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Research Paper

Characterization of water control techniques in recession of the Oueme low valley

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Abstract. In Benin, producers' difficulties in effectively managing water for recession or off-season crops have increased mainly because of the lack of mastery of adequate techniques, and the lack of access to modern or semi-modern materials of the efficient management of water in the lowlands. The purpose of this article is to identify the best irrigation practices that allow market garden production in Adjohoun, Dangbo and Bonou towns to increase in the future. To achieve this, a characterization followed by a classification of the variables was used. The study contributes to improving the efficient management of water in the valleys of Benin. Data from the study were collected from a sample of 306 producers including 96 producers in Bonou town, 112 producers in Adjohoun town and 98 producers in Dangbo town. The results show that there are three classes of producers namely; The first class characterized by the techniques of manual irrigation and the use of the river as a source of water during the dry season. The second class characterized by the use of the irrigation system with manual irrigation especially by married men in the town of Dangbo, and the third class characterized by the technique of semi-motorized irrigation, maintenance of equipment, use of water retention in the rainy season and access to gasoline. Of the five variables in the models, the maintenance techniques are determined by three variables which are the town, the ethnicity and the year of experience. The main local techniques are determined by four variables which are the town, ethnicity, age and year of experience. Seedlings are frequently moved in the town of Bonou. Mulching is frequently used in the town of Adjohoun with a frequency of use almost similar in the other towns. Improved seeds are widely used in Adjohoun and Dangbo towns. Producers' activities are more diversified in Adjohoun and Dangbo towns. Plant protection habits are more common in Adjohoun and Dangbo towns. The frequency of irrigation is higher in the town of Adjohoun.

Keywords: Irrigation system, maintenance technique, main local technique, vegetable production.

INTRODUCTION

In Benin, agriculture is the main activity of 70% of the active population. The sector provides more than 88% of export earnings and accounts for 15% of government revenue (Strategic Plan for the Revival of the Agricultural Sector (PSRSA), 2011). Its contribution to Gross Domestic Product increased from 32.3% in 2008 to 33.3% in 2011 before declining to 32.6% in 2012 and then to 33% in 2013% (Ministry of Agriculture, of Breeding and the Fishing (MAEP), 2014a). Benin's main source of economic development, Beninese agriculture, remains subsistence agriculture, mainly rain-fed, and therefore dependent on climatic hazards. Despite the immense hydro-agricultural potential of the country, only 17% (about 1,375,000 ha) of agricultural area are cultivated annually with 60% devoted to the main food crops. Similarly, out of 12,257 hectares of managed land available, only 1,284 hectares of managed land has total control against 10,973 hectares with partial control. These developments represent only 3.8% of the irrigable land potential estimated at 322,000 hectares (excluding the potential of the Pendjari and Couffo); including 205,000 hectares of lowlands and 117,000 ha of irrigable plains and valleys that can be developed value (PSRSA, 2011). In addition, climate change poses a potential threat to the already precarious livelihoods of rural people in sub-Saharan African countries and exacerbates their pre-existing vulnerability (Codjia, 2009). Therefore, a no less important alternative is the control of the water factor through the reduction of its consumption and the increase of its efficient use and its productivity (Bouman *et al*., 2005). This is justified by the fact that recently observed climatic changes induce increasingly dry ecosystems. In fact, Agbossou and Sintondji (2000) state that: "In West Africa, the 1970s were characterized by a global trend of a sudden drop in rainfall." According to Tapsoba (1997), the 1971-1990 period has an average rainfall deficit of 180 mm of water compared to that of 1951-1970. This situation dangerously mortgages agricultural production, particularly in countries where non-control of water is recognized as the main bottleneck to land productivity. Population growth and land use due to agricultural expansion and deforestation have led to multiple pressures on global freshwater resources (Nejadhashemi *et al*., 2012).

In this context, the future agricultural development strategies of most of these countries depend on the possibility of maintaining, improving and expanding irrigated agriculture. In many developing countries, irrigation accounts for up to 95% of all water uses, and plays an important role in food production and food security in sub-Saharan Africa (Shiklomanov *et al*., 2000). The countries in which the foundations of modern agriculture have been laid are those that have made real progress in the field of water control for agricultural purposes. Thus, achieving food self-sufficiency remains a priority in many countries where population growth and severe economic problems have reduced living standards and altered dietary habits, thus spreading malnutrition (FAO, 2015). To achieve this, future food security depends on the rapid expansion of irrigated areas (Gowing *et al.*, 2004). Deficits between the available resource and the demand for water, particularly agricultural, have become a recurring concern in many parts of the world (Montginoul, 2011). Environmental concerns are now forcing a call to question the large volumes allocated to irrigation. Improving water management is becoming an important strategy for addressing future water scarcity (Molden *et al*., 2003). In this paradoxical context of wetlands, where abundance does not exclude scarcity, controlling water for agricultural needs remains a major concern in several regions of the world (Lavigne *et al*., 1996). This disparity between abundance and low water valuation implies placing particular emphasis on water management practices for agriculture in Benin. A clear understanding of the different water management options, as well as the different irrigation technologies for market gardening in wetlands is a prerequisite for sustainable management of water resources in order to achieve food security (Kohansal and Darani, 2009). Therefore, one wonders what are the strategies that producers use to make the best use of wetlands for flood recession production? The purpose of this article is to identify the best irrigation practices that allow market garden production in Adjohoun, Dangbo and Bonou towns to increase in the future.

MATERIALS AND METHODS

Study area

The data used were collected in the Ouémé Valley in southern Benin. It corresponds to the lower part of the Ouémé river which starts after the confluence with the Zou river. Characterized by a flood plain in the form of an elongated triangle measuring 90 km from north to south, it is bounded on the south by Nokoué lake and the Porto-Novo lagoon; to the north, east and west, its boundaries are imprecise because they vary enormously with the size of the floods. Its area can therefore vary from 1000 to 9000 km² depending on when the observations were made (Lalèyè, 1995).

Sampling

For this study, the choice of research units was made on the basis of the diversity of geographical situations and types of exploitation (Figure 1). Indeed, three criteria were used namely: the area planted, agriculture as main activity, and the practice of recession cultivation. The sample size was determined by reasoned random sampling based on the use of the Dagnelli formula ($n = \frac{4*p*(1-p)}{0.05^2}$) with p = proportion of producers who market vegetables in the study groups. After determining the sample size, the determination of the number of households per village was made in proportion to the size of the population of each village. A survey rate of 30% was applied for the size of each municipality given time and resources.

Model's variables description

Dependent variables

The dependent variables used vary from model to model. In fact, for the main local techniques, the main local technical variables technique with tillage was included in the first model. For holding techniques, tillage variables

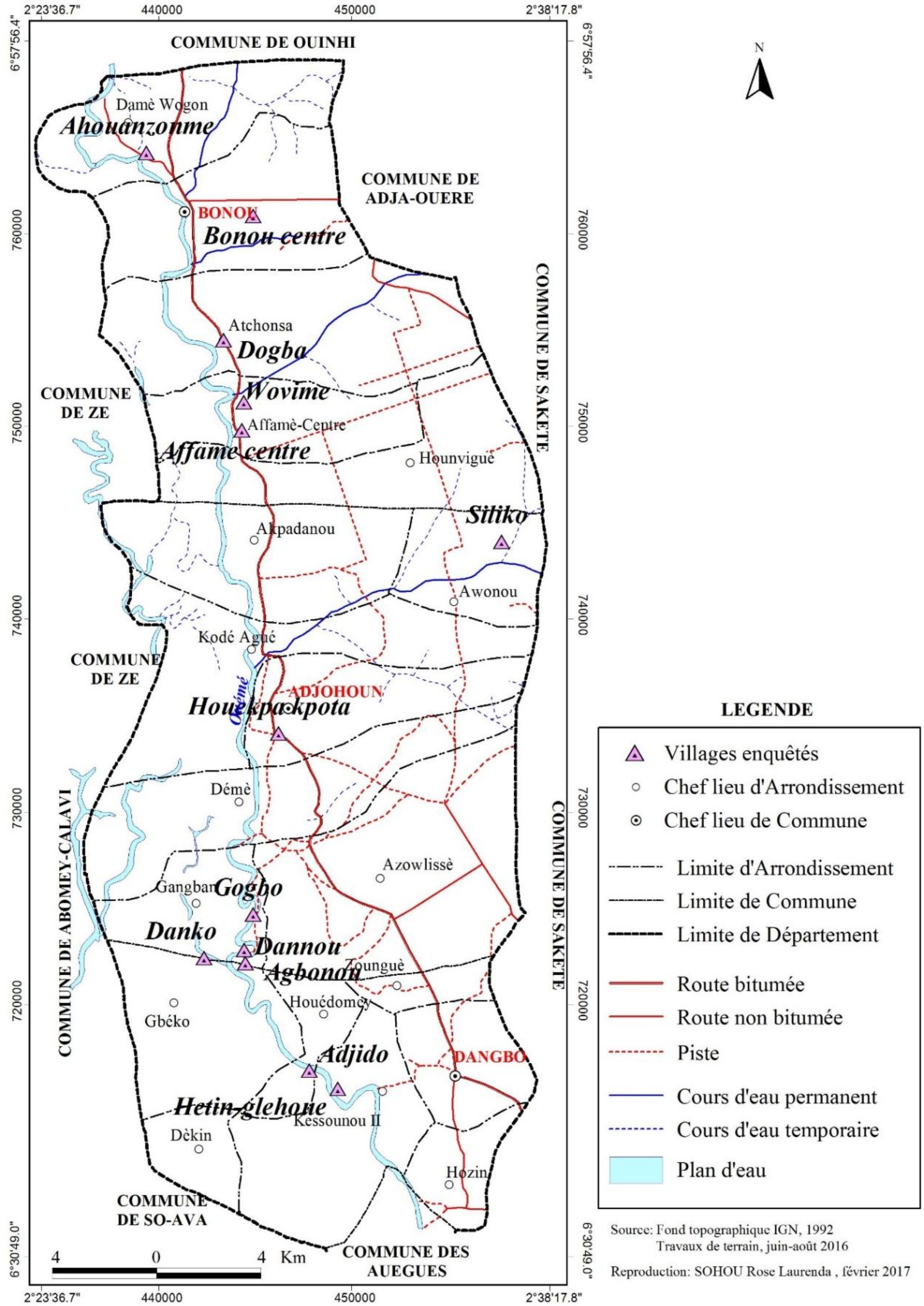

Figure 1. Sampling map of the study area.

with rice residues, tillage with maize residues, and cowpea haul are considered in the second model. According to Fuentes *et al*. (2009) and Brunel *et al*. (2013), mulching reduces evapotranspiration and facilitates water absorption by plants. In addition, these are endogenous techniques of water management.

Table 1. Description of the independent variables used in the models.

Variables		Variables types	Expected effects
Dependent variables			
Main local techniques	Mulching		Positive
	Straw		Positive
		Ordinate	
Main water maintenance	Rice straws		Positive
	Corn straws		Positive
	foliage of cowpea		Positive
Independent variables			
Sex		Binary	Positive/Négative
Districts		Ordinate	Positive
Age		Continue	Positive
Ethnic		Ordinate	Positive/Négative
Year of experience		Continue	Positive

Independent variables

The municipality: The municipality of membership is measured not only by the specificity of the producers in each town, but also by the exchange that could have between them. Indeed, the producers of the town of Adjohoun have intrinsic characteristics which could vary according to the two other towns. In addition, although the communities are adjacent, the producers may not share the information regarding flood control management techniques. The structures or organizations of producers are distinct depending on whether one is located in one of the municipalities in the study area (Table 1).

Age: The age of the respondent is a continuous variable. Several authors have shown that young people use technologies less than older people (because they may have accumulated capital or preferentially access credit because of their age) (Adégbola and Azontonde, 2006; Sall *et al*., 2000) in contrast to Glele *et al*. (2008) and Ouedraogo (2003) for whom the youngest tend to use more technologies than the elderly. For example, young farmers have a long-term planning horizon and may be more willing to take risks (Zegeye *et al*., 2001). On the basis of these observations, we believe that the sign of this variable can be positive.

Sex: Sex is a binary variable that takes the value 0 when the producer is a woman and 1 for men. The use of technology may be better for men than for women or the opposite. According to Bindlish and Evenson (1997), female farmers are more likely to seek contact with agricultural extension services than male farmers, because they want to offset their limited access to credit and other inputs by using more advisory services for extension programs. However, Nambiro *et al*. (2006) found that in Kenya male-headed households are likely to receive an extension visit. In this study, it is expected that the gender variable of the household head will be negatively related to the probability of using a water management technique for recession crops.

Ethnicity: Ethnicity here represents the language spoken in the towns of study. Thus, since the language of the study area is predominantly Weme, it could have specificities at the level of the other ethnic groups in the study area practicing recession farming techniques.

The number of years of experience in using water management techniques for recession culture is a continuous variable that can have a positive or negative influence on the use of technologies. The more experienced the farmer, the more he becomes aware of the constraints in their production systems and needs specialized knowledge. It is in this context that Adesina and Seidi (1995) and Adesina and Baidu-Forson (1996) confirmed that the experience was positively related to the adoption of new technologies.

Data collection and analysis

Analysis method

The characterization of water management techniques was done through a multiple correspondence analysis and then a classification of producers into similar groups by the Hierarchical Clustering on Principal Components (HCPC) method. The analysis was done with the R software (R Core Team, 2017) under the FactoMineR package (Sebastien *et al*., 2008). The qualitative data has been broken down according to the modalities that compose them. When a category is cited by the respondent, it is coded as 1, and 0 otherwise. The starting data matrix obtained consisted of 64 variables. As a result, we selected variables by eliminating variables with a response rate of less than 10%. The finalized data matrix is made up of 38 variables including the common and the modes of asserting. A multinomial logistic regression is performed to see if membership in one or the other class would be influenced by these factors. Since the number of years of experience and age are rarely linear variables, they have been grouped into classes for analysis. The analysis was performed with the R software under the nnet package (Venables and Ripley, 2002). The analysis of the perception of the producers was evaluated essentially by a frequency analysis in table or in graphs.

Analysis of the determinants of water management techniques

Several theoretical methods have been developed to study the adoption or choice between agricultural technologies. Various econometric models can be used to identify the determinants of adoption. The most commonly used models for adoption studies are the Tobit, Logit and Probit models. The Tobit model is the basic structure of dependent and limited variable models. It is a model for which the dependent variable is continuous but is only observable over a certain interval. Thus, it is a model that lies midway between the linear regression models where the endogenous variable is continuous and observable and the qualitative models. The Logit and Probit models are very close in terms of characteristics. The Probit is a model that follows the reduced centered normal law and Logit the logistic law. For this purpose, Gourieroux (1989) asserts that Logit models were initially introduced as an approximation of Probit models allowing simpler calculations. In this study, the multinomial Probit model was used. It allows in particular to take into account the existence of unobserved characteristics of individuals making choices. To model this situation we associate with each modality a level of utility. We will assume that each of the k modalities, indexed by k (k = 1, ..., K), corresponds to a utility level:

$U_{ik} = \mu_{ik} + \varepsilon_{ik}$ (k = 1, …, K).

Where $\boldsymbol{\mu_{ik}}$ is a deterministic function of observable variables and is an independent random variable.

The individual is supposed to choose the modality k which gives him the maximum utility. Then the probability of choosing the modality k is written according to (Fougère and Kramarz, 2008) in the following way:

$$\Pr[Y_i = k] = \frac{\exp(X'ik\beta)}{\sum_{k=1}^{k}\exp(X'ik\beta)}$$

With Yi as the choice of the individual i, k as the modalities of the choice of each individual, X'_{ik} as the characteristics of each individual i (attribute of each choice k and individual characteristic like the age, the sex) and β the coefficient of each characteristic. The stata 13.0 software was used to estimate the two multivariate probit models.

Data collection

Several methods have been combined for data collection, given the degree of precision expected. These are unstructured interviews, semi-structured interviews, and structured interviews. Data collection is based on individual surveys, supplemented by focus group discussions. This approach allowed for a better understanding of the knowledge, attitudes, practices and perceptions of the target groups in relation to the questions asked (Bless *et al*., 2006). Data collection was conducted from June to August 2016.

RESULTS AND DISCUSSION

The classification of the producers made it possible to generate 3 classes on the basis of variables characteristic of the classes. In fact, variables such as dewatering techniques using tools such as bowls and buckets, manual irrigation techniques using bowls, production towns and semi-motorized irrigation using pipe and motor pump are the most characteristic of partitioning into classes. The first class is characterized by manual dewatering techniques, two waterings per day and river water as the main source of water in the dry season (Table 2). Class 2 is characterized by a manual irrigation system practiced mainly by married men (Table 3). In this class, the activities of producers are often slowed down by diseases such as malaria, physical fatigue, headaches and hip due to manual work and permanent contact with water. Although production environments provide better conditions that can increase income and living standards. Thanks to crop diversification opportunities, as this is also the source of many permanent breeding sites that generate very high densities of crops vectors of malaria (Djegbe, 2016).

Class 3 is represented by a semi-motorized irrigation with the use of the pump at the mine, pipes for irrigation and watering per day (Table 4). In this class, producers have the means for the acquisition and maintenance of modern and semi-modern irrigation tools, these tools allow them to better take advantage of water reservoirs. Tables 2, 3 and 4 illustrate the description of the variables in class 1, 2 and 3.

The results of the Multiple Correspondence Analysis on the three classes, reveal that Axes 1 and 3 are the ones that maximize the graphical representation of the producer classification (Figure 1). The characteristics of

Table 2. Description of class 1 variables.

	Cla/Mod	Mod/Cla	Global	p.value	v.test
0.000					
0.000					
Tirbolbassineseau=Tirbolbassineseau_1	84.821	93.137	52.830	0.000	12.018
Tirbolbassine=Tirbolbassine_0	72.464	98.039	65.094	0.000	10.464
Tirtuyau=Tirtuyau_0	58.788	95.098	77.830	0.000	6.065
moment_irrigationMATSOIR=moment_irrigationMATSOIR_1	69.307	68.627	47.642	0.000	5.917
District = BONOU	76.471	50.980	32.075	0.000	5.716
SEsècheRIV=SEsècheRIV_1	63.025	73.529	56.132	0.000	4.924
Texhmotopompe=Texhmotopompe_0	55.488	89.216	77.358	0.000	4.004
SEpluvRE=SEpluvRE_0	57.143	82.353	69.340	0.000	3.966
moment_irrigation1=moment_irrigation1_0	55.625	87.255	75.472	0.000	3.859
Texhbassines=Texhbassines_1	51.269	99.020	92.925	0.001	3.439
Texhbols=Texhbols_1	51.269	99.020	92.925	0.001	3.439
SEsècheRet=SEsècheRet_0	61.194	40.196	31.604	0.010	2.569
C_entretien_matériel=C_entretien_matériel_0	53.205	81.373	73.585	0.014	2.462
Faire_valoirAchat=Faire_valoirAchat_0	57.692	44.118	36.792	0.035	2.111
C_accèscrédit=C_accèscrédit_0	64.706	21.569	16.038	0.037	2.084
C_fatiguepaludisme=C_fatiguepaludisme_0	51.462	86.275	80.660	0.048	1.975
C_fatiguepaludisme=C_fatiguepaludisme_1	34.146	13.725	19.340	0.048	(1.975)
C_accèscrédit=C_accèscrédit_1	44.944	78.431	83.962	0.037	(2.084)
Faire_valoirAchat=Faire_valoirAchat_1	42.537	55.882	63.208	0.035	(2.111)
C_entretien_matériel=C_entretien_matériel_1	33.929	18.627	26.415	0.014	(2.462)
District = DANGBO	34.426	20.588	28.774	0.012	(2.521)
SEsècheRet=SEsècheRet_1	42.069	59.804	68.396	0.010	(2.569)
District = ADJOHOUN	34.940	28.431	39.151	0.002	(3.065)
Texhbassines=Texhbassines_0	6.667	0.980	7.075	0.001	(3.439)
Texhbols=Texhbols_0	6.667	0.980	7.075	0.001	(3.439)
moment_irrigation1=moment_irrigation1_1	25.000	12.745	24.528	0.000	(3.859)
SEpluvRE=SEpluvRE_1	27.692	17.647	30.660	0.000	(3.966)
Texhmotopompe=Texhmotopompe_1	22.917	10.784	22.642	0.000	(4.004)
SEsècheRIV=SEsècheRIV_0	29.032	26.471	43.868	0.000	(4.924)
moment_irrigationMATSOIR=moment_irrigationMATSOIR_0	28.829	31.373	52.358	0.000	(5.917)
Tirtuyau=Tirtuyau_1	10.638	4.902	22.170	0.000	(6.065)
Tirbolbassine=Tirbolbassine_1	2.703	1.961	34.906	0.000	(10.464)
Tirbolbassineseau=Tirbolbassineseau_0	7.000	6.863	47.170	0.000	(12.018)

the producers of the first class are poorly represented on the axes 1 and 3. Those of the producers of the second class, are very represented on the axis 3 and weakly represented on the axis 1. Finally, the characteristics of the producers of the Class 3 are highly represented on axes 1 and 2 (Table 5).

Table 6 and Figure 2 show the contribution of the first 10 individuals along the axes. Indeed, the first 10 individuals of the first class represent 50.81% of the information of this axis with the use of the technique of irrigation with the tubes, motor pump and maintenance of the materials as variables contributing more. This axis

Table 3. Description of class 2 variables.

	Cla/Mod	Mod/Cla	Global	p.value	v.test
0.000					
0.000					
Tirbolbassine=Tirbolbassine_1	86.486	83.117	34.906	0.000	11.413
Tirbolbassineseau=Tirbolbassineseau_0	71.000	92.208	47.170	0.000	10.397
moment_irrigation1=moment_irrigation1_1	69.231	46.753	24.528	0.000	5.548
District =DANGBO	63.934	50.649	28.774	0.000	5.205
moment_irrigationMATSOIR=moment_irrigationMATSOIR_0	49.550	71.429	52.358	0.000	4.205
C_fatiguepaludisme=C_fatiguepaludisme_1	63.415	33.766	19.340	0.000	3.893
C_entretien_matériel=C_entretien_matériel_0	43.590	88.312	73.585	0.000	3.772
SEsècheMa=SEsècheMa_1	68.000	22.078	11.792	0.001	3.365
Faire_valoirHé=Faire_valoirHé_0	57.447	35.065	22.170	0.001	3.319
C_fatiguemauxdehanche=C_fatiguemauxdehanche_1	60.000	27.273	16.509	0.002	3.081
C_fatiguemauxdetête=C_fatiguemauxdetête_1	53.846	36.364	24.528	0.003	2.950
SEsècheRIV=SEsècheRIV_0	47.312	57.143	43.868	0.004	2.912
C_accès_essence=C_accès_essence_0	42.000	81.818	70.755	0.007	2.694
Texhbassines=Texhbassines_1	38.579	98.701	92.925	0.010	2.582
Texhbols=Texhbols_1	38.579	98.701	92.925	0.010	2.582
moment_irrigationMAT=moment_irrigationMAT_0	40.854	87.013	77.358	0.010	2.565
Texhmotopompe=Texhmotopompe_0	40.854	87.013	77.358	0.010	2.565
C_accèscrédit=C_accèscrédit_1	39.888	92.208	83.962	0.012	2.515
Faire_valoirAchat=Faire_valoirAchat_1	42.537	74.026	63.208	0.014	2.466
Accès_peri_piste=Accès_peri_piste_0	40.940	79.221	70.283	0.031	2.152
Accès_peri_piste=Accès_peri_piste_1	25.397	20.779	29.717	0.031	(2.152)
Faire_valoirAchat=Faire_valoirAchat_0	25.641	25.974	36.792	0.014	(2.466)
C_accèscrédit=C_accèscrédit_0	17.647	7.792	16.038	0.012	(2.515)
moment_irrigationMAT=moment_irrigationMAT_1	20.833	12.987	22.642	0.010	(2.565)
Texhmotopompe=Texhmotopompe_1	20.833	12.987	22.642	0.010	(2.565)
Texhbassines=Texhbassines_0	6.667	1.299	7.075	0.010	(2.582)
Texhbols=Texhbols_0	6.667	1.299	7.075	0.010	(2.582)
C_accès_essence=C_accès_essence_1	22.581	18.182	29.245	0.007	(2.694)
SEsècheRIV=SEsècheRIV_1	27.731	42.857	56.132	0.004	(2.912)
C_fatiguemauxdetête=C_fatiguemauxdetête_0	30.625	63.636	75.472	0.003	(2.950)
C_fatiguemauxdehanche=C_fatiguemauxdehanche_0	31.638	72.727	83.491	0.002	(3.081)

could be described as the axis of producers with a high income level, which allows them to acquire these materials and take care of them. The first 10 individuals of the second class represent about 64% of the information of this axis with the dewatering techniques with use of bowls. This axis could qualify as the axis of low-income producers, lacking the financial capacity to acquire the appropriate materials. The first 10 individuals of the third axis represent 2/3 (76%) of the information of this axis with the technique of irrigation with use of bowls in the mornings and the evenings. This axis, like the second axis, could be described as the axis of producers who do not have enough financial means to acquire the appropriate irrigation materials.

Analysis of local key techniques and maintenance's techniques

The analysis of the tables reveals that the two multivariate probit models have good predictive and estimated properties for all the techniques used. Indeed, the likelihood ratios (-304,227 for the first model and -197,505 for the second model) are significant at the 1%

Table 4. Description of class 3 variables.

	Cla/Mod	Mod/Cla	Global	p.value	v.test
0.000					
0.000					
Faire_valoirHé=Faire_valoirHé_1	30.303	64.935	77.830	0.001	(3.319)
SEsècheMa=SEsècheMa_0	32.086	77.922	88.208	0.001	(3.365)
C_entretien_matériel=C_entretien_matériel_1	16.071	11.688	26.415	0.000	(3.772)
C_fatiguepaludisme=C_fatiguepaludisme_0	29.825	66.234	80.660	0.000	(3.893)
moment_irrigationMATSOIR=moment_irrigationMATSOIR_1	21.782	28.571	47.642	0.000	(4.205)
moment_irrigation1=moment_irrigation1_0	25.625	53.247	75.472	0.000	(5.548)
District=BONOU	8.824	7.792	32.075	0.000	(6.035)
Tirbolbassineseau=Tirbolbassineseau_1	5.357	7.792	52.830	0.000	(10.397)
Tirbolbassine=Tirbolbassine_0	9.420	16.883	65.094	0.000	(11.413)
Tirtuyau=Tirtuyau_1	61.702	87.879	22.170	0.000	8.974
Texhmotopompe=Texhmotopompe_1	56.250	81.818	22.642	0.000	8.005
C_entretien_matériel=C_entretien_matériel_1	50.000	84.848	26.415	0.000	7.716
Texhbassines=Texhbassines_0	86.667	39.394	7.075	0.000	6.321
Texhbols=Texhbols_0	86.667	39.394	7.075	0.000	6.321
moment_irrigationMAT=moment_irrigationMAT_1	41.667	60.606	22.642	0.000	5.149
C_accès_essence=C_accès_essence_1	33.871	63.636	29.245	0.000	4.442
SEpluvRE=SEpluvRE_1	30.769	60.606	30.660	0.000	3.844
District =ADJOHOUN	26.506	66.667	39.151	0.001	3.428
TExharrosoir=TExharrosoir_0	21.481	87.879	63.679	0.001	3.275
Tir_arrosoir=Tir_arrosoir_0	20.714	87.879	66.038	0.003	2.997
C_fatiguemauxdetête=C_fatiguemauxdetête_0	19.375	93.939	75.472	0.004	2.863
Accès_peri_piste=Accès_peri_piste_1	26.984	51.515	29.717	0.005	2.833
SEsècheRIV=SEsècheRIV_0	23.656	66.667	43.868	0.005	2.821
C_fatiguepaludisme=C_fatiguepaludisme_0	18.713	96.970	80.660	0.005	2.809
SEsècheMa=SEsècheMa_0	17.647	100.000	88.208	0.011	2.545
moment_irrigationMATSOIR=moment_irrigationMATSOIR_0	21.622	72.727	52.358	0.011	2.541
TExhPOMPEélectrique=TExhPOMPEélectrique_1	75.000	9.091	1.887	0.013	2.485
C_fatiguemauxdehanche=C_fatiguemauxdehanche_0	18.079	96.970	83.491	0.015	2.437
Tirbolbassineseau=Tirbolbassineseau_0	22.000	66.667	47.170	0.016	2.408
moment_irrigation1=moment_irrigation1_0	18.750	90.909	75.472	0.020	2.331
C_fatiguecourbarture=C_fatiguecourbarture_1	20.536	69.697	52.830	0.036	2.096
Faire_valoirHé=Faire_valoirHé_1	18.182	90.909	77.830	0.043	2.026
Faire_valoirHé=Faire_valoirHé_0	6.383	9.091	22.170	0.043	(2.026)
C_fatiguecourbarture=C_fatiguecourbarture_0	10.000	30.303	47.170	0.036	(2.096)

level. Out of the five independent variables introduced into the models, the maintenance techniques are determined by three variables, one for tillage with rice residues, three for tillage with maize residues, and one with cowpea vines. The main local techniques are determined by four variables, and the main is tillage technique.

Model of the maintenance’s techniques

The variable town explaining membership to one of the towns in the production area is significant at 1% and has a negative influence on the use of rice and maize residues as mulching. Water management varies according to the municipality of the producers. Producers

Table 5. Description of class 4 variables

	Cla/Mod	Mod/Cla	Global	p.value	v.test
0.000					
0.000					
moment_irrigation1=moment_irrigation1_1	5.769	9.091	24.528	0.020	(2.331)
Tirbolbassineseau=Tirbolbassineseau_1	9.821	33.333	52.830	0.016	(2.408)
C_fatiguemauxdehanche=C_fatiguemauxdehanche_1	2.857	3.030	16.509	0.015	(2.437)
TExhPOMPEélectrique=TExhPOMPEélectrique_0	14.423	90.909	98.113	0.013	(2.485)
moment_irrigationMATSOIR=moment_irrigationMATSOIR_1	8.911	27.273	47.642	0.011	(2.541)
SEsècheMa=SEsècheMa_1	-	-	11.792	0.011	(2.545)
C_fatiguepaludisme=C_fatiguepaludisme_1	2.439	3.030	19.340	0.005	(2.809)
SEsècheRIV=SEsècheRIV_1	9.244	33.333	56.132	0.005	(2.821)
Accès_peri_piste=Accès_peri_piste_0	10.738	48.485	70.283	0.005	(2.833)
C_fatiguemauxdetête=C_fatiguemauxdetête_1	3.846	6.061	24.528	0.004	(2.863)
Tir_arrosoir=Tir_arrosoir_1	5.556	12.121	33.962	0.003	(2.997)
TExharrosoir=TExharrosoir_1	5.195	12.121	36.321	0.001	(3.275)
SEpluvRE=SEpluvRE_0	8.844	39.394	69.340	0.000	(3.844)
District =DANGBO	1.639	3.030	28.774	0.000	(3.938)
C_accès_essence=C_accès_essence_0	8.000	36.364	70.755	0.000	(4.442)
moment_irrigationMAT=moment_irrigationMAT_0	7.927	39.394	77.358	0.000	(5.149)
Texhbassines=Texhbassines_1	10.152	60.606	92.925	0.000	(6.321)
Texhbols=Texhbols_1	10.152	60.606	92.925	0.000	(6.321)
C_entretien_matériel=C_entretien_matériel_0	3.205	15.152	73.585	0.000	(7.716)
Texhmotopompe=Texhmotopompe_0	3.659	18.182	77.358	0.000	(8.005)
Tirtuyau=Tirtuyau_0	2.424	12.121	77.830	0.000	(8.974)

will choose for the techniques best adapted to their community of origin taking into account the constraints and/or problems related to the management of the lowlands which are acute. In addition, the use of rice or maize residues is a function of their level of production and their availability in the production area.

The ethnicity variable measuring the ability of producers to avoid language barriers in study communities negatively influences the use of corn residues as a mulching practice for maintaining water in the fields. Indeed, some ethnic groups such as gouns consider mulching as an endogenous technique inherited from their ancestors, unlike the Fons and Aizo who discovered them alongside the native people either by adoption or by diffusion effect. Because the different ethnic groups have different vernacular languages, the non-understanding of the Wémè language creates difficulties for foreigners in the appropriation of the endogenous knowledge of this area with regard to the techniques of water management for crops recession.

The year of experience has a negative influence on the use of corn residues and cowpea haul as mulch. This would mean that it is more of young people or those with fewer years of experience in using these practices that are favorable to use the techniques of keeping the water on the fields. In other words, the accumulation of years in the use of maize and cowpea hay residues as a water retention technique for vegetable production does not influence the control of the water retention technique. It is shown that farmers with a long year of experience have had time to realize the positive or negative contribution of new technologies and practices that they take more or less easily (Nkamleu and Coulibaly, 2000).

Model of main techniques

Maintaining techniques using rice residues and cowpea hay as mulch are used in Adjohoun town while maize residue straw is used more often in the towns of Dangbo and Bonou. All of these techniques are more used by Wémè. In addition, it is more likely that the rice straw technique will be used by men than by women as opposed to cowpea and corn straw. The rice straw technique is more used by experienced producers.

The rho values are estimates of the correlation coefficients. There is a very significant correlation at the 0.0001 level between corn residues and cowpea haul. As

Table 5. Description of the axes.

$quanti.var	Eta2	P-value				
Dim.1	0.688	0.000				
Dim.3	0.639	0.000				
Dim.2	0.076	0.000				
Dim.4	0.072	0.000				
Dim.5	0.035	0.023				
	v.test	**Mean in category**	**Overall mean**	**sd in category**	**Overall sd**	**p.value**
$quanti$\`1\`						
Dim.5	(2.063)	(0.037)	(0.000)	0.235	0.249	0.039
Dim.4	(3.049)	(0.058)	(0.000)	0.250	0.266	0.002
Dim.1	(6.090)	(0.145)	0.000	0.180	0.332	0.000
Dim.3	(10.377)	(0.212)	0.000	0.130	0.286	0.000
$quanti$\`2\`						
Dim.3	11.119	0.290	0.000	0.219	0.286	0.000
Dim.4	3.895	0.094	(0.000)	0.270	0.266	0.000
Dim.5	2.725	0.062	(0.000)	0.280	0.249	0.006
Dim.2	(2.206)	(0.066)	(0.000)	0.260	0.327	0.027
Dim.1	(2.707)	(0.082)	0.000	0.184	0.332	0.007
$quanti$\`3\`						
Dim.1	11.984	0.638	0.000	0.206	0.332	0.000
Dim.2	3.871	0.203	(0.000)	0.540	0.327	0.000

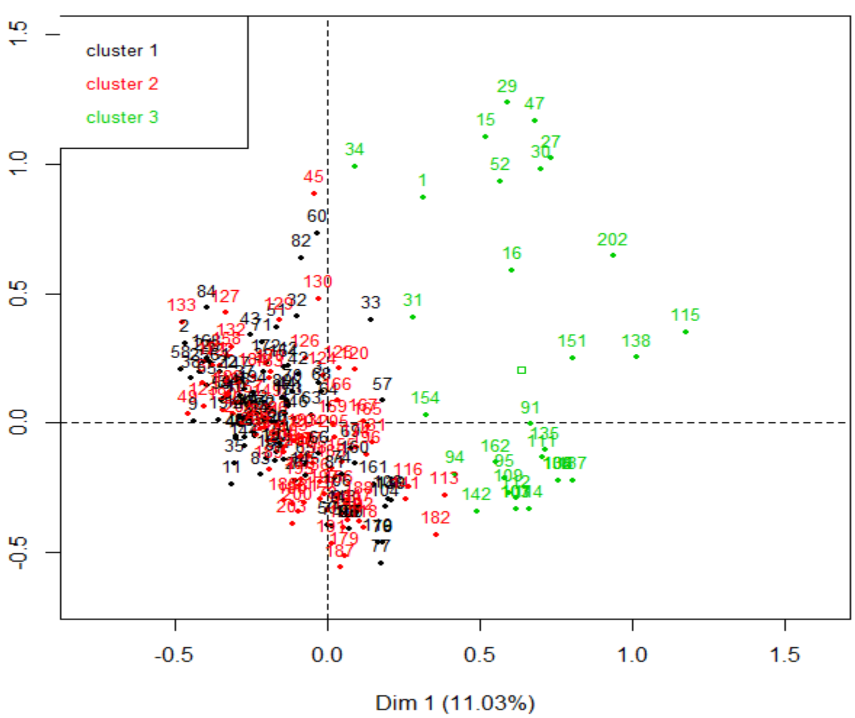

Figure 2. Multiple correspondence analysis

Table 6. The first 10 individuals represented with the first 3 axes.

Variable	Level	Coord	Contrib	Cos2	Count
Dimension 1					
Tirtuyau	Tirtuyau_1	1.272	10.84	0.461	47
Texhmotopompe	Texhmotopompe_1	1.143	8.94	0.382	48
C_entretien_matériel	C_entretien_matériel_1	1.015	8.23	0.370	56
Texhbols	Texhbols_0	1.741	6.48	0.231	15
Texhbassines	Texhbassines_0	1.741	6.48	0.231	15
SEpluvRE	SEpluvRE_1	0.793	5.83	0.278	65
moment_irrigationMAT	moment_irrigationMAT_1	0.811	4.50	0.193	48
C_accès_essence	C_accès_essence_1	0.683	4.12	0.193	62
TExharrosoir	TExharrosoir_1	-0.535	3.14	0.163	77
Tirtuyau	Tirtuyau_0	-0.362	3.09	0.461	165
Dimension 2					
Texhbols	Texhbols_0	2.450	13.28	0.457	15
Texhbassines	Texhbassines_0	2.450	13.28	0.457	15
SEpluvRE	SEpluvRE_1	-0.853	6.98	0.322	65
C_fatigue_gene	C_fatigue_gene_1	0.804	6.10	0.279	64
TExhPOMPEélectrique	TExhPOMPEélectrique_1	3.172	5.93	0.193	4
SEsècheRet	SEsècheRet_0	0.717	5.07	0.237	67
C_fatiguecourbarture	C_fatiguecourbarture_0	0.520	3.98	0.241	100
C_fatiguecourbarture	C_fatiguecourbarture_1	-0.464	3.55	0.241	112
SEpluvRE	SEpluvRE_0	0.377	3.09	0.322	147
Tir_arrosoir	Tir_arrosoir_1	0.504	2.70	0.131	72
Dimension 3					
Tirbolbassine	Tirbolbassine_1	0.973	13.46	0.508	74
moment_irrigation1	moment_irrigation1_1	1.091	11.89	0.387	52
Tirbolbassineseau	Tirbolbassineseau_0	0.722	9.99	0.465	100
Tirbolbassineseau	Tirbolbassineseau_1	-0.644	8.92	0.465	112
Tirbolbassine	Tirbolbassine_0	-0.522	7.22	0.508	138
SEsècheMa	SEsècheMa_1	1.089	5.69	0.159	25
moment_irrigationMATSOIR	moment_irrigationMATSOIR_1	-0.521	5.27	0.247	101
moment_irrigationMATSOIR	moment_irrigationMATSOIR_0	0.474	4.79	0.247	111
SEsècheRIV	SEsècheRIV_0	0.502	4.51	0.197	93
moment_irrigation1	moment_irrigation1_0	-0.355	3.86	0.387	160

a result, the use of corn straw residues probably results from the use of cowpea haul. In other words, growers using mulch with corn residues also use cowpea haul for mulching.

The technique of mulching is more used in Dangbo's district by the Goun ethnic group and does not require much experience, in contrast to it is more used in the district of Adjohoun by the weme, and requires a little more experience. (Tables 7 and 8).

Producer's perception

The analysis of the perception of the producers was evaluated by a frequency analysis in table or in graphs.

Unlike the variables such as other frequencies, other adaptation techniques, new seedling whose p-values are greater than 0.05, all the other variables are significant. The chi2 test is significant for all variables with < 0.05 p values. In other words, there is a significant difference

Table 7. Estimation model of sustainment techniques.

Variables	Coefficients	Standard errors	P>|z|
Rice straw			
Districts	**-0.393*** **	0.126	0.002
Ethnic	-0.138	0.341	0.687
Sex	-0.134	0.259	0.604
Age	-0.018	0.171	0.280
Experience's year	0.025	0.186	0.181
_Constance	0.551	0.792	0.487
Corn straw			
Districts	**0.233** **	0.110	0.035
Ethnic	**-0.744** **	0.333	0.026
Sex	0.081	0.222	0.717
Age	0.015	0.0142	0.294
Experience's year	**-0.027* **	0.0157	0.088
_Constance	0.934	0.741	0.207
Nests of cowpea			
Districts	-0.119	0.163	0.467
Ethnic	-0.323	0.385	0.401
Sex	0.147	0.296	0.619
Age	-0.004	0.019	0.847
Experience's year	**-0.050** **	0.025	0.041
_Constance	0.627	0.867	0.470
Observation number= 212			
Log likelihood = -304, 22734			
Prob>chi2 = 0,0015			
Wald chi2 (15) = 36, 43			
/atrho21	-0.212	0.127	0.095
/atrho31	-0.051	0.179	0.776
/atrho32	0.566	0.175	0.001
rho21	-0.209	0.121	0.085
Rho31	-0.051	0.179	0.775
Rho32	0.512	0.129	0.000
Likelihood ration test of rho21= rho31 = rho32 = 0			
Chi2 (3) = 14,6493			
Prob>chi2 = 0,0021			

Legend: **means sig. at 5%, * means sig. at 1% and *** means sig. at 0.1%.

between the municipalities whose graphs will provide more details (Table 9).

The analysis in Figure 3 shows that mineral fertilizer is not widely used in all municipalities with a very slight advantage for the town of Adjohoun.

At the level of production techniques, we notice variations from one town to another. Adjohoun and Dangbo towns, for example, have the highest frequencies in terms of the number of weeding cycles. Improved seeds are widely used in Adjohoun and Dangbo towns. The irrigation frequency is higher in the Adjohoun town because of the manual water supply, unlike in areas where semi-motorized irrigation allows a single intake to supply the daily water requirement of the plant. In addition, plant protection habits are more common in Adjohoun and Dangbo towns. In view of the manual effort required to bring water to plants, people feel a greater need to limit evapotranspiration. Overall, technical training needs were more in demand in Adjohoun town, followed by Dangbo and Bonou respectively (Figure 4). This demonstrates the willingness of people to better master water management techniques.

Table 8. Estimation of the main techniques model.

Variables	Coefficients	Standard errors	P>|z|
Straw			
Districts	0.379***	0.115	0.001
Ethnic group	-0.640*	0.337	0.057
Sex	0.011	0.223	0.961
Age	0.024*	0.143	0.096
Experience’s year	-0.045***	0.157	0.004
_Constance	0.460	0.750	0.540
Mulching			
Districts	-0.680***	0.112	0.000
Ethnic group	0.875**	0.392	0.026
Sex	0.381	0.248	0.123
Age	-0.270*	0.016	0.099
Experience’s year	0.044**	0.017	0.011
_Constance	-0.775	0.866	0.370
Observation number = 212			
Log likelihood = -197,502			
Prob>chi2 = 0,0000			
Wald chi2 (15) = 46,09			
/atrho21	-1.680	0.273	0.000
rho21	-0.933	0.035	0.000
Likelihood ration test of rho21 = 0			
Chi2 (1) = 90,634			
Prob>chi2 = 0,0000			

Legend: **means sig. at 5%, * means sig. at 1% and *** means sig. at 0.1%.

Table 9. Chi2 test results between the variables in the table and the districts.

Variables	Degree of freedom	p-value	X-squared
Sowing frequency	4	0.271	5.164
mineral fertilizer frequency	4	0.001	18.815***
Weeding frequency	28	0.000	41.846***
displacement of sowing frequency	2	0.002	12.382***
straw using frequency	2	0.000	26.600***
culture change frequency	4	0.001	19.515***
Magico_religious frequency	2	0.008	9.621***
Improved seed frequency	2	0.000	36.498***
Activities’s diversification frequency	2	0.000	56.459***
protection plant frequency	2	0.000	62.164***
Irrigation frequency	2	0.039	6.495**
migration frequency	2	0.000	66.749***
Other adaptation’s techniques frequency	2	0.599	1.025
Other frequency	2	0.208	3.138
Technical Training frequency	2	0.017	8.141**

Legend: **means sig. at 5%, * means sig. at 1% and *** means sig. at 0.1%.

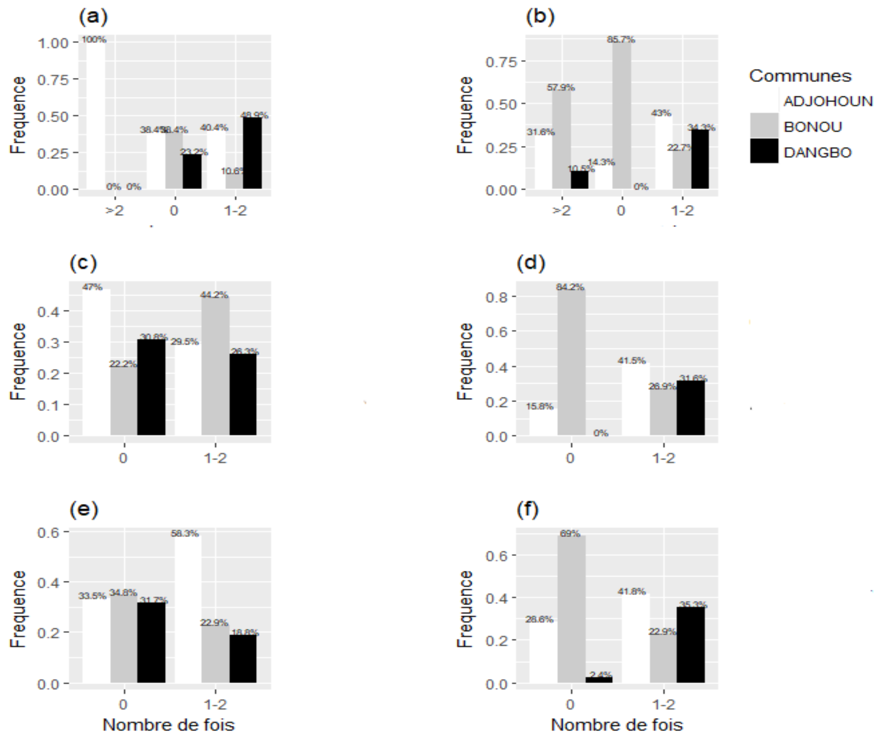

Figure 3. Frequencies of (a) mineral fertilization, (b) weeding, (c) seedling movement, (d) mulching, (e) Magico_religious, (f) improved seed at the town level.

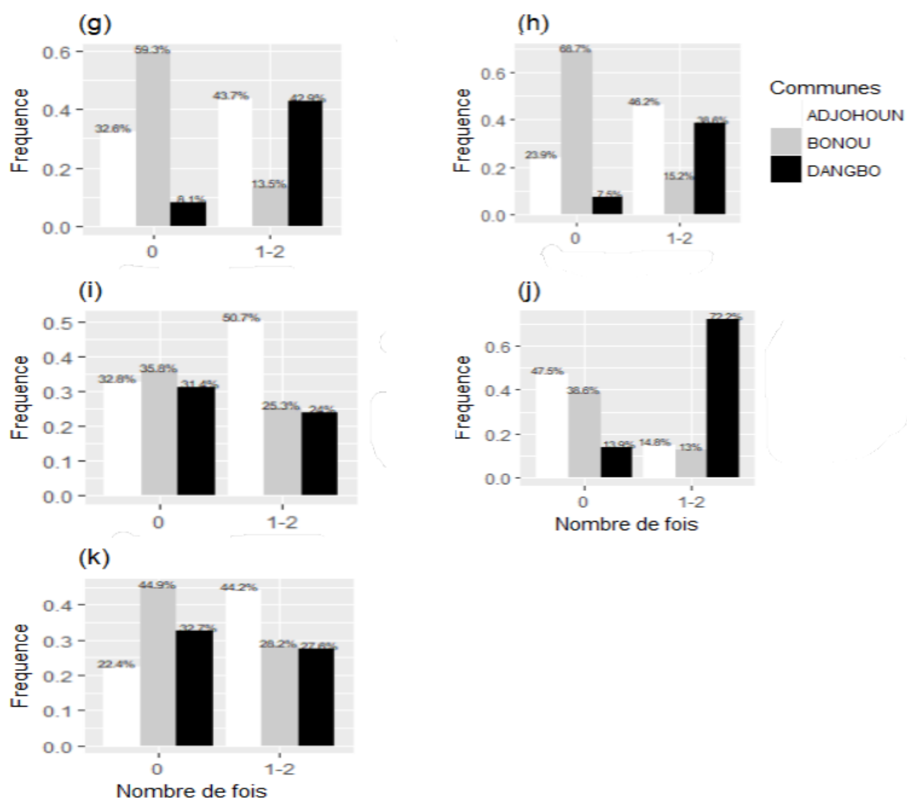

Figure 4. Frequencies of (g) diversification of activities, (h) plant protection, (i) irrigation, (j) migration, (k) Technical training at town level.

CONCLUSION

The objective of the present study was to identify the best irrigation practices that could allow the vegetable production of Adjohoun, Dangbo and Bonou towns to increase in the future. The multiple correspondence analysis, a classification of producers into similar groups by the HCPC method, and the multinomial Probit model were used. The study reveals three classes of producers characterized by the type of dewatering, the irrigation method, the sex of the producer and the number of watering. In addition, the models reveal that the maintenance techniques are determined by three variables: town, ethnicity and year of experience. Variations in the use of the main local techniques depend on four variables: town, ethnicity, age and year of experience. Improving the productivity of market garden crops to meet the food needs of the Beninese population makes the improvement of water management practices, a very important axis, especially in times of recession. The perception study showed that people are aware of the beneficial effects of mulching and wish to build capacity in water management. Thus, it is important for policymakers to formulate specific policies and programs that aim to improve the endogenous techniques used by producers.

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