direct impact of education on producers' ability to adopt improved production techniques. As Tchouamo et

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al. (2005) noted, more educated producers are more likely to use modern farming methods, enhancing the productivity and sustainability of their vegetable farms. Similarly, educated farmers tend to have a better grasp of market dynamics and are better equipped to manage risks in vegetable production (Fofana et al., 2010).

Our findings also confirm that the presence of a telephone network positively influences the adoption of at least one of the five market garden crops. As highlighted in the literature, an efficient telephone network significantly aids agricultural production by improving communication among producers, suppliers, and markets. Sassi and Goaied (2013) note that access to a telephone network enables farmers to obtain timely information on market prices, weather, and new farming techniques, thus optimizing their decision-making. Additionally, Duflo et al. (2012) emphasize that mobile telephony reduces risks associated with market uncertainty and enhances the profitability of market gardening by optimizing supply chains. This same positive effect and interpretation apply to the presence of a market gardening promotion structure near producers.

Our data analysis also reveals a negative influence of farm management tool usage on the adoption of at least one of the five market garden crops. While seemingly counterintuitive, this finding is understandable given the recent introduction of these tools in market gardening in our context. Gathigi (2011) similarly found that the introduction of complex management tools can impede the adoption of new agricultural practices due to integration challenges with traditional systems and insufficient producer training. Likewise, Tchouamo et al. (2005) noted that farm management technologies can sometimes lead to information overload and increased administrative burden, potentially discouraging some producers.

What's more, our research shows that the type of area, specifically its proximity to the water table, positively influences the adoption of at least one of the five market garden crops. Indeed, easy access to groundwater due to a shallow water table allows producers to ensure stable and continuous irrigation, crucial for market garden production and thus favoring its adoption. Duflo et al. (2012) similarly highlight the significant advantage for market gardeners in areas near water tables, as it ensures good water availability and reduces reliance on climatic conditions. As well, Tallet (1983) argues that irrigation facilitated by proximity to the water table is a key factor for market gardening adoption, especially in semi-arid regions where groundwater access enables 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

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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).

A seemingly ambiguous finding in our study is that professional experience positively influences onion adoption while negatively affecting krinkrin adoption. Similarly, gender positively influences pepper adoption but negatively impacts krinkrin adoption. For onions and pepper, experienced producers likely better identify favorable growing conditions and apply more efficient irrigation and fertilization methods, thus improving profitability (Duteurtre, 2006). This aligns with Koffi and Oura (2019), who suggest that professional experience generally fosters the adoption of innovative agricultural practices. For instance, strengthening onion producers' technical and organizational capacities is crucial (David-Benz & Seck, 2018). The negative influence on krinkrin adoption by both experience and gender could be attributed to experienced producers' preference for more profitable and established crops like onion and chili, potentially viewing lesser-known crops like krinkrin as less lucrative or riskier. In essence, experienced producers, having mastered popular and profitable crops like chili and onion, are hesitant to diversify with less conventional options (Sassi & 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

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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.

This study employed a multivariate probit model to analyze the determinants of local crop adoption (tomato, pepper, onions, krinkrin, and okra) in southern Benin, contributing to the scientific discourse on adoption factors. The findings revealed the following adoption rates: pepper (78.48%), tomato (49.58%), okra (39.87%), krinkrin (31.43%) and onions (17.93%). Notably, the adoption of these local vegetable crops showed interdependence, with the decision to adopt one influencing the adoption of others. Most surveyed producers favored adopting two (27.43%) or four (25.74%) crops simultaneously. Key factors influencing local market gardening crop adoption were identified as the presence of a village market, education level, telephone network availability, proximity to the water table, and site security. Based on these results, the study recommends that agricultural policies promoting market gardening should focus on supporting inter-professional organizations, harmonizing production according to agricultural development centers and developing infrastructure and equipment for year-round availability of fresh produce.

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