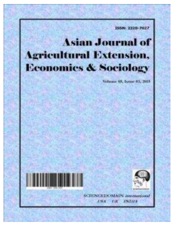

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Effects of the Agro-net Technology on Financial Profitability of Cabbage and Pepper Production in Benin

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Authors' contributions

This work was carried out in collaboration between both authors. They jointly designed the study. Author LSY wrote the protocol, carried out the field survey, performed the statistical analysis and wrote the first draft of the manuscript. Author BGH supervised the work, provided additional literature, fine-tuned the analyses of the study and oriented results' interpretation towards relevant policy implications and edited the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: Chemical pesticides have been the main option for pest control adopted so far by vegetable growers in Benin, in spite of the health risks involved. In order to reduce such risks, researchers developed insect nets (agro-net technology), as a means of physical pest control. This study aimed to assess the financial profitability of the use of that technology in cabbage and pepper production, so as to advice on its better management and enable greater adoption.
Study Design: Comparison was made of key indicators of resource management and financial profitability of a farm (productivity, profit ratio), among users and non-users of insect nets in the main vegetable production systems in southern Benin.
Place and Duration of Study: Benin's National Institute of Agricultural Research (INRAB), in

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collaboration with the Faculty of Agronomic Sciences (FSA), from 2010 to 2011.
Methodology: Stratified and random sampling and a structured questionnaire were used to collect data from 205 farmers (consisting of 20% insect net users and 80% non-users) in Mono and Couffo departments of Benin. Component analysis, K-means, cluster analysis, Student's T test were used to identify the different vegetable production systems. Crop budgeting was used to evaluate and compare resource management indicators (labor and capital productivity) and profitability indicators (gross revenue, cost of production, net revenue, benefit / cost ratio) between these systems.
Results: Three vegetable production systems were distinguished in the study area: Intensive system, semi-intensive system and extensive system. Only 20% vegetables growers use insect nets; they practice intensive and semi-intensive systems. The technology improved profitability, only for cabbage in the intensive system where the benefit / cost ratio and capital productivity increased slightly by 15.6%. On the contrary, due to large increases in labor costs, pepper production using the nets in intensive and semi-intensive systems led to 42.8% and 25.7% profit reductions. Decreases in labor productivity worth 48.3% and 72.6% were also observed.
Conclusion: Overall the agro-net or insect net technology increased labor costs, while output values did not increase more than proportionally. The study provides evidence that an agricultural technology should substantially reduce labor costs and improve labor productivity before it can be widely adopted by farmers, especially the poor. Technology adaptation to crops' specific growth requirements is also needed to go beyond existing productivity and profitability advantages.

Keywords: Insects net; agro-net technology; vegetables production system; financial profitability; labor productivity.

1. INTRODUCTION

1.1 Background and Justification

Urban and peri-urban Agriculture (UPA) is a concept that is rapidly developing in sub-Saharan Africa due to increased urbanization. It provides a means of increasing diversity in urban food supply [1]. Considering the low performance of rural based agricultural production systems, UPA therefore, offers an option for addressing urban food insecurity [2,3]. In this regard, vegetable production has become an important economic activity [4]. In Benin, vegetable production is an important source of employment in urban and peri-urban areas, mostly along river banks and valleys [5]. It provides high incomes and addresses the issue of unemployment by creating approximately 60,000 jobs directly and 25,000 indirectly [6]. In addition to its economic importance, vegetable production and consumption has contributed towards enhancing food and nutrition security, since it is a source of various nutrient supplements in Benin people's diets, which were previously mainly based on starchy foods [7]. It is against this background that, the Government of Benin has prioritized vegetables as one of the twelve key sub-sectors to be promoted as outlined in the Strategic Plan (2011) for Boosting the Agricultural Sector.

Despite high level intervention, the vegetable sub-sector in Benin continues to face many challenges. These have been documented [5,8] and main constraints identified in southern Benin as: land scarcity, shortage of specific agricultural inputs (seeds and fertilizers), poor water control, lack of credit and pest attacks. Generally in sub-Saharan Africa, insect and mite pests are a major cause of yield loss in vegetable crops [1]. In order to ensure pest control on these crops, farmers often spray chemical insecticides, with increasing quantities of unapproved products. This has led to increased presence of chemical residues in crops and on the environment (soil and ground water) which seriously affect both human and animal health.

The use of insect nets is now being promoted as a means of reducing the costs of pesticide use, safeguarding human and animal health, and protecting the environment. Insect nets have been found to be efficient in fighting *Plutella xylostella* attacks on cabbage in Benin. Besides, Cecidomyie of cabbage and bok choy are quite unmanageable without insect nets. Dull bug and chrysomela (or golden beetle) on pepper, tomato and cucumber can also be controlled efficiently with insect nets [9].

1.2 Objectives of the Study

The main objective of the study is to analyze the financial profitability of the use of agro-net technology on cabbage and pepper production. Specific objectives include: (i) identification of existing production systems and assessment of resource use with and without the net; (ii) evaluation of the effects of the technology on financial profitability of the identified systems; (iii) policy recommendations about the use of agro-net technology.

2. LITERATURE REVIEW

A production system is a technical combination and coordination of inputs (resources or factors of production) at a given level of technology to produce a given level of output [10,11]. In Benin vegetables are produced in various production systems such as modern gardening systems as a market-oriented and continuous farming activity, and lowlands or flood recession systems where vegetables are cultivated intensively. These are urban or sub-urban production systems which use manual or motorized irrigation. Among the vegetables produced through this system, pepper ranks second (about 70% of growers) thus attract considerable attention among producers and government extension services providers [8,4]. On the other hand, cabbage is produced by only 30% of growers [12].

Kouvonou et al. [13] found that the vegetable sub-sector development in Togo is stimulated by an increase in unemployment rate among young men and women, a strong demand for produce, and an attractive production profit. Surprisingly, the differences between types and kinds of growers do not influence the mode of vegetable farm management. However, more men than women substitute hired labor for fertilizer in the allocation of production resources.

Adegbola et al. [8] assessed the financial profitability of vegetables in various production systems in southern Benin. For example, in pepper production, highest profits were observed with “medium producers, Naguézé pump users” and “small producers, pump users " while only “small producers, pump users "had the highest profits in tomato production. The study concluded that the use of an irrigation system in a relatively well managed farm of average size was one of the critical drivers of vegetable production’s profitability.

Fanou [14] found that bio-driven improved technologies such as biological insecticides, did not improve the profitability of vegetable production. For example, tomato production is shallow area using indigenous variety and application of cotton insecticide was more profitable than those produced using biological pest control. However, cabbage production using application of aqueous neem extract and motorized irrigation were more efficient. He therefore, concluded that there are no consistent results associated with the efficiency of vegetable production through the use of biological pest control method. However, crop specificities in relation to soil fertility requirement and inherent vulnerability to pest attacks are critical determinants of physical productivity, which is a prerequisite for financial profitability.

Market demand is particularly critical for vegetable farming’s profitability. For example, cabbage generates more income to growers because of its trade intensity in the West Africa sub-region and ease of storage than other vegetables [14,15]. In this case, the growers should increasingly target niche markets (high-income and snobbish consumers), where there is greater willingness to pay more for organically-produced crops. The use of bio-pesticides has contributed to increased competitiveness of such crops in Ghana [16]. Marketability (including product quality) is one of the critical factors driving the financial profitability of vegetable production, hence, the adoption of a new agricultural technology as an expression of the farm’s business environment and farmers’ subjective perceptions [17,18,19].

3. CONCEPTUAL BACKGROUND AND METHODOLOGY

3.1 Conceptual Background

The economic analysis of production systems aims to identify and disseminate best practices and monitor their impact, and to identify regional priorities for rural investment and research [20]. It provides the ground for cost-effective agricultural development interventions and improved livelihoods for target groups. It is done in this paper using the concepts of production efficiency, productivity and profitability.

Productivity is a direct expression of production efficiency. It is an ‘output/input’ ratio, either in physical or monetary terms; it is therefore referred to as technical efficiency or economic efficiency respectively. Marginal productivity, which is the marginal effect of the last unit of input, is a critical determinant of production decision-making. Indeed, optimal production is determined at the point on the production curve where marginal productivity equals marginal cost. When several inputs or production factors are considered, the input-output relationship is expressed by a multiple-factor production function; the most frequently used being the Cobb-Douglas production function[1]. It is used to determine partial productivity of each factor, and the overall economic efficiency. It is assessed through production function modeling. The present study will not do such modeling, which should rely on long-term field experiments with appropriate randomization. It rather assesses average productivity and financial profitability of vegetable production systems using mean values of cross-section data.

Financial profitability is the "capacity" of a business to provide income that is commensurate with invested capital [2]. It expresses the magnitude of profit; the latter is the result of business management capacities and conditions. It is the first necessary condition for the firm's survival; it is the "raison d'être" of the firm. While profitability justifies and drives business, it also helps to evaluate the performance of resources invested by investors [21]. Financial profitability is the business opportunity indicator most widely used. Benefit / cost ratio and internal rate of return stand for it. They are calculated respectively for short-term investments and multi-year projects. They both represent a profit ratio, which corresponds in the first case to productivity (expressed as a ratio of monetary values) minus 1.

3.2 Selection of Sites and Crops

The study was conducted through a three-stage site selection. First, the UPA/PAN [3] project intervention areas were targeted. Second, sites were selected as those where field trials and pre-extension tests were previously conducted [4]. These include the localities of Seme-Kpodji, Cotonou, Pahou, Ouidah in the Atlantic department; Lokossa Athiémé, Bopa, Houéyogbé, Comé and Grand-Popo in the Mono department; and Dogbo, Lalo, Klouékanmey, and Aplahoué and Toviklin in the Couffo department. Third, Mono and Couffo departments were chosen, as areas where the agro-net technology was first introduced. These sites were selected because quantitative data on producers' knowledge about the technology were already available in the project's database.

The crops' selection was done based on acreage coverage and use of the agro-net technology. Agricultural statistics of Mono-Couffo (2010-2011) indicate that tomato (44.6% of total garden crops area), pepper (30.2%) and leafy vegetables (16.3%) were the most produced vegetables. Insect nets have been tested in Benin first on cabbage, then on pepper and tomato. Hence the choice of cabbage and pepper for this study.

3.3 Sampling and Data Collection Methods

The study sample was selected among vegetable growers of Mono and Couffo departments. Each grower must have been informed about the agro-net technology. Therefore, producers selected for the study sample was drawn from the list of vegetable growers who participated earlier in training on pest control in vegetable production using insect nets on cabbage, tomato and pepper. In this regard, the municipalities of Aplahoué, Athiémé, Bopa, Comé, Djakotomey, Dogbo, Grand-Popo, Houéyogbé, Klouékanmey, Lalo, Lokossa and Toviklin were selected as the final sites where the study should be conducted. A total of two hundred and five (205) farmers were randomly selected. These farmers include 80% non-users (experiment observers) and 20% of users (experimenters) of the agro-net technology (Table 1). The proportion of users is low because the technology is new and is at its very early stage of adoption. A large proportion of non-users was included in the sample in order to capture reliable and representative data from growers of the two crops in the agro-net project

[1] In economics, a production function represents the relationship between the output and the combination of factors, or inputs, used to obtain it: Q=f(L,K). The Cobb-Douglas production function is a particular form of the production function: Q(L,K) = A $L^{\beta} K^{\alpha}$). It is widely used because it has many attractive characteristics (http://economicpoint.com/production-function/cobb-douglas.

[2] "Capital" refers in general to financial resources available for use. It may mean 'financial assets or the financial value of assets, such as cash' or 'the factories, machinery and equipment owned by a business and used in production' (http://www.investopedia.com/terms/c/capital.asp). Capital is wealth in the form of money or assets, taken as a sign of the financial strength of an individual, organization, or nation, and assumed to be available for development or investment. In accounting, it is a business to generate income. In economics, it means factors of production that are used to create goods or services and are not themselves in the process (http://www.businessdictionary.com/definition/capital.html).

[3] UPA/PAN: Urban and Suburban Agriculture / Pesticide Action Network.

[4] The PCM program was jointly conducted by the National Institute of Agricultural Research Benin (INRAB), the regional vegetable councils (CRM)) and the APECTETRA NGO.

area, and to arrive at relevant profitability values from non-users that can be compared with those of users.

Semi-structured interviews with individual farmers and group discussions were conducted in August 2011 using an interview guide. In September-October 2011, a detailed questionnaire was used to collect detailed data required for the analysis.

3.4 Methods of Data Analysis

First, a typology of vegetable production system was established to identify the relevant categories of vegetable growers, using the following criteria: area sown during previous crop year (2010), number of years of experience in the activity, household size, number of workers employed, costs of hired labor, seeds, fertilizers and pesticides used during the previous season, and age of the producer. Principal Component Analysis (PCA) and classification in dynamic clustering or K-Means Cluster Analysis were used to identify and describe the different vegetable production systems. K-Means helps to aggregate vegetable growers into different clusters, and PCA helps make the description of each group.

Partial budgeting was used to evaluate and compare financial profitability between the different production systems identified. Accounting profit, which focuses only on explicit costs, was calculated per unit area. Nonetheless, opportunity costs were considered for non-monetary transactions. Variable costs include input costs (fertilizers, pesticides and seeds) and temporary labor wage. Fixed capital consists of tools such as hoes, dabas, watering cans, shovels, wheelbarrows, rakes and machetes. Other costs such as land rents and payments in kind for extension services were not considered. Gross margin was calculated as gross revenue valued at farm gate prices minus variable costs, and net margin is gross margin minus fixed costs. The latter consist of depreciation of all farm tools of more than one year lifetime (hoe, machete, watering pump and insect nets and their installation). The annuity by type of equipment (Ami) was estimated by the following formula:

$$Am_i = n_i * P_i / D_i$$

Where:

Am_i=annuity tools considered in the production of vegetable i;
n_i =number of tools used by the vegetable grower in cabbage and pepper production;
P_i =unit purchase price;
D_i=lifetime of the tool.

In calculating gross revenue for each crop, we assumed that all harvest is completely sold at the selling price declared by the vegetable grower. The Student t test was used to see if there is a significant difference between existing production systems and new technology for average costs and margins per hectare. This test also contributed to identifying the most profitable production system. The most ubiquitous indicator of profitability is the benefit / cost ratio or profit ratio, i.e. the ratio between the net revenue or profit and total production cost.

Comparisons between non-users and users of the agro-net technology in the different production systems were then made, with the aim of estimating increases in profit ratio provided by the use of the technology. In order to deepen the production efficiency analysis, labor productivity and capital productivity – with and without the use of insect nets – were used as indicators of economic performance of the identified production systems. They were calculated as follows[5]:

- Labor productivity=(Gross revenue - all costs except labor)/ number of worker units
- Capital productivity=(Gross revenue - all costs except capital)/ Capital

These formula are proxies of marginal productivities (i.e. marginal output of X / quantity of X). In the absence of production functions, marginal output of each production factor (X) was calculated as “Gross revenue – all costs except X”. This was done under the assumption that other factors are used at the threshold of zero profitability, i.e. their contribution to the total output is exactly equal to their costs.

*[5] Please note that number of workers is not exact measure of labor. Man-days is more appropriate and is calculated as: Sum (number of workers *age class coefficient *number of days worked). This formula could not be used in this study because reliable data were not available on number of days worked and age class coefficients in vegetable production.*

Table 1. Structure of the study sample

Munici-palities	Non users	Agro-net users	Total	Munici-palities	Non users	Agro-net users	Total
Aplahoué	36	0	36	Grand-Popo	31	2	33
Athiémé	5	7	12	Houéyogbé	4	4	8
Bopa	8	1	9	Klouékanmey	4	5	9
Comé	25	5	30	Lalo	5	7	12
Djakotomey	0	3	3	Lokossa	3	4	7
Dogbo	35	3	38	Toviklin	8	0	8
Total sample (number)	164	41	205				
%	80	20	100				

Source: Survey data, September-October 2011

Under that limitation, comparisons between production systems were then made to determine the extent to which the use of the agro-net technology improves labor and capital factor productivity. Analysis of variance with the Fisher F test and Student t test were used to determine if there is a significant difference between the ratios calculated.

4. RESULTS AND DISCUSSION

4.1 Typology of Vegetable Crop Production Systems and Differential Use of Agro-nets

The typology of vegetable production systems in the study area was established. Fisher F-test was used to identify the main discriminant variables. The most significant variables at the 1% level include: Area sown in the previous year 2010, number of agricultural workers, costs of labor and cost of seeds, fertilizers and pesticides. Using the Principal Component Analysis (PCA) and classification by dynamic clouds (K-Means Cluster Analysis), three production systems were identified: Intensive production system, extensive production system and semi-intensive production system.

The intensive production system is practiced by producers in their sixties, with high purchasing power. With large land size and high input use per ha, they are large farmers and have good experience in vegetable production. They support high labor costs and use insect nets. The extensive production system is practiced mostly by small vegetable growers, quite young (22-35), with low use of production factors (land, labor and capital). They do not use insect nets, probably because of high costs associated with the use of the technology. The semi-intensive production system is characterized by moderate use of production factors. Producers in this group are aged 36-60 and also use insect nets. They represent 53% of growers and 11.2% of insect net users, against 22% and 8.8% for intensive growers (Table 2).

4.2 Comparison of Farm Resource Management and Financial Profitability Indicators

Table 3 shows that pepper and cabbage production is profitable in the identified systems. However, the intensity of use of production factors varies greatly from one production system to another. Highest margins were observed with the intensive system and the lowest with the extensive system. However, the benefit / cost ratio of the extensive system (4.13 and 2.65 for pepper and cabbage) was higher than that of other systems, indicating that both crops are highly and more profitable in that system. The limited or non-improved profitability in semi-intensive and intensive systems stems from higher production costs (4-7 times those of the extensive system) with the agro-net technology whereas crop yields and per unit output value did not significantly increase.

Table 2. Distribution of vegetable growers by production system and use /non-use of insect net

Production systems	Without net	With net	Total
Extensive	24,88% (51)	0% (0)	24,88% (51)
Semi-intensive	1,95% (86)	11,22% (23)	53,17% (109)
Intensive	13,17% (27)	8,78% (18)	21,95% (45)
Total	80% (164)	20% (41)	100% (205)

Note: Figures in parentheses are numbers of growers
Source: Survey data, September-October 2011

Table 3. Financial profitability and factor productivities of pepper and cabbage production systems without the use of insect nets

Items	Pepper			Cabbage		
	Intensive system	Semi-intensive system	Extensive system	Intensive system	Semi-intensive system	Extensive system
Gross revenue (Fcfa/ha)	3709316.3±715666.04^{a}	2090550±910221.7^{b}	870626.3±58689.4^{c}	5405568.2±869231.07^{a}	4631394.1±1080222.9^{b}	2616194.8±171369.7^{c}
Total production cost (Fcfa/ha)	1293187.2±263219.4^{a}	709978.1±91325.2^{b}	169855.8±35679.01^{c}	2104291.6±795918.6^{a}	1621611.9±743441.6^{b}	716653.4±35820.19^{c}
Net revenue or Profit (Fcfa/ha)	2416129.1±904893.28^{a}	1380571.9±1637793^{b}	700770.5±46020.78^{c}	3301276.6±146624.94^{a}	3009782.2±673562.6^{b}	1899541.4±271099.02^{c}
Benefit/Cost ratio (Profit ratio)	1.87^{a}	1.94^{b}	4.13^{c}	1.57^{a}	1.86^{b}	2.65^{c}
Labor productivity (Fcfa/Manday)	4085.92^{a}	3238.19^{b}	3562.14^{c}	5784.61^{a}	4708.15^{b}	8030.55^{c}
Productivity of capital	2.86^{a}	2.94^{b}	5.74^{c}	2.57^{a}	2.86^{b}	4.53^{c}

Notes: a, b and c: level of significance 1%. The means are statistically different from one letter to another at the level of 5%

Table 4. Financial profitability and factor productivities of pepper and cabbage production systems with and without insect nets

Items	Pepper				Cabbage			
	Semi-intensive system		Intensive system		Semi-intensive system		Intensive system	
	Without net	With net	Without net	With net	Without net	With net	Without net	With net
Grossrevenue (Fcfa/ha)	2090550 ±910221.7	2626327±878408	3709316.3±715666.04	4374700±1 172604	4631394.1±1080222.9	4996100±687931	5 405568.2±869231.07	7 790500±1 090780
Pesticides (Fcfa/ha)	46823.5±10005.2^{b}	33206±16194^{a}	66420.3±9351.1^{d}	26913±11550^{c}	113080.4±71964.5^{b}	93696±62048^{a}	204600±86 800^{d}	105299±83025^{c}
Labor (Fcfa/ha)	113448.3 ±10709.6^{b}	495417±103503^{a}	412536.9±36153.4^{d}	866234±179408^{c}	321225.1±109132.4^{b}	502500±18285^{a}	331370.5±171895.3^{d}	763695±291923^{c}
Gross margin(Fcfa/ha)	1552576.8±832979.6^{a}	1625 150±463746^{a}	2696761.1±517626.1^{b}	2921094±264223^{b}	3196595.06±414982.02^{b}	3 407155±287970^{a}	3 576617.1±156768.1^{d}	5523396 ±162930^{c}
Total production cost(Fcfa/ha)	709978.1±91325.2^{b}	1 243677±235762^{a}	1293187.2±263219.4^{d}	1833938±430328^{c}	1621611.9±743441.6^{b}	1743836±799463^{a}	2 104291.6±795918.6^{d}	2657429±1 301500^{c}
Net margin or Profit (Fcfa/ha)	1380571.8±163779.3^{a}	1 382650±450296^{a}	2416129.1±904893.28^{b}	2540762±231103^{b}	3009782.1±673562.6^{b}	3252264±111532^{a}	3 301276.5±146624.94^{d}	5133071±210720^{c}
Benefit/cost ratio (Profit ratio)	1.94^{b}	1.11^{a}	1.87^{d}	1.39^{c}	1.86^{b}	1.87^{a}	1.57^{d}	1.93^{c}
Labor productivity (Fcfa/Manday)	3238.19^{b}	1875.36^{a}	4085.92^{d}	2754.66^{c}	4708.15^{b}	3504.25^{a}	5784.61^{d}	5152.34^{c}
Productivity of capital	2.94^{b}	2.11^{a}	2.86^{d}	2.38^{c}	2.86^{b}	2.87^{a}	2.57^{d}	2.93^{c}

Notes: a and b: level of significance 5%; c and d: level of significance 1%. The means are statistically different from one letter to another at the level of 5%

In pepper production insect nets are used only in experimental farms and nursery, and not in the real field (farm), probably because the plant's height is such that early installation of the nets – as it is recommended – would impede flowering and disturb the plant's development. Moreover, it would require more net rolls and higher and more arches for their installation. Overall, the use of the agro-net technology in pepper fields is time consuming and labor-demanding, meaning higher production costs than without it. Producers were therefore advised to limit the use of the net only in nursery for this crop. In the case of cabbage, the net is set in nursery and on-farm experimental fields because cabbage plants rest on the floor until flowering.

Some experienced vegetable growers claimed to be satisfied with the use of the net in pepper nursery. The agronomic advantages include protection of plants from damage caused by animals and crickets, and stronger plants for transplanting. But they complained about the presence of whitefly that pass through the mesh, thus causing extra cost of purchasing insecticides for joint treatments. Indeed, according to Simeni Tchuinte [22], in the field (i.e. real farms) pepper stands out among traditional vegetable crops but producers do not fully benefit from their investments because of diseases caused by insects.

Above Table 4 shows that gross revenues are significantly improved for both crops with the agro-net technology. However, the use of this technology requires significant initial investments, which producers in extensive systems cannot afford. That's the reason why the profitability analysis is limited to semi-intensive and intensive systems. It appears from this table that the use of insect net in intensive and semi-intensive systems is not more profitable than old production practices of pepper. The benefit/cost ratio is respectively 1.94 and 1.87 for the intensive and semi-intensive production systems without the use of the net, against 1.11 and 1.39 in the same systems with the use of the net, i.e. respectively 42.8% and 25.7% profit reductions. On the contrary, cabbage production under insect nets is more profitable with the nets in both systems. The benefit/cost ratio is respectively 1.86 and 1.87 for the semi-intensive production system without and with the use of the net. For the intensive production system, corresponding figures are 1.57 and 1.93. In addition, the use of net reduces pesticide costs. This result confirms previous findings [23,24]. Regarding economic performance, Table 3 also shows that labor productivity has not improved with the nets in both systems for cabbage and pepper production. Indeed, significant decreases in labor productivity appear between 'without' and 'with the technology' for pepper production in both semi-intensive and intensive production systems. Compared to non-users, labor productivity of users have decreased by 72.6% in the semi-intensive system and by 48.3% in the intensive system. Corresponding figures for cabbage are 34.3% and 12.3%.

The reason is that the use of insect nets demands too much labor, and the recommended technical route is long and tedious. Likewise, the use of insect nets in pepper production does not contribute to improving capital productivity in intensive system and semi-intensive system. Only in cabbage intensive system is capital productivity significantly improved with the use of insect nets, from 2.57 to 2.93, i.e. an increase by 15.6%.

5. CONCLUSION AND POLICY IMPLICATIONS

Pepper and cabbage production is profitable in the three production systems, yet only the extensive system offers the most interesting benefit / cost ratio (greater than 3) for both crops. Vegetable growers in the extensive system do not use the agro-net or insect net technology because it involves high initial investments and costly labor use which they cannot afford. The use of agro-net technology in semi-intensive and intensive systems did not improve the profitability of the two crops, except for cabbage in intensive system where the benefit / cost ratio increased slightly by 15.6%. Likewise, labor productivity in pepper production decreased by 72.6% with the semi-intensive system and 48.3% with the intensive system. The study therefore recommends that vegetable growers adopt the technology for cabbage– and maybe other crops with flat geometry spreading on the floor – in order to improve crop yields and quality through healthy avoidance of insect attacks. Considering the drudgery of work and high labor costs involved in applying current recommendations for using the technology, it appears that correction is required on the technical specifications (the net's design, arches/skeleton for installing it, and optimal adaptation of the technical route) of the technology to producers' farming practices. Only then can the technology be widely adopted, because it will become financially accessible to the extensive system growers (currently 80%)

who will then move from their current status of non-users to that of users. They will also derive substantial profits while offering healthy vegetables to fulfill the existing high demand in domestic and regional markets.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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