Cropping Sequence in Micro-Scale Vegetable Gardens in the Northwest Region of Cameroon

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Abstract   Micro-scale agriculture plays a key role in Cameroon's economy. However, poor farm planning and suboptimal sequencing of farm operations among other factors tend to frustrate farmers, resulting to mismanagement of the often meager resources at their disposal. This study sought to find out an annual cropping pattern or sequence for vegetable farmers that maximizes annual returns and enhances the optimal allocation and utilization of farm resources amidst weather risks and climate variability. With the case of the Northwest Region of Cameroon, this study made use of primary data collected with the help of a questionnaire administered to randomly sampled vegetable farmers from 6 preselected farm communities. Dynamic programming techniques were applied to estimate a recursive farm model. This study identified three cropping seasons per year, the cultivation of five main classes of vegetables and over 15 species in the study area. The findings of this work further specified that vegetable farming was most profitable during the drier periods of the year. Farmers were advised to priorities the cultivation of the fruit vegetables during the first and third cropping seasons while the leafy vegetables were advised to be prioritized during the second cropping season (fruit-leafy-fruit vegetable cropping sequence). The findings of this work justified that adjusting cropping patterns as recommended, without a necessary increase in resource use, a farmer can make an annual profit of 5155307 FCFA, which is significantly higher than the average profit of 4298909.667 FCFA realized from cultivating of all the five vegetable enterprise combinations in the study area.

Keywords: vegetable gardens, cropping sequence, deterministic dynamic programming

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1. Introduction

Alleviating poverty, eradicating malnutrition and coping with climate change are some of the major preoccupations of contemporary Africa [1]. Like the continent at large, Cameroon is yet to create the necessary economic conditions for the effective exploitation of the huge agricultural potential of the country. A major subsector that holds strategic potentials in combating malnutrition and poverty is the food crop subsector, with vegetable production playing a significant role. Vegetable farming thus proves to be one of the drivers of especially pro-poor growth in the country and beyond. As such, the success of Cameroon's micro-scale vegetable farming is not only important for the producer and the nation but has significant impact on access to food for the population of the Central African sub region as a whole [2]. This justifies why the government of Cameroon and her development partners have recently made efforts towards the support and development of micro-scale vegetable farming across the country.

Farm size is an important issue in economics of agriculture. However, given the challenge that millions of rural households face in developing countries such as Cameroon in accessing agricultural land, most families have settled for smaller holdings. In peri-urban settings these challenges are reinforced and mini-farmlands now predominate given the competing land uses albeit at the expense of food self-sufficiency and security of families. Micro-scale family farms that are less than 0.5 hectares are now pervasive in the economic life of Cameroon, not only for food production, but also key for social protection as well eco-preservation which is the livewire of such mini-farms. This type of farming is usually characterized by low yields, little or no value addition, intensive labour use, limited use of agrochemicals, low application rates of modern technologies and high levels of production inefficiency [3]. Unlike large-scale commercial agriculture, micro-scale farming plays a dual role of being a source of household food supply as well as income generation from sale of surplus. The diversity of crops grown on a small area of land further distinguishes micro-scale vegetable farming from other types of farming. The aforementioned characteristics of micro-scale vegetable farming often result to low yields, poor product quality, alarming rates of post-harvest losses, high production costs, low profitability and consequently increased incidence of poverty and hardship.

Given these merits, the government of Cameroon and its partners such as the FAO invest money and effort in policy environments that support micro-family farms. However, the measures put in place for the enhancement of micro-scale vegetable farming have been perceived necessary but not sufficient. Policy failures have tended to undermine the relevance and economic potentials of this subsector. This situation poses an increasing threat to food security not only to Cameroon but to neighboring countries and beyond. Given the survivalist nature, these farms have been resiliently reliant on the household for the supply of its factor inputs, including; labour input, land (near the family home), water for irrigation (often liquid domestic waste), capital, and green manure from household waste, among others. This challenge is further enforced by effects of weather risk and climate variability, poor sequencing of farm enterprises and general inefficacies in farm planning. This makes micro-scale vegetable farming less resilient to economic and environmental shocks like price fluctuations and rainfall variability. These shocks often have a negative incidence on their productivity and profitability. A farmer is therefore challenged to prioritize the cultivation of the most rewarding crop enterprises subject to the expected environmental and economic outcomes during a particular period. This study thus hypothesizes that the enterprise choices cultivated by a farmer per cropping season do not significantly influence his annual profits. The remainder of this paper is structured as follows. In section 2 we describe the material and methods used for the study. Section 3 presents the results, while section 4 contains the conclusions and policy implications of the study.

2. Materials and Methods

2.1. Description of Study Area

This study is carried out in the Northwest Region of Cameroon. The region is located along the western highlands of the country, precisely between latitude $5^0 43"$ and $7^0 9"$N longitude $9^0 13"$ and $11^0 13"$E in the Republic of Cameroon. The region shares boundary to the north and west with the Federal Republic of Nigeria, to the south with the South and Southwest Regions of Cameroon and to the east with the Adamawa Region of Cameroon. This region covers a total surface area of 17400km^2, characterized by the western highlands, with prominent land features like mountain ranges (e.g. Bamenda-Sabga mountain range), plateaus (e.g. the Bmenda-Oku-Kumbo-Njinikom high plateau) plains and valleys like the Ndop plains and the Menchum valleys respectively [4]. Located along the savanna region of the country, the Northwest falls within the Western Highlands Agro ecological zone. As can earlier be guessed by virtue of geographic location, climatic conditions in this region have greatly been modified [5]. This region presents a predominance of an equatorial type climate, shown in the monomodal rainfall pattern experienced with nine months of rainy season and three months of dry season. Average annual temperatures range between 13-22°C while soil types vary greatly across the region but with a predominance of loam and sandy-loam soils which are reasonably fertile and favorable for farming, especially vegetable farming. By virtue of geographic location and climatic conditions, this region presents a savanna type vegetation cover with large expands of grass fields, annual shrubs and sparsely populated trees.

According to Cameroon's National Institute of Statistics (2010), the Northwest Region of Cameroon is the third most populated region of Cameroon, with an estimated population of 1.8 million by the 2010. The region consists of seven administrative divisions and 34 subdivisions headed by divisional officers and sub divisional officers respectively, with auxiliary support from traditional rulers under the immediate supervision of the Governor who is the greatest administrative authority of the region. This region boasts of a strong and influential traditional administrative setup with many first class, second class and third class chiefdoms. These chiefdoms are ruled by traditional authorities (Fons), who provided auxiliary support to the government for the smooth administration of the population. Similar to other regions of Cameroon, the Northwest presents a predominantly agrarian economy with agriculture and its related activities being the main economic driving force, employing up to 80% of the population and accounting for their livelihoods and sustainability. Women constitute a majority of farmers in the Northwest, cultivating mostly food crops like maize, beans, cocoyam, yams, cassava, vegetables, etc. primarily for household consumption and the commercialization of excesses to supplement family incomes. On the other hand, most men in this region are engaged in nonfarm activities like trading, vocational jobs like building and construction, carpentry, automobile mechanics, etc. The relatively fewer men who venture into agriculture engage more into livestock farming and the cultivation of plantation crops like coffee, cocoa, oil palm, etc. These animals and plantation produce are mainly for commercialization although minute quantities are consumed within the household. In addition, some men raise these livestock like sheep, cattle, goats, pigs and fowls as a form of social security (insurance) scheme to caterer for unforeseen outcomes like illnesses, school fees, other traditional and religious festivities like weddings, Christmas celebration, feast of the ram, etc. Other economic activities in the Northwest include; palm wine tapping, craftwork, commercial motor transport, etc. Craftwork, most especially has solid grounds in this region most probably due to the availability of raw material from the natural environment and the strong influence indigenous cultures have on the population's way of life. The industrial sector on its part in this region is highly underdeveloped owing to poor economic policies, inadequate infrastructural development, and generally high levels of unawareness among the population. However, to a small extend, individuals at their respective levels are involved in the transformation and processing of farm produce. This is done on a very small scale, using rudimentary tools and technologies which are generally inefficient and do not guarantee good quality. In response to this major setback, the government and her development partners are making efforts towards revamping the industrial sector in this region and the nation at large.

2.2. Analytical Framework

In trying to maximize farm profits farmers may attempt to increase the size of their farms. This increase in farm size comes with an increase in input use and a corresponding increase in cost of production, but controversially, it does not guarantee an obvious increase in profits. A better way to address this problem is therefore to make decisions and choices that will increase output without necessarily increasing, neither the size of the farm land cultivated, nor the amount of inputs used. This can be achieved through proper farm planning and optimal sequencing of small scale vegetable farm enterprises. To efficiently plan and sequence these vegetable enterprises, the farmer needs to carefully assess both the biotic and abiotic factors that determine the cost incurred and returns accrued from year-round vegetable farming. Thus prompting the poor farmers not only to make complicated agronomic decisions on crop rotations but also to make smart economic decision on what crop mix sequentially succeeds the other. These farmers tend to adopt traditional procedures like trial and error, experience and instincts as guidelines to farm planning [6]. These traditional decision making techniques are generally unscientific and inefficient compared to scientific agronomic and economic guides to farm planning. Some factors that influence the decisions of which vegetables to produce made by these farmers include; environmental variables which are beyond the control of the farmer such as; amount of rainfall, soil composition, temperature,

topography, etc. However, in this study, these environmental factors do not vary significantly across the study area. This means that all the vegetable farmers face almost the same environmental conditions and thus the differences in the decisions they make cannot be attributed to these variables only. Some other variables that significantly cause farmers to make different decisions of which vegetable to produce include; level of education of the farmer, age of the farmer, amount of capital available to the farmer, total area of land available to the farmer, the method of irrigation accessible to the farmer, etc.

A typical exemplary situation where a vegetable farmer needs to make production decisions and choices so as to come up with a profitable cropping sequence is presented on Figure 1. As seen in Figure 1, a vegetable farmer in the Northwest region can cultivate vegetables three times in a year (three stages). For example, during the first season, he may make the decision to cultivate tomato or water melon or any other crop as the case may be. During the second season, he may choose to cultivate onion or cabbage or huckleberry or any other vegetable as the case may be, while he can choose to cultivate carrots or cucumber or any other crop as the case may also be during the third stage. These decisions will depend on the socioeconomic characteristics of each farmer and the environmental conditions the farmer finds himself in. The main problem this study seeks to address therefore is to find out the most profitable crop a farmer should decide to cultivate at each stage so as to give an optimum annual cropping sequence that yields maximum annual profits.
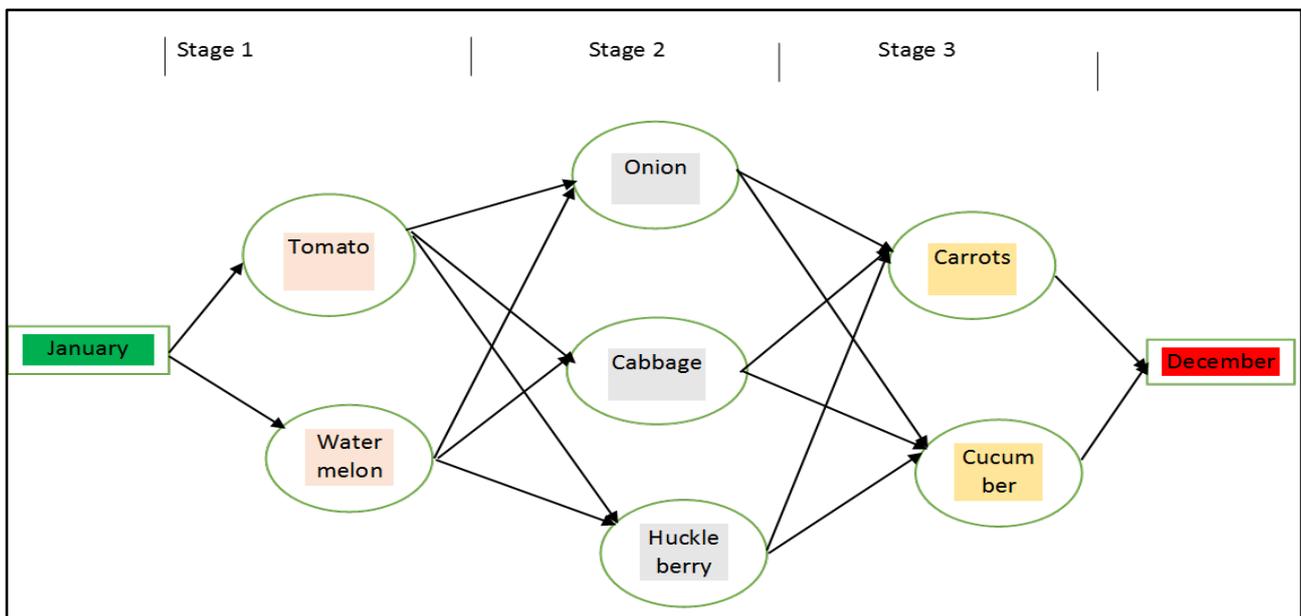

Figure 1. Exemplary cropping sequences for a vegetable farmer (Source: author's conceptualization)

Various approaches have been employed to empirically model farm planning and performance. These techniques can be classified based on whether they specify a functional form on the underlying production function or not (i.e. parametric versus nonparametric). The most popular techniques used in literature are Linear Programming, Risk programming, Game Theory Analysis, Data Envelopment Analysis and Stochastic Frontier Analysis. Among these techniques used in farm planning, LP and DEA prove to be the most widely used. The DEA

technique first introduced by Farell [7] and further developed by Charnes et al. [8] employs a nonpara-metric approach to estimate technical efficiency. The LP technique on its part which was introduced by George Dantzig in 1947 has also been extensively applied in farm planning. However, the main criticism of these techniques as underscored in literature is that they ignore the dynamic and recursive attributes of the farm decision making process. These techniques fail to incorporate the impact that present farm decisions would have on future

production, thus they are limited to a snap-shot analysis of contemporary conditions. With this shortcoming, it becomes difficult to make long-term decisions and sound forecasts on sustainable crop rotation plans and sequencing patterns. Dynamic programming attempts to bridge this gap. Dynamic programming is a resource allocation and optimization tool which is very useful in scheduling and sequencing various operations. The term dynamic programming was originally used in the 1940s by Richard Bellman to describe the process of solving problems where one needs to find the best decisions one after another. By 1953, he refined this to the modern meaning, referring specifically to nesting smaller decision problems inside larger decisions. This approach is therefore more suitable for multi-stage decision making and farm planning and is thus employed in this study. Other analytical techniques employed in this study are descriptive statistics, inferential statistics, and farm budgeting analysis. Descriptive statistics are used to describe the various socio economic characteristics of the farmers that affect the farm decision making process. It involves the use of means, frequencies, and figures such as bar charts, pie charts and tables. Inferential statistics are used to establish the relationship that exists between the profits of the different crop enterprise combinations and assesses the comparative rates of returns on farm investment. Farm budgeting, gross margin, profitability and return on investment (ROI) analysis are employed to evaluate the profitability of each vegetable enterprise per cropping season. These profitability levels are later factored into the dynamic programming model to give the most profitable annual cropping pattern or sequence.

2.3. Empirical Model

The recursive dynamic programming model is specified in this study within a cross-sectional framework. This model specifies three vegetable cropping seasons (March-June, July-October and November-February). These seasons appear as the various stages of the dynamic programming model. The model seeks to maximize annual profit (LHS) as a function of the seasonal profits accrued from the respective enterprise choices made by a farmer (RHS) at each stage (cropping season). This model as specified below is estimated for micro-scale vegetable farmers considered under this study as follows;

$$\text{Max } Z_{ijz} = \left\{ \sum_{i=1}^{k} \left(P_i X_i - C_i \right) \right\}_n$$
$$+ \left\{ \sum_{j=1}^{k} \left(P_j X_j - C_j \right) \right\}_{n+1} + \left\{ \sum_{z=1}^{k} \left(P_z X_z - C_z \right) \right\}_{n+2} \quad (1)$$

Subject to:

$$\sum_{i,j,z=1}^{k} \left(di + dj + dz \right) \quad (2)$$

Where

Z_{ijz} = maximum annual profit, $\left\{ \sum_{i=1}^{k}(P_i X_i - C_i) \right\}_n$ = the profit realized during the first farming season (Mar-Jun),

$\left\{ \sum_{j=1}^{k}(P_j X_j - C_j) \right\}_{n+1}$ = profit realised during the second farming season (Jul-Oct)

$\left\{ \sum_{z=1}^{k}(P_z X_z - C_z) \right\}_{n+2}$ = profit realised during the third farming season (Nov-Feb),

n = stage 1 (first cropping season), n+1 = stage 2 (second cropping season), n+2 = stage 3 (third cropping season), P_{ijz} = market prices of respective enterprises in a particular season, X_{ijz} = various states (output of chosen vegetable enterprise per hectare), C_{ijz}= total cost per hectare of producing a chosen enterprise; d_i, d_j, d_z= enterprise choices cultivated by a farmer during the first, second and third cropping seasons respectively. k = number of vegetables enterprises cultivated at each stage.

2.4. Nature and Source of Data

A list of vegetable farming communities was generated with help of information from the Northwest Regional delegation of agriculture. Six vegetable farming communities were randomly selected from the sample area (Santa, Bafut, Oku, Bamungo, Bambui and Babanki). Twenty farmers were randomly selected and contacted in each of the six communities. The simple random sampling technique was employed so that each farmer in the study area had an equal chance of being selected. This therefore gave a sample size of 120 farmers. This study employed a questionnaire as the main instrument for data collection. The specific intensions of the study were translated into clear questions and presented on the questionnaire. Both open and closed ended questions were well structured and in simple language such that answers to these questions provided necessary data for the study. On this questionnaire, featured questions to capture the biography information and characteristics of farmers, their farm records and perception, challenges and prospective solutions to identified constraints. This questionnaire was typically coined into three section. The first section had questions which captured the biographic status and general social characteristics of farmers, section two contained questions on the economic status of the farmers while section three of the questionnaire contained questions on the general structure of farm resources, input use and production output levels. This was administered by personal discussion with the respondent (asking and answering session). This data was then extracted from the questionnaire to compute costs of production, farm profits and returns of farm investments which were in turn factored into the empirical model.

2.5. Estimation of Input-Output Variables

The variables analyzed in this study include total crop output, total cost of variable farm inputs, the total cost of fixed farm inputs, the cost of depreciation of farm tools and equipment, the profitability of the crop enterprise combinations and the return on investment of the crop enterprise combinations. They are estimated as follows:

2.5.1. Total Output

Farm yields per hectare, measured in kilograms of vegetable produced are used in the analysis. Measurements are taken in local measuring unit like;

buckets, baskets, bundles (farmers mostly use these non-conventional units of measurement). Samples of the various items are latter weighed on a standard scale and the local units converted to standard units (kg).

2.5.2. Total Fixed Cost

The annual fixed cost of production is estimated by determining the value of the depreciation of the farming tools and storage facilities.

2.5.3. Depreciation Cost

This is the loss in value of the farmer's asset (farmer's tools and equipment) due to use or obsolescence. The straight line method was used. The basic assumption is that the farmer's asset has a uniform rate or reduction in value over its useful life span. The following equation is used in calculating depreciation.

$$D = \frac{C - S}{n} \qquad (3)$$

Where D = depreciation value, C = Original cost of material, S = Salvage value, n= number of useful years.

2.5.4. Total Variable Costs

These are the costs of all inputs which can be varied in on production season conveniently. They include the value of planting material, the amount spent on fertilizer (organic and inorganic), the amount spent on farm labour, fuel for irrigation, transportation cost and amount spent on pesticides.

2.6. Determination of Profitability

The gross margin technique of farm budgeting analysis was used to access profitability of crop enterprises in the cropping system. Gross margin is an important concept in farm planning. It measures the contribution of an enterprise to the total farm profit [9]. Thus, the gross margin of each enterprise is an important determining factor in selecting a combination of enterprises on the farm. The gross margin of a farm enterprise is the difference between the total value of production and the total variable cost. The difference between, the gross margin and the total fixed cost gives the profitability of the cropping system. This could be expressed as:

$$\pi = \sum_{i=1}^{n} P_i Q_i - \left[\left(\sum_{j=1}^{m} r_j x_j + K \right) \right] \qquad (4)$$

Where π = profitability of the system, P_i= estimated unit price of output, Q_i= estimated quantity of output, r_i=estimated unit price of variable input, x_i= estimated quantity of variable input, K= total fixed cost, n,m= sample size.

2.7. Return on Investment

The return on investment (ROI) is used to assess the performance of the crop enterprise combinations in the entire cropping sequence. ROI often called the accounting rate of return is an approach used to incorporate the amount of invested capital into a performance measure. ROI is the ratio of net income to the invested capital in a farm business [9].

$$\text{ROI} = \frac{\text{Net income}}{\text{Invested capital}} * \frac{100}{1} \qquad (5)$$

ROI projects the effect on farm income of a particular investment and estimates the return to the capital engaged. The overall return of a project is an important indicator of the efficiency of resource use [10]. This measure of ROI highlights the benefits farm managers can obtain by controlling costs and boosting revenues while paying attention to the level of investment.

Table 1. Classes of Vegetables Cultivated in the Study Area

	Class of Vegetable	Scientific name	Frequency of Cropping	Percentage of Male farmers	Percentage of female farmers
1	**Fruit Vegetables**				
	Tomato	*Lycopersicon esculenttum*	86	79.1	20.9
	Okra	*Abelmoschus esculentus*	38	36.8	63.2
	Garden egg	*Solanum melongena*	20	38.1	61.9
	Sweet pepper	*Capsicum frutescens*	48	83.3	16.7
	Hot pepper	*Capsicum annum*	53	52.8	47.2
	Watermelon	*Citrullus lanatus*	58	87.9	12.1
2	**Leafy Vegetables**				
	Cabbage	*Brassica oleracea*	82	55	45
	Leaks	*Allium porrum*	42	42.9	57.1
	Huckleberry	*Solanum nigrum*	64	37.5	62.5
	Parsley	*Petroselinum crispum*	57	26.3	73.7
	Lettuce	*Lactuca sativa*	38	29	71
3	**Seed Vegetables**				
	Green Beans	*Phaseolus vulgaris*	45	37.8	62.2
	Maize	*Zea mays*	24	41.7	58.3
4	**Tuber Vegetables**				
	Irish Potato	*Solanum tuberosum*	70	45.7	54.3
5	**Root Vegetables**				
	Carrot	*Daucus carota*	61	36.1	63.9

Source: Survey data, 2017.

2.8. Distribution of Classes of Vegetables Cultivated

Besides the native species of vegetables cultivated in the study area (mostly perennials) which command more of cultural value than economic value, this study reveals five main classes and over fifteen species of short seasoned vegetables cultivated in the Northwest region of Cameroon. These classes include; fruit, leafy, seed, stem and tuber vegetables. It was further observed that, the most cultivated classes of vegetable in terms of quantity produced and number of farmers involved were the fruit and leafy vegetables, while the root vegetables recorded the least production levels and cropping frequencies. The seed and tuber vegetables on their part recorded moderate cropping frequencies but were limited in terms of varieties and species cultivated. However, the frequency of cultivation of these respective classes of vegetables varied greatly among men and women. While the men championed the cultivation of fruit, and root vegetables, the women on their part lead in the cultivation of the leafy, seed, and tuber vegetables.

3. Results and Discussion

3.1. Socioeconomic Profile of Micro-scale Farmers

The findings of this study reveal that respondents ranged from 23 to 64 years with a mean age of 31.6 years whereas more than half of the respondents were below the mean age. This has a strong influence on their enterprise choices, scale of production and season of cultivation. There were more male respondents (61.7%) compared to female (38.3%), suggesting that vegetable farming (especially off-season cropping) in the study area is more male inclined. Respondents practice varied methods of irrigation, over 34.2% of farmers made use of the purely traditional technique of irrigation (with the use of buckets and other household utensils). Another 35.8% made use of the semi modern irrigation technique (with the use of modern watering cans and water tanks), while 19.2% made use of the modern irrigation technique (involving the use of water pumps and sprinklers). However, about 10.8% of the farmers did not practice any of the irrigation forms as they equally failed to cultivate vegetables during the dry season of the year. Looking at storage of farm produce, it was observed that only 33.3% of respondents temporarily stored their produce (on bare cemented floors) for a maximum period of two days while 66.7% sold their produce immediately upon harvest with zero storage nor transformation.

With these varied characteristics, farmers are likely to allocate their farm resources differently, schedule their farm operations differently, respond to economic and environmental signals differently and hence sequence their annual production patterns differently.

3.2. Seasonal Cropping Frequencies of Respective Enterprises

Micro-scale vegetable farmers of the Northwest Region of Cameroon cultivate five main classes of vegetable enterprises and over 15 different species. A farmer here cultivates the fruit, leafy, seed, root and tuber vegetables at least once a year. These respective enterprises have been seen to respond differently to fluctuations in environmental and economic signals, as such their cropping frequencies vary significantly across periods of the year. Table 2 shows the average cropping frequencies across the three cropping seasons of the year. From Table 2, it is observed that micro-scale vegetable farming is a year-round activity and as such a farmer in the study area cultivates at least one of the five enterprise combinations at every given period of the year. Furthermore, the fruit vegetable enterprise was the most cultivated enterprise combination during the first cropping season (March-June), with a frequency of 104 farmers. Similarly, the leafy vegetables recorded the highest cropping frequencies during the second and third cropping seasons (July-October and November-February respectively). The seed and tuber vegetables were cultivated only during the first cropping season (March-June) and hence presented zero cropping frequencies during the second and third cropping seasons. The Root vegetable enterprise recorded a moderate cropping frequency across the three annual cropping seasons. These cropping patterns suggest that micro-scale vegetable farmers prioritize the Fruit vegetables during the first cropping season, and the leafy vegetables during the second and third cropping seasons, thus making the fruit (C1) and leafy (C2) vegetable cropping pattern the most predominant.

Table 2. Farmers' enterprise combinations

Enterprise Combination	Enterprise composition	Cropping Frequency per Season		
		Season 1	Season 2	season 3
Fruit vegetables	Tomato-Okra-Garden egg-Hot pepper-sweet pepper watermelon-Cucumber	104	15	18
Leafy vegetables	Cabbages-Leaks-Nightshade-Parsley-Lettuce	74	19	19
Seed vegetables	Maize	87	0	0
Tuber vegetables	Irish potato	42	0	0
Root vegetables	Carrot	30	7	15

Source: Survey data, 2017.

3.3. Profitability of Vegetable Enterprise Combinations

The results of this study revealed that the highest returns to vegetable farming were recorded during the third cropping season (Nov-Feb). On the other hand, the second cropping season (Jul-Oct) presented the least profits/ha for all the enterprise combinations cultivated during this period. As shown in Figure 2, the seed and tuber vegetables (C3 and C4) were not cultivated during the second cropping season.

As noted in Figure 2, the root vegetable enterprise combination (C5) was the least profitable crop enterprise combination all through the three cropping seasons (average profits of 961 500 FCFA/ha, 961500/ha and 1 084 500 FCFA/ha respectively), while the fruit vegetable enterprise mix (C1) proved most profitable all through the year (1580679 FCFA/ha, 1432464 FCFA/ha and 2281795 FCFA/ha). The leafy, seed and tuber vegetables equally proved very profitable all through the year (though not as profitable as the fruit vegetables).

3.4. Seasonal Profitability of Vegetable Farming

Vegetable farming generally proved to be a very profitable activity at all periods of the year, capable of sustaining and improving the leaving standards of micro-scale farmers. However, findings in Table 3 reveal that vegetable farming is most rewarding in the study area during the dryer periods of the year. This validates the

observations wherein, the third cropping season (Nov-Feb) presented the lowest levels of rainfall and the highest payoffs to vegetable cultivation (average profits of 1827348.3 FCFA/ha), followed by the first cropping season (Mar-Jun, with average profits of 1827348.3 FCFA/ha) which in turn witnessed lower rates of rainfall than the second cropping season (Jul-Oct). The second cropping season on its part reported the highest levels of rainfall and the lowest profits (1228932.3FCFA). The findings therefore suggest an inverse relationship between amount of rainfall and profitability of vegetable cropping in the study area.

Profitability however varied greatly not only across seasons but also among respective farmers.

3.5. Optimal Cropping Sequence of Micro-Scale Farmers

The results of the dynamic programming model for farmers under this subgroup suggested that the fruit vegetable enterprise combination (C1) was the most profitable (average profit of 1580679 FCFA/ha) during the first cropping season of the year (Mar-Jun) thus qualifying for the optimal cropping sequence at this stage. The leafy vegetable crop enterprise mix (C2) for same reasons of highest average profitability (1292833 FCFA/ha), qualified for the optimal cropping sequence at the second stage (Jul-Oct) while the fruit vegetable enterprise mix again proved most profitable during the third cropping season (2 281 795 FCFA/ha) and reappeared at this stage (Nov-Feb). This optimal annual cropping sequence yields an approximate annual profit of 5155307 FCFA.
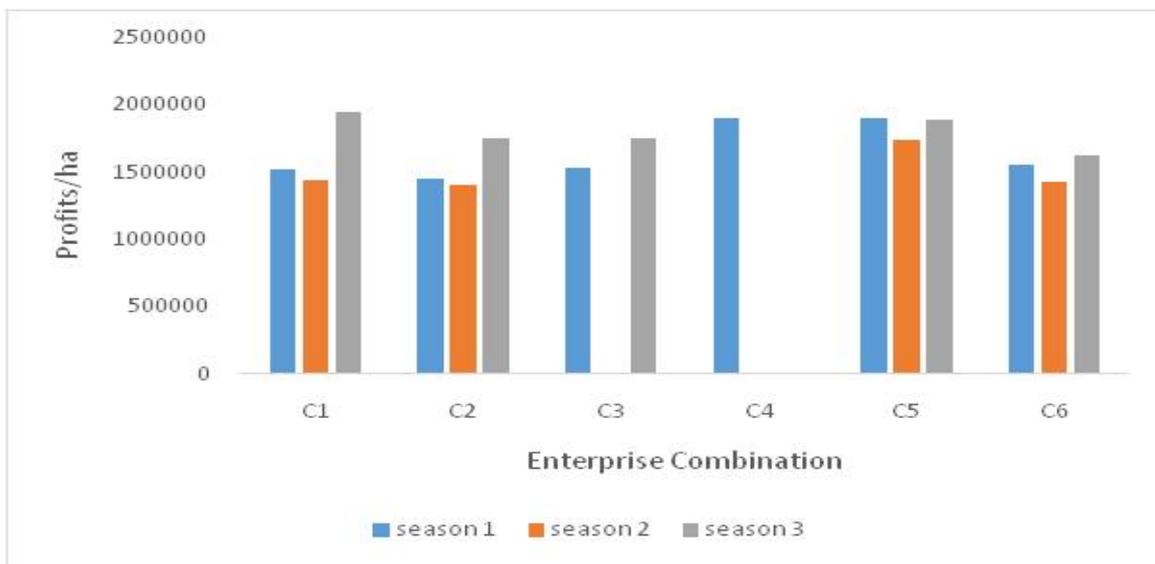

Figure 2. Profitability of different crop enterprises of micro-scale Farmers (Source: survey data, 2017)

Table 3. Seasonal Profitability of Vegetable Farming

| Combination	Total Cost/ha (FCFA)			Average profits/ha (FCFA)			Return on Investment/ha		
	Season 1	Season 2	Season 3	Season 1	Season 2	Season 3	Season 1	Season 2	Season 3
C1	434946	434946	397893	1580679	1432464	2281795	359.5	348.6	599.8
C2	373833	333333	373833	1292833	1292833	2115750	342.1	342.1	551.7
C3	344133	-	-	1322533	-	-	384.3	-	-
C4	277400	-	-	1055600	-	-	380.5	-	-
C5	291000	250500	291000	961500	961500	1084500	330.4	330.4	372.5
Average	344262.4	339593	354242	1242629	1228932.3	1827348.3	359.36	340.36667	508

Source: Survey data, 2017.
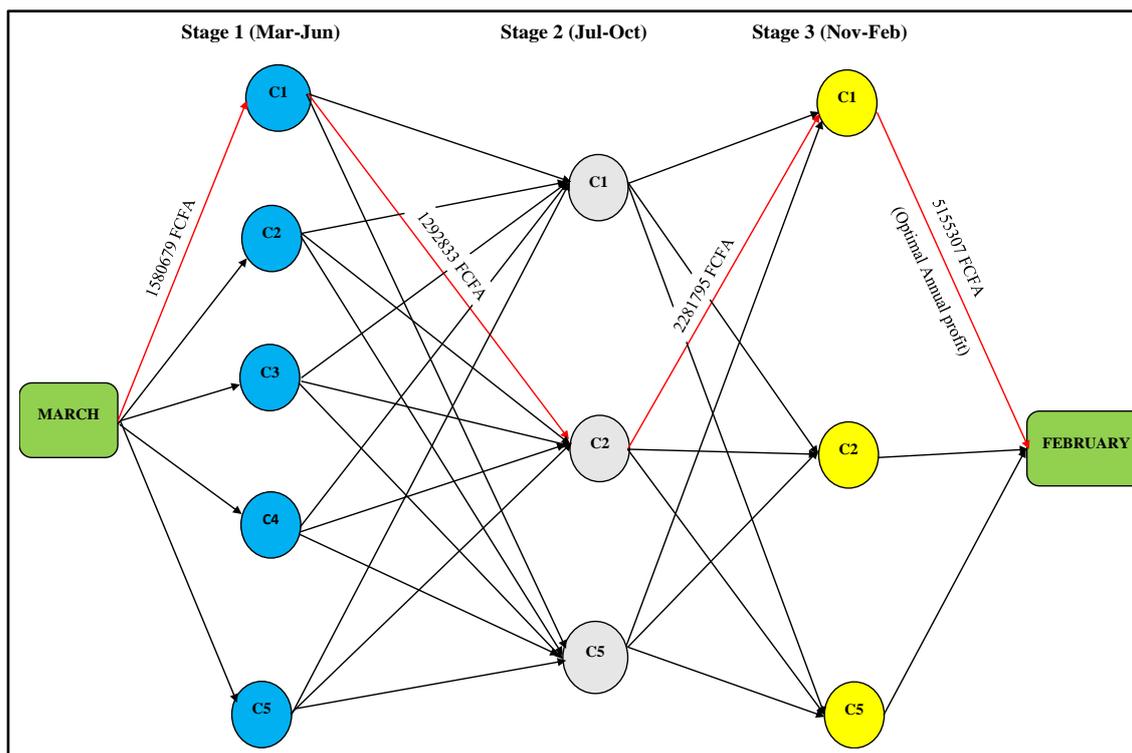
Figure 3. Optimal Cropping Sequence of Vegetable Enterprises for Micro-scale Farmers

Figure 3 demonstrates the maximum annual profit that a farmer can generate from the cultivation of the aforementioned vegetable enterprises is 5155307 FCFA.

However, this profit can only be realized if the farmer adjusts his/her cropping schedule so as to prioritize the optimal path (sequence) indicated in figure 3 (C1-C2-C1). This optimal cropping sequence specifies that a famer should prioritize the cultivation of the fruit vegetables during the first and third cropping season of the year (March-June and November-February respectively), most probably because this is the season with the most favorable climatic condition, with moderate rainfall. These fruit vegetables are very susceptible to climatic factors like soil humidity and as such, thrive best under moderate rainfall or irrigated conditions.

The leafy vegetable, more tolerant to high soil humidity levels, make this enterprise combination the most profitable combination during this period.

It is very important to note that for the purpose of reduction of risk of crop failure and seasonal food insecurity, a farmer can only prioritize this optimal cropping sequence to maximize profits but is not advised to completely terminate the production of the vegetable enterprises which do not appear on the optimal cropping sequence. These enterprises (seed, tuber and root vegetables) although with lower profitability still play a key role to household food security.

4. Conclusion

The min-nature of the micro-scale farms allows for adequate allocation of resources to farm operations. Farmers tend to rely exclusively on the household for the provision of major farm inputs like labour, capital, and water for irrigation, as well as organic manure for soil quality improvement. All these household by-products are supplied to the family gardens at minimal cost, thus driving down average production cost per hectare while generating high returns on investments. Micro-scale vegetable farming is particularly adapted to households' quest for food security and income generation in Cameroon. Efficient farm planning and optimal scheduling of farm enterprises and resources is without doubt crucial for food security, sustainability and enhancement of livelihoods.

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