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Production Efficiency and Building Marketing Strategies for Smallholder Tomato Farmers in the Adaklu Anyigbe District of Ghana: Linear Programming and Parametric Linear Programming Approach

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Many cultivars of tomato (*Solanum lycopersicum*) are grown worldwide, including those cultivated by most smallholder farmers in Ghana as a cash crop. Ghana's agricultural production is highly dependent on rainfed and its marketing systems are not efficient for the smallholder farmer who grows tomato and other staple crops. Better marketing and production strategies are necessary for the smallholder farmers to improve income levels. Linear programming and parametric linear programming models were applied to develop optimum income-maximizing crop allocation strategies for smallholder farmers. Optimum crop allocation on a 2.5-ha farm was 1.25 ha (50%) tomatoes, 0.75 ha (30%) maize, and 0.50 ha (20%) cassava. Optimum income levels were estimated using land and labor constraints, variable cost conditions, and production data for these crops in three single local markets and a combination of the markets. Theoretically, income could be maximized by selling only to Ashiaman Market compared with the other two market, but in practice, farmers need to ship produce to all three markets because of transactional cost which are incurred through transportation. Increasing the farm size from 2.5 ha to 8.64 ha for the selected crops increased income in both the single and combined markets even after accounting for increased labor inputs. Considering these findings, Government role is considered necessary in developing and strengthening Farmer Base Organization in value chain concept for tomato production and establish market information centre in the District.

Key words: *Solanum lycopersicum* (tomato), Production efficiency, Marketing strategies, Transactional cost, Smallholder farmer.

Introduction

1. Background

Many cultivars of tomato (*Solanum lycopersicum*) are grown worldwide, including those cultivated by most smallholder farmers in Ghana. Farmers growing tomatoes solely under rainfed conditions often encounter a glut of tomatoes at harvest, which, combined with the product' s high perishability, inadequate storage facilities in production areas, a lack of available processing sites, and poor market access, can result in high postharvest losses (Robinson and Kolavalli, 2010a).

During the 1960s, the government established a system of state and cooperative farms in an attempt to improve agricultural productivity in Ghana, but Due (1969) concluded that the attention given to the state farms should have been directed to private farmers and fishermen who produced 98% of the domestic food but were denied government support. Miracle and Seidman (1968), suggested the need for the government to extend agricultural technical support and incentives to small private farmers, and this would have gone a long way to increase domestic food production in Ghana. From the 1970s to the early 1980s, overall tomato production declined from 100,000 to 50,000 t per year (Robinson and Kolavalli, 2010b). Production gradually rose to around 100,000 t per year in the latter part

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of the 1980s and then to about 200,000 t per year during the 1990s, but it has been declining slowly in the 2000s. In addition, about 100,000 t per year of fresh tomatoes are imported from Burkina Faso, and imports of tomato paste from heavily subsidized EU producers have increased from 3,200 t in 1994 to 24,007 t in 2002. It is difficult for local tomato growers and processors to compete with the subsidized EU imports because they are priced below production costs (FAO, 2006).

Clottey *et al*. (2009) concluded that production efficiency could be improved by forming new micro-enterprises in both urban and rural areas. National production averages per hectare in the 1970s and 1980s were estimated to be 4.8 t/ha (Robinson and Kolavalli, 2010b), but were estimated to be 13 t/ha in the 1990s (Wolff, 1999). More recently, estimates have ranged from 7.5 t/ha (Robinson and Kolavalli, 2010b, Statistical Research Information Directorate 2003 Data) to 6.7 t/ha (Asuming–Brempong and Boakye, 2008). Overall, there has been little sign of progress in either the area cropped or the yield over the past two decades (Robinson and Kolavalli*,* 2010a). Prices of fresh tomatoes vary tremendously by season and region, but they were rarely below 200.00 cedi (GH¢) in Navrongo in the Upper East Region or GH¢ 150 in Techiman in Brong Ahafo in 2007−2009 (Fig. 1a).

Maize, cassava, yam, and plantain were reported by (WABS Consulting Ltd., 2008) to be the main staple crop grown in Ghana. Cassava one of the major important rural, urban staple food and raw material for the local industries, can yield from 10 t/ ha needs an efficient integrated production and marketing systems to give a stable supply (Nweke, 2004). In Ghana 60% of cassava planted were cash crops to the farmer (Nweke *et al*., 2002) playing a role to alleviate poverty. From 1997−2006, Ghana experienced 3.1% annual increase in maize volume at an estimated yield of 1.6 t/ha due to low adoption of technologies, but 4−5 t/ha can be achieved under improved technologies (WABS Consulting Ltd., 2008) when an effective lack of access to production inputs and efficient produce markets are addressed.

2. Government Policy Related To Tomato Production and Marketing

Agriculture policies in Ghana varied during the colonial era (1874−1957), post-colonial era (1957−1966), era of government participation (1966−1981), and the era of liberalisation (1981−present) (Asuming-Brempong, 2003). Subsistence agriculture received little support during the colonial era, but industrial crops were developed for export. After the introduction of socialist ideology during the post-colonial era, the GHIHOC Canneries in Nsawam (Eastern Region) and Wenchi (Brong Ahafo Region) and the Pwalugu Tomato Factory (Upper East Region) were built by the Government in the 1960s (Ablorh-Odjidia, 2003) (Fig. 1a). These three factories closed in the late 1980s, however, because of technical ineffectiveness, poor financial management, lack of spare parts, outmoded equipment, and poor marketing (Robinson and Kolavalli*,* 2010a). Public–private partnerships (PPP) were established in 2011 to encourage intensification and expansion of selected agro-based raw materials, such as oil palm, cassava, cocoa, cotton, sorghum, sugar-cane, pineapples, citrus, mangoes, and tomatoes. Best agronomic practices, in terms of yield, quality, and productivity for local agricultural raw materials, were among the policy prescription to be supported by PPP (Ghana Government Portal, 2011). The Ghana News Agency (2007) reported that reopening the Pwalugu Tomato Factory with the new name Northern Star Tomato Company Limited under a PPP would guarantee a market for tomato farmers in the 10 districts of the region and it current operations is reducing postharvest losses.

The Medium Term Agricultural Development Programme of the Ministry of Food and Agriculture focuses on the comparative and competitive advantages of the available markets for all crops and vegetables in all agro-ecological zones to stabilize the economy, create a foundation for sustainable and accelerate job creation in the agro-based industries (Ministry of Food and Agriculture, 2007). The Ministry of Food and Agriculture also created the Ghana Food and Agriculture Sector Development Policy (Ministry of Food and Agriculture, 2007) to increase competitiveness and enhance integration into domestic and international markets by strategically developing domestic production and marketing of tomatoes. The policy aims to improve infrastructure (e.g., roads to production centers) and market information to solve the following problems: weak market integration between local, district, and regional markets; low standardization and product differentiation in domestic markets; an unfavorable trading environment in local markets; and limited opportunities for market ex-

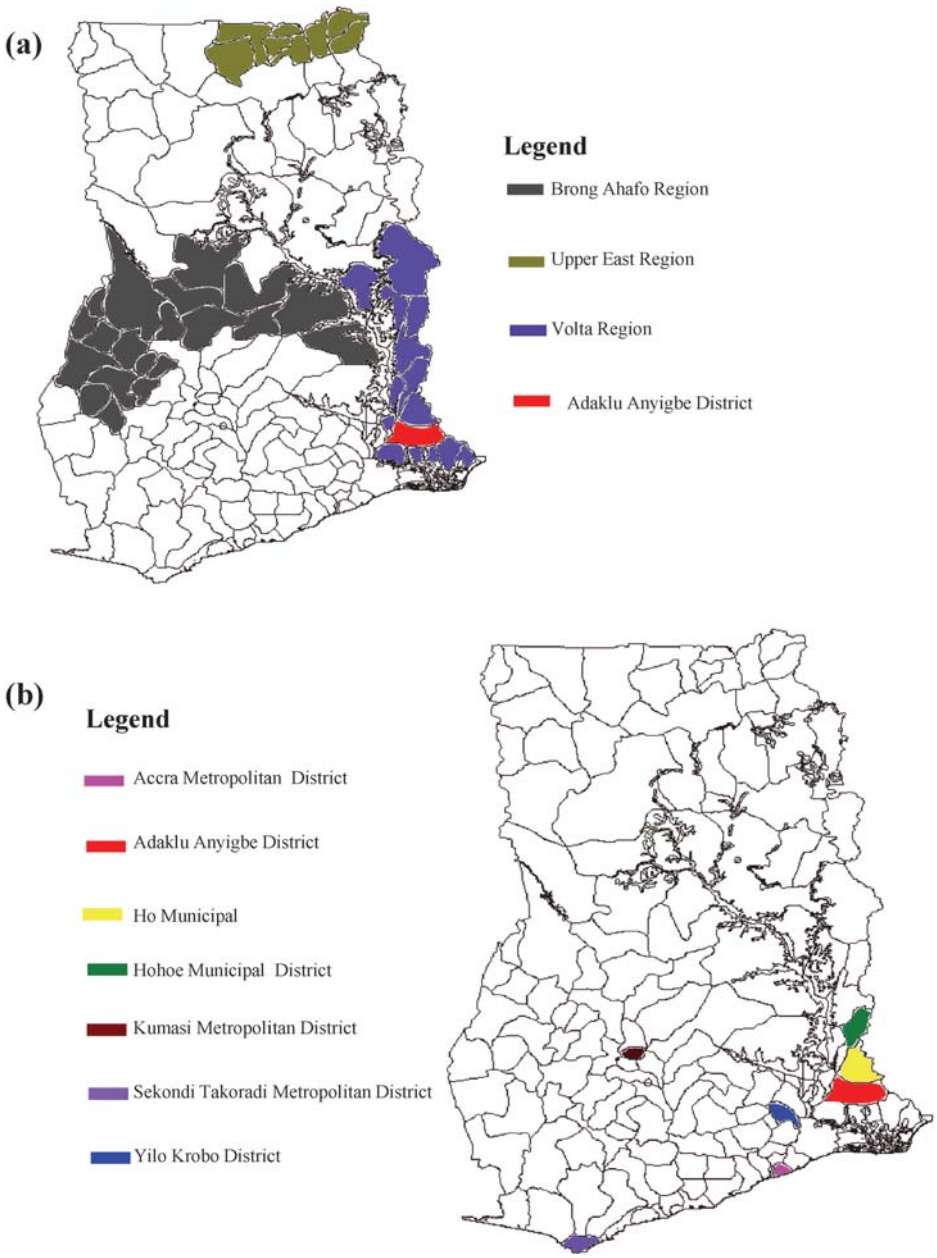

Fig. 1. (a) Map of Ghana, highlighting the study area (Adaklu Anyigbe District) and other marketing centers. (b) Map of Ghana, highlighting the Volta Region and Adaklu Anyigbe District.

pansion for producers, traders, and exporters. The Medium Term Agriculture Sector Investment Plan (Ministry of Food and Agriculture, 2011) which is to implement FASDEP II form 2011–2015, set the goals of increasing income growth by reducing postharvest losses of tomatoes to between 25% and 50% of the total harvest, improving the value added, and developing new products in existing markets.

3. Study Objectives

Tomato production in Adaklu Anyigbe District in southeastern Ghana has traditionally been on the subsistence level for home consumption, with little being sent to local markets by smallholder farmers. Is now cultivated on small-scale commercial level.

Production is strictly rainfed, with two crops produced a year during the major and minor rainy seasons. Both sexes are involved in the production, even though

male smallholder farmers outstripped the female smallholder farmers. Inorganic fertilizers are used extensively, but some smallholder farmers also sparingly use organic manure. Agro-chemicals are used in the control of insect pests and some diseases. The Agricultural Extension Department has also introduced the use of organic extracts and integrated pest management, which is yielding positive results.

Marketing is done using wooden crates of different sizes, and prices fluctuate according to the supply at a given time. Traders from markets in places such as Accra, Takoradi, Kpong, Hohoe, Ho, Tema, and other places come to the Adaklu Anyigbe District to purchase tomatoes (Fig. 1b). Women in these larger markets, known locally as "market queens," do not allow smallholder farmers to sell their own harvested tomatoes in these markets. The market queens earn more income than the smallholder farmer who sells in the local and surrounding markets.

The aims of this study were to compare the production efficiencies of tomatoes with those of maize, cassava, groundnuts, and peppers for smallholder farmers in Adaklu Anyigbe District and to evaluate and suggest marketing strategies to increase their income. Linear programming and parametric linear programming models were used to evaluate the strategies.

Materials and Methods

1. Study Area

Adaklu Anyigbe District is one of 18 districts in the Volta Region (Fig. 1a). In 2005, the district was carved out of Ho Municipality, which now borders it to the North, with South Dayi District on the west, Akatsi District and North Tongu District on the south, and the Republic of Togo on the east. It has a land area 1,061 km² and is at 6° 16−37′ N and long 0° 24−50′ E. The district's population was 52,850 in 2000, with 26,953 (51.3%) females and 25,896 (48.7%) males, and an average growth rate of 1.17% (Ghana Statistical Service, 2000). Mean monthly temperatures range from 22° to 32℃. The highest rainfall occurs in June and the lowest rainfall is recorded in December. Soils are generally sandy loams, and the vegetation is semi-deciduous and characterized by short, tall grasses, scattered thick forests, and savannah species. Most (70%) of the labor force is involved in agriculture, producing maize, cassava, yam, cowpea, groundnuts, sweet potato, vegetables (tomato, eggplant, okra, and pepper), and fruits (pineapple, mango, etc.). Goats, sheep, cattle, pigs, and poultry are also reared, and non-traditional export agriculture commodities such pineapple, honey, snails and mushrooms can be found in the district.

Tomato, maize, cassava, yam, and groundnuts are the major cash crops. Maize and cassava are the main staples of smallholder farmers in the district, and shifting cultivation is the predominant farming system. A market day is held every 5 days in three district markets on a rotating basis; Kpetoe and Ziope markets are the major markets, and Adaklu Waya is a minor market.

2. Data

The primary data were collected from the District Agricultural Development Unit (DADU) of Adaklu Anyigbe to prepare a 1 ha crop budget for each of the following crops tomato, maize, cassava, groundnuts, and pepper. The cost of renting the land was not added to the 1 ha crop budget for all the crops. The data also included 2.5 ha of farmland for the cultivation of all the crops. Data on the annual shipment of a 1 ha tomato farmland size was also obtained. Secondary data were obtained from the Statistical Research Information Directorate in Accra, the Volta Regional Agricultural Development Unit, and from DADU on the average monthly wholesale prices and average farmgate prices of tomato, cassava, maize, groundnuts, and pepper. In the simplex algorithm, linear programming (LP) and the parametric linear programming (PLP) models were used to determine the best (profit maximizing) combination of farm activities for a smallholder farmer. The objective function determines the maximum income from the five crops to three single markets (Kpetoe, Ho and Ashiaman) Fig. 1b as well as a combined market for a smallholder farmer, considering land and labor constraints. To estimate revenue, we needed data on the shipments of tomatoes in the production months of January and May–December. We also estimated the average monthly farmgate and wholesale prices at three selected markets and the quantity harvested from 1 ha of tomato farmland (52 kg per crate). The profit coefficient for tomato was then obtained by multiplying the average monthly price in GH¢/52 kg per crate of tomato in 2010 by 9 (months of production) by 52 kg per crates of the average production/ ha. The profit coefficients for the other crops were obtained from the 1 ha crop budgets; we used the average farmgate price of each crop and the

total production (kg) per hectare to obtain the total revenue. Variable costs included the costs of production inputs, such as seed, fertilizers, pesticides, fungicides, and packaging materials. The labor coefficient was obtained by multiplying the daily average hours that an average smallholder farmer spent per day farming the crops by the average number of days spent working per each month in a year. The cost of the land for farming was not taken into consideration in this study. The PLP model was estimated based on the LP simulation under the fixed condition of labor inputs with 2.5 ha−8.64 ha land use.

3. The Model

The selection of the crops that an income-maximizing smallholder farmer should grow under the given resource constraint conditions was estimated with an LP model. The objective function (Eq. 1) and land and labor constraints (Eqs. 2 and 3) are defined as follows:

Objective function:

$$\text{Max: } I=\sum_{i=1}^{9} P_{1i}\cdot Q_{1i}(X_1)+\sum_{j=2}^{5} P_j X_j-\sum_{j=1}^{5} C_j X_j$$

Where

I : Income of an income-maximizing smallholder farmer in a year (GH¢)

P_{1i} : Price Coefficient of Tomato in each month (GH¢/kg)

$Q_{1i}(X_1)$: Shipment Quantity of Tomato in each month (kg/ha)

X_1 : Crop Acreage of Tomato in a year (ha)
i=1(Jan), 2(May), 3(Jun), 4(Jul), 5(Aug), 6(Sep), 7(Oct), 8(Nov), 9(Dec)

X_j : Crop Acreage of crop j in a year (ha)

P_j : Price Coefficient of each crop (GH¢/ha)

C_j : Unit Production Cost of each crop (GH¢/ha)
j=1(Tomato), 2(Maize), 3(Cassava), 4(Groundnuts), 5(Pepper)

Equation (1) is the objective function. To calculate the price coefficient of Tomato in each month, we needed the shipments in the month of January, May, June, July, August, September, October, November and December depending upon the annual production in one (1) hectare of tomato farmland, and these months' average farm gate prices. And then the shipments in each month converted into GH¢ were calculated. To calculate the price coefficients of Maize, Cassava, Groundnuts and Pepper, we needed the quantity harvested from the one (1) hectare of these crops' farm-

Table 3. Data used for the analysis of income level for 2.5 ha

	Constant	Relation	Tamato	Tomato January	~	Tomato December	Tomato Variable Cost	Maize	Maize Variable Cost
Profit Coeficient			—	43,446.00	~	54,554.50	-1,167.50	12,960.00	-1,224.25
Land	2.5 to 8.64	>=	1.00	—	~	—	—	1.00	—
Shipment 01	0.00	=	1.00	-1.00	~	—	—	—	—
~	~	~	~	~	~	~	~	~	~
Shipment 12	0.00	=	1.00	—	~	-1.00	—	—	—
Tomato Inputs	0.00	=	1.00	—	~	—	-1.00	—	—
Maize Inputs	0.00	=	—	—	~	—	—	1.00	-1.00
Cassava Inputs	0.00	=	—	—	~	—	—	—	—
Groundnut Inputs	0.00	=	—	—	~	—	—	—	—
Pepper Inputs	0.00	=	—	—	~	—	—	—	—
Labor Coeficient 01	624.00	>=	0.00	—	~	—	—	0.00	—
~	~	~	~	~	~	~	~	~	~
Labor Coeficient 12	576.00	>=	0.00	—	~	—	—	0.00	—
Hired Machinery Services	0.00	=	—	—	~	—	—	-125.00	—
Hired Labour Planting	0.00	=	-160.00	—	~	—	—	-60.00	—
Hired Labour Spraying	0.00	=	-50.00	—	~	—	—	-50.00	—
Hired Labour Weeding	0.00	=	-120.00	—	~	—	—	-216.00	—
Hired Labour Fertilization	0.00	=	-24.00	—	~	—	—	-40.00	—
Hired Labour Harvesting	0.00	=	-144.00	—	~	—	—	-100.00	—
Maize Selection	0.00	<=	-0.30	—	~	—	—	0.70	—
Cassava Selection	0.00	<=	-0.20	—	~	—	—	-0.20	—

* Tomato 1 crate=52 kg; Maize 1 bag=100 kg; Cassava 1 bag=91 kg; Groundnut 1 bag=82 kg; Pepper 1 bag=20 kg

land in a year, and average farm gate prices.And then the quantity harvested from the one (1) hectare of each farmland converted into GH¢ was calculated for each crop.Unit production costs of tomato, maize, cassava, pepper and groundnut in one (1) hectare were calculated from their crop budget taking into consideration their variable costs.

Subject to:

$$\text{Land constraint: } 2.5 \geq \sum_{j=1}^{5} X_j \quad (2)$$

$$\text{Labor constraint: } FL_k \geq \sum_{j=1}^{5} L_{jk} \cdot X_j \quad (3)$$

Where

FL_k : Total number of hours of Family Labor in month k

L_{jk} : Unit Labor Input for crop j in month k k＝1(Jan)～12(Dec)

Equation (2) and (3) are the land and labor constraint respectively. For instance, in the maximization of objective function (1), 2.5 hectare farmland can be used for total land use, and the total number of labor hours

Table 1. Estimation of optimal income level and allocation of crops sold in single and combined markets by the LP model

Variable	Market			Combined market
	Kpetoe	Ho	Ashiaman	
Tomatoes (ha)	1.25	1.25	1.25	1.25
Maize (ha)	0.75	0.75	0.75	0.75
Cassava (ha)	0.50	0.50	0.50	0.50
Groundnuts (ha)	0	0	0	0
Peppers (ha)	0	0	0	0
Income (GH¢)	335,932	731,416	1,066,320	946,075

Table 2. Estimation of income in the combined market by the PLP model

	Farm area (ha)	
Variables	2.50	8.64
Tomatoes Land	1.25 ha	4.32 ha
Maize Land	0.75 ha	2.59 ha
Cassava Land	0.50 ha	1.73 ha
Groundnuts Land	—	—
Pepper Land	—	—
Income level ((GH¢))	946,075	3,270,641

and 8.64 ha farms in the combined market in the PLP model

Cassava	Cassava Variable Cost	Gnuts	Groundnut Variable Cost	Pepper	Pepper Variable Cost	Hired Machinery Services	Hired Labour Cost 01	Hired Labour Cost 02	Hired Labour Cost 03	Hired Labour Cost 04	Hired Labour Cost 05
3,600.00	-320.00	1,640.00	-340.00	15,000.00	-745.50	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00
1.00	—	1.00	—	1.00	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
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—	—	—	—	—	—	—	—	—	—	—	—
1.00	-1.00	—	—	—	—	—	—	—	—	—	—
—	—	1.00	-1.00	—	—	—	—	—	—	—	—
—	—	—	—	1.00	-1.00	—	—	—	—	—	—
0.00	—	0.00	—	0.00	—	—	—	—	—	—	—
～	～	～	～	～	～	～	～	～	～	～	～
40.00	—	40.00	—	0.00	—	—	—	—	—	—	—
-125.00	—	-125.00	—	—	—	1.00	—	—	—	—	—
-160.00	—	-80.00	—	-160.00	—	—	1.00	—	—	—	—
—	—	-50.00	—	-50.00	—	—	—	1.00	—	—	—
-125.00	—	-240.00	—	-360.00	—	—	—	—	1.00	—	—
—	—	—	—	-120.00	—	—	—	—	—	1.00	—
-60.00	—	-225.00	—	-600.00	—	—	—	—	—	—	1.00
-0.30	—	-0.30	—	-0.30	—	—	—	—	—	—	—
0.80	—	-0.20	—	-0.20	—	—	—	—	—	—	—

supplied by family members in each month is strictly limited (Table 3).

Results

1. Production Efficiency and Income in Single and Combined Markets

Table 1 shows the results of the income levels derived from the LP model on the optimum allocation of farmland among crops when selling to the three individual markets (Kpetoe, Ho, and Ashiaman) and the combined market. In all cases, it was better to produce only tomatoes, cassava, and maize and to avoid growing groundnuts and peppers under the given resource constraints and market conditions. The best crop allocation on a 2.5 ha farmland was 1.25 ha for tomatoes, 0.75 ha for maize, and 0.50 ha for cassava in all cases.

The maximum income (GH¢ 1,066,320) for a smallholder farmer derived from the LP model was by shipping 100% of the crops to the Ashiaman Market. The income of a smallholder farmer after shipping 100% of his crop to the Ho Market is GH¢ 731,416 and it is only GH¢ 335,931 in the Kpetoe Market as the farmer sells 100% of the crop there. Generally, a smallholder farmer faces upon the combined market situation in everyday transactions because traders come from all three of these markets and because of transactional costs which is incurred through transportation. Combined market in Table 1 shows (GH¢ 946,075) to be the average income after shipping 70%, 25% and 5% of the crops from Ashiaman, Ho and Kpetoe markets respectively.

2. Increasing Income in the Combined Market

The smallholder farmer is still a price taker, so enlarging the area of farmland from 2.5 to 8.64 ha is another potential strategy to increase household income. The results of the PLP model are shown in Table 2. GH¢ 946,075 shown in Table 1 is the average income of the three markets under 2.5 ha. At 8.64 ha, the maximum income a farmer can earn with an optimal crop allocation in the combined market is GH¢ 3,270,641. As all other variable costs are maintained on the 8.64 ha but the shadow price of the labor constraint needed by the farmer to is GH¢ 5,241 will earn the farmer the maximum income of GH¢ 3,270,641. May is a critical month that requires more labor since all other months recorded no values from the PLP model. The labor cost of exactly (GH¢ 5,241) which is the shadow price will cause the objective function value to be GH¢ 3,270,641. This means that a smallholder farmer can increase income by enlarging the size of the farm and increasing labor inputs in May.

Conclusions

The analysis of production efficiency of five crops in Adaklu Anyigbe indicated that farmers should produce three crops to maximize profits under the given resource constraints. On a 2.5-ha farm, a farmer should apportion 1.25 ha (50%) for tomato cultivation, 0.75 ha (30%) for maize, and 0.50 ha (20%) for cassava. The results of the LP models (Table 1) indicated income level varied by market using the optimum allocation of crops. The highest income level was could be obtained by selling all crops at the Ashiaman Market (GH¢ 1,066,320), although in the real-world, farmers usually ship products to all three markets because of transactional costs.

The results from the PLP model suggest that it would be beneficial for smallholder farmers to increase the size of their farms and add additional labor inputs in the month of May, which is a critical production period. A farmer can earn a total of GH¢ 3,270,641 by increasing the farm to 8.64 ha if no extra labor inputs are needed (Table 2). The deciding factor is the price of additional labor inputs, and our analysis indicates that farmers can increase income by increasing the size of their farms, even after accounting for the additional labor inputs.

Smallholder farmers need to earn higher incomes to support their livelihood. This comparative assessment shows that the smallholder farmer could obtain higher incomes through optimal crop allocation and market sales under current household resource constraint conditions. Considering these findings, Government role is considered necessary in developing and strengthening Farmer Base Organizations (FBOs) in value chain concept for tomato production and establish market information centre in the District. This study pinpointed the need to obtain and use time series data of different indicators to create reliable management information system for planning, implementation, monitoring and evaluation of production and marketing of tomato in the future. It would be interesting to look at how the technical and allocative efficiencies of tomato, maize and cassava have changed over time with the use of panel data from other production and marketing centers in Ghana.

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