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Research Article

Profitability of Market Garden Production in Southern Benin: Economic Index of Dewatering Systems on Farmers' Income

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Abstract

Water management is a real challenge in the market gardening sector. Then, dewatering systems are used for the efficient management of water in market gardening operations. The aim of this article is to evaluate the profitability of market gardening in the context of dewatering systems using (petrol motor pump, domestic gas motor pump and solar panel pump) compared with manual watering. Data were collected in 07 departments in southern Benin, covering 20 municipalities. A total of 1,600 growers were randomly selected after establishing a sampling frame of market gardeners in each municipality. The data concerned socio-demographic characteristics, prices and quantities of inputs, and outputs from market garden production. Descriptive statistics were used to describe the sample and then to highlight the economic profitability indices of each drainage system. The multinomial logistic regression model was used to analyse the factors influencing the choice of market gardeners for each system. The results show that market gardeners achieved an average net margin of 159,352.6 XOF/ha. The average labor remuneration rate is 265,275.9 (± 377,752.8) XOF/man-year. The activity is profitable regarding net margin. The solar panel watering system proved to be the most profitable, followed by manual watering and the petrol pump. Gender, age, level of education, use of family and permanent labor, and entrepreneurial training were the main determinants of the choice of watering systems. This study suggests using of solar panel systems and considering of the factors involved in the choice of drainage systems to propose the most appropriate technologies to market gardeners.

Keywords

Profitability, Economic Indices, Determinant, Dewatering Systems, South Benin

1. Introduction

In Benin, vegetable crops are grown in a variety of regions, including plateaus, alluvial plains, valleys and lowlands. They enable small-scale producers to generate regular income throughout the year. Market gardening accounts for an average of 30-50% of the income of farming households that practice it in southern Benin [6]. For [37], it generates a gross income of 11,150 F CFA with a gross margin of 6,775 F CFA, i.e. a net monthly salary of 172,621 F CFA for producers.

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Market gardening helps diversify diets and improve nutrition, particularly in rural areas [2]. In addition, it represents an important source of fresh fruit and vegetables, essential for a balanced diet. Although very significant, national production of vegetable crops does not yet meet domestic demand [37]. Benin's markets are heavily dependent on imports.

With little or no long-distance transport and excessive handling, locally grown vegetables are less prone to contamination by dangerous pathogens [7]. In addition, market gardeners can implement strict hygiene practices to minimize the risk of crop contamination [4]. Market gardening is also a major source of employment for many producers in Benin's peri-urban and rural areas. In the latter, it generates nearly 70% of jobs mainly along rivers and/or valleys, contributing to the diversification of income-generating activities [21]. [3], in the same vein, point out that on a social level, this sector represents a source of employment for thousands of people benefiting directly or indirectly. However, growth in this agricultural sub-sector appears to be limited, and is hampered by a number of obstacles.

Constraining factors for the market gardening sector in Benin include the lack of land, poor government support, market access and the insufficiency or inadequacy certain production factors such as irrigation systems for the crops grown [15]. In this sense, devices are used to evacuate excess water from agricultural soils and for irrigation to control moisture levels and optimize growing conditions for crops [11, 28]. These systems can include subsurface drains, canals, pumps, and other structures [5].

Dewatering systems, including manual, solar, gasoline and domestic gas methods, each offer distinct advantages that meet specific needs and different socio-economic and environmental considerations. They lead to improved productivity and reduced losses, which can have an impact on the economic profitability of market gardeners. The aim of the present work is to understand the economic profitability indicators of market gardening in a context of use of the different dewatering systems, as well as the determinants of the choice of dewatering systems. It answers the following questions:

1) What is the effect of drainage systems on economic indices vegetable production?
2) What determines the choice of drainage systems in market garden production?

2. Theoretical Framework

The theoretical positioning of this work brings together two main theories. These are innovation theory and the theory of marginal productivity of inputs. Innovation theory examines the way in which technologies or practices develop and spread within a farm. In the context of dewatering systems, it encompasses aspects such as modernization, mechanization, technological advances and sustainable, efficient systems. The literature highlights the importance of innovation in improving irrigation efficiency, reducing environmental impacts and ensuring water and energy savings [14, 25]. Innovative practices include the adoption of pressurized irrigation systems, smart management technologies such as frequency converters [19]. Using this theory, we could not only identify advances in terms of drainage systems in Benin as well as market gardeners' choices, but also assess how these drainage innovations (water drainage and/or irrigation) affect the productivity and profitability of market garden farms.

In addition, the theory of marginal productivity of inputs, developed by economists such as John Bates Clark and Léon Walras, explains how the optimal use of production factors (labor, capital, land, etc.) can maximize production and profit [8]. Thus, the marginal productivity of an input, such as water in the case of irrigation in market gardening, can vary according to the quantity used and, above all, the application technique used to do so. Thus, different drainage systems can have different impacts on the marginal productivity of water and other inputs, leading to variations in economic performance [26]. Considering that systems are a production input for farmers. Optimal use of the latter should increase agricultural production and thus producers' income. However, the cost of installing and maintaining these systems can have a negative impact on producers' net income.

3. Methodology

3.1. Study Area

For this research, southern Benin was chosen as the study area. It includes the departments of Atlantique-Littoral, Ouémé, Mono-Couffo and Zou, and is located between 6°20 and 7°30 north latitude and between 1°35 and 2°45 east longitude. A total of 20 municipalitys have been selected: Abomey, Adjohoun, Aguégués, Bonou, Comè, Cotonou, Covè, Dangbo, Grand-Popo, Klouékanmey, Lalo, Ouidah, Ouinhi, Sèmè-Kpodji, Tori-Bossito, Zagnanado et Zè, Djidja, Dogbo

3.2. Sampling

The aim was to cover a representative geographical area of the southern region of Benin in order to obtain a diversified sample of data on dewatering systems. The random sampling technique was chosen to ensure the representativeness of the data collected on drainage systems in this region of Benin, and to reduce any selection bias. This sampling approach enabled us to gain an overall view of the issues related to drainage systems in this region of Benin, and to propose appropriate recommendations.

3.3. Collected Data

The data were collected between October and December 2023 and include general information on the socio-economic

and demographic characteristics of the market gardeners and the type of labor used, as well as information on the equipment used for water extraction at the sites, and the production inputs and outputs.

3.4. Data Analysis

Data analysis was carried out using Stata version 15 software, according to the data available. First, descriptive statistics were used to describe the respondents' profile. This involved describing their intellectual status, mode of site acquisition, capacity-building status, use of manpower and some socio-demographic characteristics. The same analysis method was used to determine the frequency of use of drainage systems.

Secondly, economic performance indicators were analyzed using the operating account method proposed [29]. This is a step-by-step approach starting from marketing inputs to economic profitability indicators. The method is as follows:

1) Gross Product

In other words, it is called total yield. It represents the quantity of output (Q) obtained per unit area. Ha (equivalent of acre) is the unit of area used. The Gross Product is expressed in Kg/ha.

$$GP = Q/S$$

Where Q= total quantity of product obtained and S= area sown.

2) Gross Product Value

The Gross Product Value (GPV) is the multiplication of the Gross Product (GP) by the selling price unit (Pu) of the Product. For the purposes of this study, it represents the product Gross Product multiplied by the unit price for each of the crops grown. It is expressed in XOF per area (XOF/ha) and is determined by the following formula:

$$GPV = GP * Pu \quad (1)$$

With Pu = Product unit selling price.

The sum of the GPV for all crops represents the overall GPV the gardener.

3) Total Cost

Total cost is divided into Variable Cost (VC) and Fixed Cost (FC) [20]. They are obtained according to the formula:

$$TC = VC + FC \quad (2)$$

In this formula, variables costs are those linked to production and which depend the size of the farm. These are costs linked to inputs, casual labor and other variable expenses. Fixed costs are factors that do not change. They include the depreciation costs of farm equipment (cutters, hoes, axes, sprayers, basins, etc.) and permanent labor. These costs are expressed in XOF/ha.

4) Gross margin (GM)

The variable production costs are deducted from the GPV. Its unit of measurement is the XOF/ha and the formula is:

$$GM = GPV - VC \quad (3)$$

5) Net Margin (NM)

The net margin is obtained by deducting fixed costs (FC) from the gross margin (GM). It is expressed in XOF/ha and calculated by the following formula:

$$NM = GM - FC \quad (4)$$

It refers to the producer's net profit. If the net margin is positive. It measures the grower's economic profitability. The higher the fixed costs, the lower the net margin [36]

6) Average Labor Productivity (ALP)

According to [10], ALP is defined as the net margin per unit of family labor used. Mathematically, it is expressed by the following formula:

$$ALP = \frac{NM}{FL} \quad (5)$$

With NM the net margin (in XOF/ha), FL the total amount of family labor used per unit of area (HJ/ha) and ALP the average net labor productivity in XOF/HJ.

The estimation of family labor is made by considering the effort provided by each of the household components, i.e. men, women and children. [1] have used an approach to evaluate the amount of work by gender and age group. According to this work, the Total Workforce (*TW)* is given by the following formula:

$$ET = (number\ of\ men) + 0{,}75 * (number\ of\ women) + 0{,}50 * (number\ of\ children\ between\ 6\ and\ 14\ years\ old)$$

The ALP is interpreted as economic profitability by comparing it with the price (p) of salaried labor paid in the study area [10]. Thus, we have the following two (02) cases: (a) if ALP>p, mean the gardening activity is economically profitable according to the wages of the market gardener, and (b) if ALP<p, the activity is not economically profitable. For the last case, it is better for the farmer to sell his labor force on the labor market than to be on his own farm.

7) Internal Rate of return (IRR)

The Internal Rate of Return or IRR expresses the net margin per unit of total capital invested. In this case, the total capital invested is nothing more than the sum of total production costs and the value of family labor. It is mathematically expressed by the formula:

$$TRI = MN\ /(CT + VFL) \quad (6)$$

With NM the net margin of the production activity (in XOF/ha)

and VFL the value of family labor (in XOF/ha). VFL is obtained by multiplying the physical quantity of total family labor by the average price p (salaried labor in the study area). The internal rate of return is therefore expressed in percentage (%).

According to [33], the IRR is interpreted by comparing it with the interest rate (i) applied by microfinance institutions in the study area. Thus, we have the following two (02) cases of interpretation: (a) if IRR>i, the activity is economically profitable from the point of view of capital investment, and (b) if IRR<i, the activity is not economically profitable from the point of view of capital investment.

8) Benefit-Cost Ratio (BCR)

It expresses the total financial gain obtained by investing one monetary unit (1 XOF for example). In agricultural economics, it is defined by the following formula:

$$RBC = GPV/(TC + VL) \quad (7)$$

Where PBV is the gross product in value, TC the total costs excluding the value of family labor, and VFL the total value of family labor. In fact, VFL is obtained by multiplying the physical quantity of total family labor by the average price p of hired labor in the study area. In economic profitability analysis, BCR is interpreted by comparing it with the value 1. If BCR >1, then 1 franc invested generates more than 1 XOF in profit, and the product production activity is said to be economically profitable. On the other hand, if BCR < 1, then 1 franc invested generates less than 1 XOF in profit, and the product's production activity is said to be economically unprofitable, as the producer earns less than he invests.

In a third step, multinomial logit regression is used to identify the determinants of adoption of one dewatering system over another. This is based on modeling the behavior of producers following various alternatives [31, 32]. It has the advantage of relaxing the assumption of independence of alternatives. The farm perceives utility in adoption or not a system. This utility is expressed by the following mathematical formula:

$$U_{ij} = \beta_j X_{ij} + \varepsilon_{ij} \quad (8)$$

Uij represents the utility of grower i to opt for a given dewatering system j and β are constants, X= 1, 2, 3.....k are the independent variables of the model and εij represents the random factors that are not under the grower's control. Producer i's utility is associated with a probability expressed as follows:

$$P_{ij} = \frac{1}{1+e^{-X_{ij}}} \quad (9)$$

$$(X_{ij} = 1) = (U_{ij})\ avec\ j \neq n$$

P represents the associated probability and Yij being the explained variable that takes the value 1 if the market gardener i opts for alternation j and 0 if not. The multinomial logit regression subjects the market farmer to disjoint and exhaustive alternatives represented by the explained variable Yij which is the choice of a system [17]. Manual watering is chosen here as the reference modality not only because it is the most widely used technique, but also because it is the basic recourse of all market gardeners. The idea is to highlight the factors that may lead market gardeners to opt for one system over another.

4. Results

4.1. Qualitative Socio-economic Characteristics of Market Gardeners

4.1.1. Description of the Intellectual State of Market Gardeners

Table 1 presents the intellectual profile of market gardeners. It provides information on the respondents' level of education, literacy and vocational training.

Table 1. *Intellectual status of market gardeners.*

Variables		Man		Woman		Total		
		Young	Adult	Young	Adult	Young	Adult	Chi2 (p)
		Frequency (%)		*Frequency (%)*		*Frequency (%)*		
Education level	No	14.41	85.59	29.44	70.56	21.03	78.97	13.71 (0.00)
	Primary	27.43	72.57	4.55	45.45	36.31	63.69	11.75 (0.00)
	Secondary 1st Cycles	13.04	86.96	50.00	50.00	27.63	72.37	12.40 (0.00)
	Secondary 2nd cycle	76.47	23.53	25.00	75.00	63.04	36.96	10.08 (0.00)
	University	62.96	37.04	100.00	0.00	66.67	33.33	1.66 (0.19)

Variables		Man		Woman		Total		
		Young	Adult	Young	Adult	Young	Adult	Chi2 (p)
		Frequency (%)		*Frequency (%)*		*Frequency (%)*		
Literacy level	No	24.80	75.20	37.30	62.70	29.82	70.18	11.25 (0.00)
	Advanced	50.00	50.00	0.00	0.00	50.00	50.00	-
	Elementary	22.58	77.42	35.71	64.29	26.67	73.33	1.70(0.19)
Professional training		8.25	91.75	9.43	90.57	8.67	91.33	0.06 (0.80)

Source: Survey data, 2023

The socio-economic and demographic characteristics of the market gardeners show a diversity of profiles in terms of intellectual level. The results show significant differences in levels of education and literacy between young people and adults, depending on gender. The result on respondents' level of education shows that over 75% of both adult and female respondents were not in school. The number of young men with no schooling is significantly lower than that of young women, while in the adult class the frequency of men with no schooling is significantly higher than that of women (p = 0.00). In terms of literacy, 24.80% of young men and 37.30% of young women are illiterate, compared with 75.20% of adult men and 62.70% of adult women (p=0.00). As far as vocational training is concerned, the frequencies are similar between young people on the one hand and adults on the other, with a non-significant difference. This means that, in terms of vocational training, the profiles do not differ. In the study area, across all generations, interest in vocational training does not vary significantly.

4.1.2. Access to Land on Market Garden Sites

Table 2 shows the distribution of land access methods according to the age and gender of respondents.

Table 2. *Land acquisition mechanism.*

Variables		Man		Woman		Total		
		Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	Chi2 (p)
		Frequency (%)		*Frequency (%)*		*Frequency (%)*		
Site acquisition method	Purchase	53.85	46.15	30.00	70.00	47.22	52.78	1.64(0.19)
	Heritage	17.41	82.59	34.02	65.98	22.82	77.18	10.24(0.00)
	Don	40.00	60.00	42.86	57.14	41.38	58.62	0.02(0.87)
	Rental	34.94	65.06	54.24	45.76	42.96	57.04	5.24(0.02)
	Borrowing	22.22	77.78	15.79	84.21	19.57	80.43	0.29(0.58)
	Gage	62.50	37.50	0.00	100.00	45.45	54.55	3.43(0.06)
	Provision of services	20.69	79.31	34.62	65.38	27.27	72.73	4.02 (0.04)

Source: Survey data, 2023

The results show significant differences in site acquisition patterns by age category and gender. Over 50% of young men purchased their site, compared with 30% of young women. Inheritance is the most frequent mode of acquisition for adults, for both men (82.59%) and women (65.98%), with a significant difference between the genders (p = 0.00). Renting is more common among young women than young men (34.94%), while 65.06% of adult men and 45.76% of adult women rent their site (P(chi2) = 0.02). Although more common among young women, is more often used by adults

overall. These adults are also more represented in borrowing (77.78% for men and 84.21% for women) and making available (79.31% for men and 65.38% for women), both of which are more common among adults than young people, with a marginally significant difference for making available (p = 0.04).

4.1.3. Advice and Training Received

The table below provides information on the different types of advisory support that market gardeners receive for their farms in southern Benin.

Table 3. *Support and advice received by market gardeners.*

Variables	Man		Woman		Total		Chi2 (p)
	Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	
Specialized technical advice	26.97	73.03	38.37	61.63	31.31	68.69	9.65 (0.00)
Management consulting for organizations	26.51	73.49	37.87	62.13	30.62	69.38	6.55 (0.01)
Market access advice	4.83	75.17	36.99	63.01	29.41	70.59	7.68 (0.00)
Applied food and nutrition advice	23.29	76.71	44.74	55.26	32.69	67.31	13.38 (0.00)
Corporate consulting	22.94	77.06	53.52	46.48	35.00	65.00	17.67 (0.00)
Legal advice on access to land/Financing and insurance	25.51	74.49	55.88	44.12	33.33	66.67	10.47 (0.00)
Training in organic farming	23.27	76.73	32.39	67.61	27.03	72.97	3.52 (0.06)
Business management training	22.92	77.08	36.90	63.10	28.07	71.93	5.14 (0.02)

Source: Survey data, 2023

The advice and training received by market gardeners is essential for the development of sustainable and efficient farming practices. The data show that specialized technical advice and business management training are the main types of advisory support received. Adults (both men and women) are the majority beneficiaries of all types of advice, with high percentages of access for specialized technical advice (73.03% for men and 61.63% for women). However, young women stand out for their relatively high access to business advice (53.52%) and legal advice on access to land, financing and agricultural insurance (55.88%), although the majority of beneficiaries remain adults. These results indicate an uneven distribution of access to advice and capacity building, highlighting the need for a more inclusive approach to ensure that all producers, regardless of gender or age, can benefit from these services to improve their skills and productivity.

4.1.4. Use of Manpower

Table 4 shows the distribution of the types of labor used by market gardeners according to age and gender.

Table 4. *Types of labor used by market gardeners.*

Variables	Man		Woman		Total		Chi2 (p)
	Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	
Use of casual labor	25.13	74.87	38.07	61.93	29.90	70.10	11.00 (0.00)
Use of family labor	27.38	72.62	43.86	56.14	33.87	66.13	12.56 (0.00)
Use of permanent workforce	20.35	79.65	38.16	61.84	27.51	72.49	7.22 (0.00)

Source: Survey data, 2023

The use of labor in market gardening in southern Benin varies significantly according to the sex and age of the growers. Adult women are more likely to use family labor (56.14%), while adult men are more likely to use permanent labor (79.65%). These differences may reflect family dynamics and social structures in these communities. The predominant use of family labor by women could indicate a reliance on family networks for farm work, while men may have more financial means to hire permanent workers. Improving access to resources for hiring permanent labor could increase the efficiency and productivity of women market gardeners.

4.2. Quantitative Socio-economic Characteristics of Market Gardeners

Descriptive statistics for quantitative variables are summarized in Table 5.

Table 5. *Statistics of quantitative variables.*

Variables	Men mean (std)	Women mean (std)	Set mean (std)	t (p)
Age	43.81 (14.24)	38.87 (10.47)	41.91 (13.14)	5.01 (0.00)
Experience in market gardening	13.54 (8.92)	9.39 (6.41)	11.95 (8.29)	6.76 (0.00)
Household size	6.88 (3.74)	6.35 (1.97)	6.68 (3.19)	2.21 (0.01)
Site area	6.34 (7.55)	6.18 (10.8)	6.28 (8.93)	0.23 (0.40)
Finished area	8.36 (66.57)	2.98 (3.98)	6.29 (52.34)	1.34 (0.08)
Area planted	0.34 (0.64)	0.29 (0.3)	0.32 (0.53)	0.30 (0.11)

Source: Survey data, 2023

Quantitative variables such as age, experience in market gardening, household size and site area show marked differences between men and women. Men are generally older and more experienced in market gardening than women (43.81 vs. 38.87 years). Male-headed households are slightly larger, and the sites they farm are similar in size to those of women. The area planted does not differ significantly between the sexes (0.34 ha for men and 0.29 ha for women). However, men seem to develop and sow more land than women. These data underline the importance of providing ongoing training and support to women to help them gain experience and optimize the use of their land, which could help increase their agricultural productivity.

4.3. Description of Dewatering Systems Used

Market gardeners in southern Benin essentially use four types of cultivation systems. The gendered distribution of dewatering systems using is resumed in Table 6.

Table 6. *Proportion of use of different dewatering systems.*

Dewatering system types	Men		Woman		Total		Chi2 (p)
	Young	*Adult*	*Young*	*Adult*	*Young*	*Adult*	
Manual watering	21.14	78.86	37.04	62.96	27.31	72.69	14.72 (0.00)
Motor-driven petrol pumps	35.90	64.10	32.14	67.86	34.33	65.67	0.20 (0.65)
Domestic gas motor pump	28.57	71.43	38.46	61.54	31.46	68.54	0.83 (0.36)
Solar panel	100.00	0.00	50.00	50.00	62.50	37.50	1.60 (0.20)
No	25.00	75.00	100.00	0.00	45.45	54.55	4.95 (0.02)

Source: Survey data, 2023

The watering systems used by market gardeners vary according to gender and age, with a marked preference for gasoline-powered motor pumps and manual watering. Young women seem to prefer manual watering, while young men use solar panels exclusively. These choices may be influenced by initial costs, the availability of resources and the ease of use of each system. Encouraging the use of more sustainable and efficient systems, such as solar panels, could help reduce operational costs and improve the energy efficiency of vegetable farms.

4.4. Economic Profitability Indices

All the calculated indices of profitability are summarised I the Table 7.

Table 7. *Summary of economic profitability indices.*

Variables (Indices)	Definition	Manual watering	Petrol pump	Domestic gas pump	Solar Panel pump	Set
		Mean (Std)	Mean (Std)	Mean (Std)	Mean (Std)	Mean (Std)
GPV (XOF)	Gross Product Value	402979.9 (326278.5)	318857.5 (187719.2)	305042.7 (190169)	470048.7 (476238.1)	374232.2 (295101.2)
VC (XOF/ha)	Variable cost	175618.8 (178677.1)	126417.3 (121741.7)	230281.6 (129585.3)	154485.1 (232050.3)	171700.7 (165513.6)
FC (XOF/ha)	Fixed cost	38515.27 (39747.51)	57758.04 (55036.27)	29061.89 (40555.75)	47380.04 (64017.27)	43178.81 (49839.2)
TC (XOF/ha)	Total costs	214134.1 (179990.9)	184175.3 (130078.7)	259343.5 (139721)	201865.5 (233686.2)	214879.6 (170869.2)
MB (XOF/ha)	Gross margin	227361.1 (228878.1)	192440.2 (145778.2)	74761.12 (164861.2)	315563.18 (324830.5)	202531.4 (216087)
NM (XOF/ha)	Net margin	188845.8 (224223.2)	134682.1 (137601.4)	45699.23 (168969.1)	268183.27 (312853.1)	159352.6 (210911.7)
ALP (XOF/h.year)	Average labor Productivity	263088.9 (365680.2)	410321 (334604.9)	43897.55 (392834.7)	343796.15 (417891.4)	265275.9 (377752.8)
IRR	Internal rate of return	1.17 (1.38)	0.95 (0.95)	0.31 (0.69)	1.670976 (2.097932)	1.025244 (1.279483)
BCR	Benefit- Cost Ratio	2.17 (1.38)	1.95 (0.95)	1.31 (0.69664)	2.65 (2.06)	2.02 (1.27)

Source: Survey data, 2023

Table 7 summarizes the economic profitability indices. The gross product obtained is around 374,232XOF. It is higher for producers using solar panels. After deducting variable costs from the value of the noise product, the gross margin is positive, whatever the type of system. This shows that market gardeners are able to meet their operating costs over the course of a production cycle. The net margin corresponds to the balance of the gross margin less fixed costs. The results show that the net margin is positive whatever the system. It is estimated at around 159,352XOF/ha for all growers. As a result, market garden production is economically profitable in terms of net margin. The results on growers' profitability according to irrigation methods reveal significant variations in terms of economic performance. The solar panel appears to be the most advantageous system, offering high economic profitability (268183.27 XOF/ha), despite potentially higher initial costs (476238.1) and its instability (considering standard deviations). This system yields a gross product value of (470048.7 ± 476238.1). The manual watering system is the second most profitable. This system also generates a high gross margin (MB) (227361.1). In addition, the domestic gas-powered motor-driven pump system appears to be the least profitable, with the lowest gross and net margins underlining significant economic challenges. The profit/cost ratios from the dewatering systems are all greater than 1. Consequently, production is economically profitable in all systems. These results confirm those obtained for net margins. In short, the solar panel appears to be the most advantageous system, offering high profitability despite potentially higher initial costs.

4.5. Determinants in the Choice of Dewatering Systems

The choice pf a dewatering system is influenced by many

factors. Taking the manual dewatering system as a base of analysis, the results found are in the table 8.

Table 8. *Factors influencing the choice of drainage systems.*

Variable		Petrol pump		Domestic gas pump		Solar Panel pump	
		Coef	dxdy	Coef	dxdy	Coef	dxdy
Gender	Producer's gender	0.76***	0.10	-0.20	0.01	.414	0.00
Age	Age of producer	0.01	0.00	0.04***	0.00	-.042	0.00
NIVINSTRUT	Education level	0.77***	0.10	0.75***	0.01	1.917***	0.20
SITMAT	Marital status	-1.13*	0.15	0.17	0.01	-.122	0.00
SUPAME	Developed area	-0.01	0.00	0.01	0.00	-.028	0.00
SUPEMB	Area planted	-0.14	0.02	0.98***	0.02	-.033	0.00
UMOOC	Use of casual labor	-0.18	0.02	0.74	0.02	1.392***	0.00
UMOF	Use of family labor	-0.31	0.05	2.77***	0.08	-2.116***	0.31
UMOP	Use of permanent workforce	0.77***	0.10	-0.34	0.01	2.307***	0.01
FORGENT	Entrepreneurial training	1.17***	0.17	-1.7***	0.05	19.805	0.00
NAEXP	Years of experience	0.05***	0.00	-0.07**	0.00	-.262**	0.01
TAILMEN	Household size	-0.25***	0.03	-0.33***	0.00	0.192	0.00
_cons	Constant	-1.70		-5.50			11.24
Reference methods: Manual dewatering system		Number of obs = 1600 LR chi2(20) = 331.64 Prob > chi2 = 0.00 R2 username = 0.28					

Source: Survey data, 2023

The results of multinomial logit regression comparing the use of motor-driven petrol pumps, domestic gas pumps and solar panel pumps with manual watering, taking the latter as the reference modality, show that the gender of the grower has a significant ($p<0.01$) positive influence on the use of motor-driven petrol pumps, while it has no significant effect on the use of domestic gas pumps. Better-educated men with experience in market gardening prefer gas-powered motor pumps to manual watering, while women with low investment power prefer manual watering. Age has a significant effect only for the domestic gas motor pump (dxdy = 0.001).

The level of education has a positive and significant impact ($p<0,00$) on the adoption of all types of drainage system, indicating that better-educated farmers are more likely to use these technologies than to stick with manual drainage. The coefficients of 1.91, 0.77 and 0.75 respectively for the solar panel, petrol motor pump and domestic gas motor pump show an even stronger preference for more educated growers to use the solar panel system (as do the dxdy marginal effects). Educated market gardeners have a more advanced notion of what farm mechanization is and its added value for other producers who adopt it. As a result, they are more open to new technologies.

It also emerges that the use of manpower is also a determining factor in the choice of watering systems. Growers who use permanent labour for their market gardening activities tend to choose the solar panel (2.307) or the petrol motor pump (0.77) over manual watering. On the other hand, those with family labor prefer the domestic gas motor pump (2.77), while being less inclined to opt for the solar panel (-2.116).

Entrepreneurial training increases the probability of adopting the gasoline-powered motor pump (dxdy = 0.171) but decreases that of using the domestic gas-powered motor pump. Producer experience negatively influences the adoption of the solar panel (-0.262) and the domestic gas motor pump (-0.07), but positively that of the petrol motor pump (0.05). The same applies to household size. Household size has a negative effect on both dewatering systems, while has no influence on the choice of solar panel system. Growers with larger households tend to continue using the manual system, due to the availability of labour.

5. Discussion

Inheritance is the most common mode of acquisition for adults. Renting is more common among young women than young men. The work of [23] has shown that the main mode of sustainable access to cultivable land in market gardening is inheritance. These results corroborate those of [18] which show that inheritance remains the main mode of access to land. Contrary to these studies, [16] show that purchase is in first place in market gardening systems, followed by rental.

Overall, the solar panel dewatering system offers the highest efficiencies, while motor-driven pumps, particularly gasoline-powered, appear to offer greater economic stability with more efficient use of labor. [22] has shown that production systems with solar panels can reduce labor costs and improve production efficiency, resulting in substantial economic benefits. In contrast, research by [9] indicates that market gardeners using manual dewatering methods often achieve higher yields thanks to their ability to manage water more efficiently and adapt to local conditions. On the other hand, [35] found that small-scale motor-driven irrigation pumps, while not significantly improving incomes, still offer better productivity than manual methods, which are often limited by problems of labour intensity and efficiency. Manual irrigation generally results in lower crop yields than gasoline- or diesel-powered motor-driven pumps, due to higher costs and less frequent irrigation [12].

Determinants of watering system choice indicate that socio-demographic factors such as gender, age and level of education strongly influence growers' decisions. Previous studies show that in market gardening, women prefer manual water pumps due to their perceived safety and efficiency over traditional watering methods, highlighting the relationship between gender and the adoption of watering technologies [34]. In addition, education level and age significantly influence mechanization decisions; younger, more educated growers tend to adopt higher levels of mechanization, including solar panel pumps, to improve their productivity [24].

In addition, the type of labor available in this case the use of family and permanent labor significantly influences the choice of drainage systems. The availability of permanent labor significantly influences the choice of irrigation systems by market gardeners [13]. According to [27], systems that require more complex operations may require permanent labor, while simpler systems could be managed by family staff. Moreover, irrigation is manually done family labor, and particularly by unpaid children in onion production in Burkina [30]. These studies highlight the relationship between the labor used and the choice of irrigation system.

6. Conclusion and Implications

This research has assessed the profitability of the different drainage systems used in southern Benin. Market gardeners use four types of watering system: manual watering, petrol motor pumps, domestic gas motor pumps and solar panels. The systems are all profitable from the standpoint of net margin and profit/cost ratio, with the solar-panel watering system showing higher and highly variable profitability. Factors such as gender, age, level of education and manpower used were the main determinants of the choice of drainage system. In the light of these results, it is preferable to opt for the solar system, although both motor pump systems (manual and petrol) are cost-effective. In addition, we need to consider the type of manpower available to guarantee dewatering. As family labour is becoming increasingly scarce in households as a result of school enrolment and vocational training, empowerment by means of petrol-driven motor pumps and occasional replacement by physical labour would be an undeniable asset for these two systems, failing the use of the solar system. A limitation of this study, which remains to be explored in future studies, is the social contribution of the solar system for the households adopting it.

Abbreviations

XOF	West African CFA Franc
std	Standard Deviation

Author Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

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