Profitability, labour input, fertilizer application and crop protection in vegetable production in the Arusha region, Tanzania

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Table of contents

Abstract

An analysis was made of the inputs, costs and profit of vegetable production in three areas in the Arusha region of Tanzania. The major aim of the study was to establish whether vegetable producers would have the means to invest in modern production methods, such as hybrid seeds and drip irrigation, to improve and intensify their production.

The average income from crop production, as measured from 65 data sets on individual crop production, was 17,362 Tanzanian Shilling per hectare per growing day in the production field (TZS/ha/Gday). This amounts to around 7,500 TSZ per day throughout the year from 0.53 hectare which is the average area of vegetable production of the farmers in the study. After deduction of approximated daily expenses of a five-member household, the remaining earnings would only make a gradual introduction of hybrid seeds and drip irrigation possible, if the purchase of these goods has to be financed from earnings of vegetable production alone. Farmers complained about the lack of access to affordable credit. Companies supplying hybrid seeds and modern vegetable production equipment would do wise to offer safe and affordable credit.

Profit per crop was primarily influenced by labour input and to a lower extent by yield level and product prize.

Average labour input per crop ranged from three to thirteen hours per hectare per growing day in the production field (h/ha/Gday). The average for all crops was 6.4 h/ha/Gday, amounting to 3.4 hours per day for every day of the year on 0.53 hectare of vegetable production. Eighty nine per cent of labour spend, was hired labour, constituting 54 per cent of the average total production costs.

Costs of fertilizer application, on average were eighteen per cent of total production costs. Amounts of inorganic fertilizer applied varied considerably between areas and between vegetable fields in an area. Farmers complained about high costs of inorganic fertilizers, which may be the reason for low amounts applied.

Average costs of crop protection were six per cent of total production costs. Most of the active ingredients of fungicides applied are of the mancozeb type, while most of the active ingredients of the insecticides used belong to the organochlorines and organophosphates. Herbicide use was limited and only found in carrot production.

To protect farmers' and consumers health, and the environment, comprehensive efforts are needed to especially replace toxic insecticides.

Key Words: Vegetable production, Profitability, Labour use, Fertilizer application, Crop protection, Arusha, Tanzania

1 Introduction

In terms of quality of human nutrition, vegetable products in Tanzania form a significant part of the daily diet (Weinberger and Msuya, 2004). The production of vegetables is a valuable economic activity, providing employment and income (Weinberger and Lumpkin, 2005; Porter *et al*., 2010). The area of vegetable production in Tanzania amounted to 115,000 ha in 2007, with a total production of 635,000 tonnes (National Sample Census of Agriculture, 2012a). Major vegetable crops in Tanzania according to acreage are potatoes, tomatoes, okra, onion and cabbage (Table 1). Presently many of the vegetable cultivars used for production are of the open pollinated type (Everaarts *et al*., 2011, 2014).

Table 1. Total area of major vegetables in Tanzania and in the Arusha region (2007).

Crop	Tanzania		Arusha region	
	Area (ha)	Production (t)	Area (ha)	Production (t)
Potatoes	38,814	129,152	1,380	3,996
Tomatoes	26,612	321,127	1,351	18,866
Okra	9,982	13,440	150	94
Onion	8,782	24,656	754	1,925
Cabbage	5,752	46,411	434	4,649
Amaranths	4,143	16,536	120	309
Swiss chard	3,380	12,457	173	566
Bitter Aubergine	3,280	12,060	263	751
Chillies	3,204	10,750	69	276
Watermelon	3,139	17,679		
Pumpkins	2,198	11,932		
Cucumber	1,879	6,165	272	1,464
Radish	1,449	1,629	122	110
Eggplant	1,203	6,521	75	519
Carrot	810	4,553	176	993
Total	114,627	635,068	5,339	34,518

Source: National Sample Census of Agriculture 2007/2008, 2012.

Population growth and urbanisation in countries such as Tanzania increase the demand for commercially produced vegetables (Matuschke, 2009). Consequently, farmers have to intensify the production of vegetables or increase the area for production.

In recent years vegetable production per hectare in tropical Asia increased considerably due to the introduction of higher yielding hybrid cultivars (Bastakoti, 2009; Basuki *et al*., 2009; Dagupen and Pasolo, 2009). The same development is likely to take place in East Africa. Vegetable breeding companies have started to screen and develop hybrid vegetable cultivars for the East African conditions with promising results. The yield of a locally developed hybrid cultivar of bitter type African eggplant was 53 per cent higher as the local cultivar (de Putter *et al*., 2012). As seeds of hybrid cultivars commonly are more expensive than open pollinated cultivars, production methods need adaptation too, in order to fully realise the yield and economic potential of hybrid crops (Everaarts and de Putter, 2009; Everaarts *et al.*, 201X).

It is not clear whether local vegetable producers will be able to afford the more expensive seeds and have the opportunity to invest in modern production methods, as few documented data are available on profit and cash flow of vegetable producers in Tanzania.

To collect data on the profitability of vegetable production, an investigation was carried out on the inputs, costs and profit of production of vegetable crops in the Arusha region of Tanzania.

In this paper we present the results of an analysis of profitability, labour input, fertilizer application and crop protection in vegetable production in the Arusha region, Tanzania.

2 Materials and methods

2.1 Location, climate and soils of the study area

The Arusha region is located in Northern Tanzania. Arusha city, the capital of the region, is located at 1600 m.a.s.l. (Figure 1). The Arusha region has a bimodal precipitation pattern, with a short rainy period from October to November and a long rainy period from April to May. The average annual precipitation ranges between 250 - 1,200 mm (National Sample Census of Agriculture, 2012b). Mean monthly temperature for the region varies, depending on the altitude, between 26^{o}C in December and 21^{o}C in June. The soils used for vegetable production in the area generally are chromic Luvisols and ochric Andosols (Jones *et al.*, 2013), i.e. well drained dark brown or dark grey calcareous sandy loams of volcanic origin, rich in organic matter and moderate to highly fertile (de Pauw, 1983).

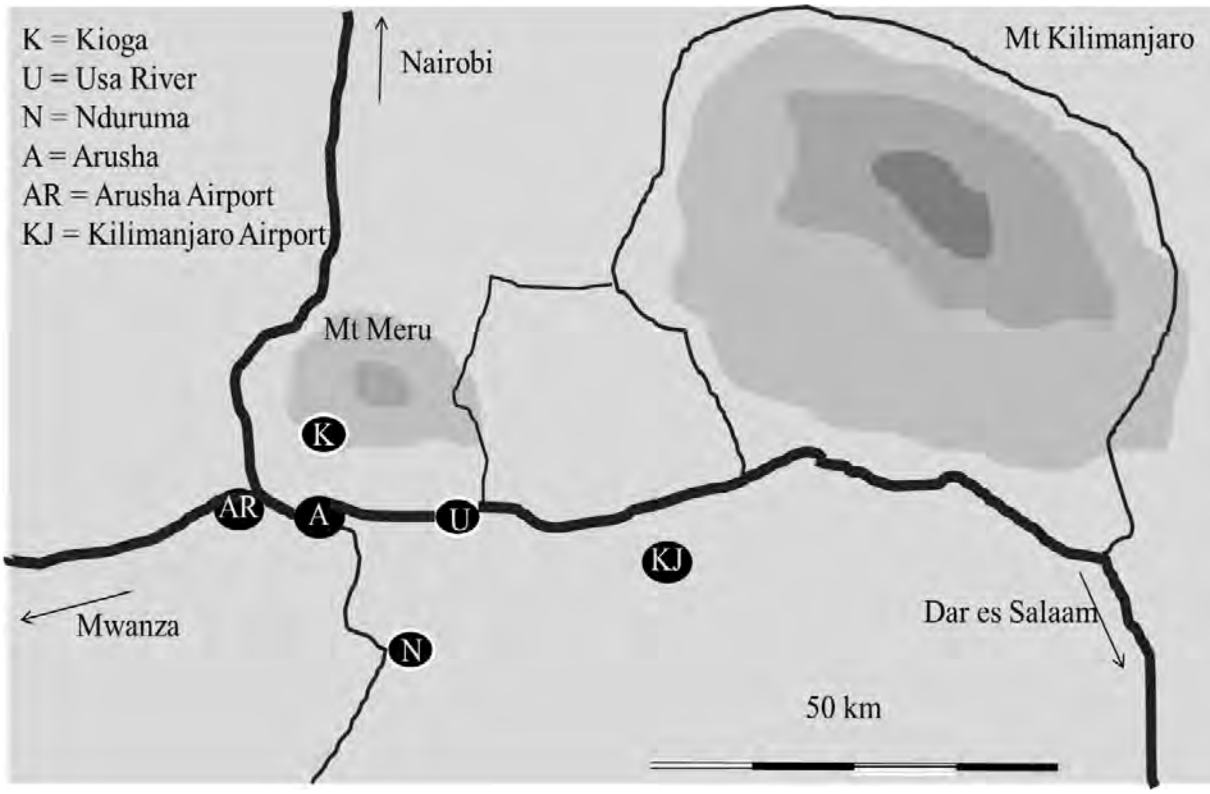

Figure 1. Location of Arusha city, Kioga, Usa River and Nduruma.

2.2 Selection of vegetable producing areas and area description

To select representative vegetable producing areas in the Arusha region for data collection, five vegetable producing areas in the region were visited in September 2010. During the visits the topography, altitude and size of the production areas was noted, the diversity of crops and field sizes were observed and a general impression of the professionalism of vegetable production in each area was obtained. Based on these visits two areas were rejected. One of them for being too far away from Arusha to be practical for data collection and the other one being too limited in area and in crop diversity.

The three areas selected for data collection were centred around three villages in the Arumeru district (Figure 1): (i) Kioga, around 5 km north of Arusha city on the slopes of Mount Meru, (ii) Usa

River, 15 km east of Arusha city along the national road to Moshi, and (iii) Nduruma, about 18 km south east of Arusha city.

2.2.1 Kioga

Kioga is in a gently sloping area at an altitude of around 1,690 m.a.s.l.. The area is characterized by existence of large plots with food and vegetable crops, lined by trees, shrubs and grass strips. Scattered banana plants, both in and outside fields, dot the landscape. Plots generally are within walking distance of the farm house. Roads are rough and feeder roads to the fields may be steep and narrow. Water for irrigation generally is available throughout the year. Dairy cows may be kept at the farms.

2.2.2 Usa River

Usa River is a small community at about 1,235 m.a.s.l.. The terrain is hilly with scattered and locally more abundant, more or less natural vegetation and banana plants. Vegetable fields may be located at some distance from each other. The area generally is well accessible. Small rivers supply a number of farmers with water for irrigation throughout the year, but other farmers depend on rainfall for crop production.

2.2.3 Nduruma

Nduruma is located at an altitude of 1,030 m.a.s.l.. The area is flat with few trees and shrubs. Soil tillage of the generally large fields, commonly is with ox drawn plough. Accessibility of the area is good. Water availability is restricted and vegetable crop production mostly depends on rainfall. Sheep and goats are more frequent in Nduruma, as compared to the other two areas.

2.3 Selection of farmers

Through the network of a horticultural trade and production company in Arusha, fifteen professional vegetable producers from each of the three areas were invited to participate in the study. The farmers invited were selected as based on the following criteria:

(i) For farm income and financing of vegetable crop production, the farmer should rely for a large part on vegetable production (contract farming, involving loans and inputs was excluded). Mixed farms (livestock, food crops) were allowed, but the share of vegetable production should contribute significantly to the farm income;

(ii) Vegetable plots at the farm should be at least 0.2 ha for major vegetable crops, such as cabbage, potatoes and tomatoes, and at least 0.1 ha for minor crops, like Chinese cabbage, sweet pepper and leafy vegetables;

(iii) The farmer should be younger than fifty years, as to select active producers;

(iv) The farmer should be a commercial vegetable farmer with at least five years of experience in vegetable production;

(v) The farmers should grow at least four vegetable crops a year;

(vi) While in the study, the farmer should sell his produce to middle men or directly at a local market.

All farmers were invited to a one day introductory workshop in Arusha on January 28, 2011. In the workshop the aim of the study and the proposed method of data collection were introduced to the farmers. The farmers discussed the aim, methods and intended results of the study in groups. As a result, most farmers were interested to participate. A few farmers declined, while others appeared to lack the necessary critical attitude to participate. At the end of the workshop ten farmers from each vegetable producing area were registered as participants in the study.

After the workshop three one day visits were paid to Kioga, USA River and Nduruma respectively, with the ten participating farmers of each area, to receive instruction and discuss and practise data recording in the field.

2.4 Selection of crops

Crop selection was determined by the crops the participating farmers had planned to grow.

2.5 Method of data collection

From the end of January 2011 to December 23, 2011, the farmers made notes daily, describing all activities, inputs, yield and income of a particular vegetable plot (including activities for a nursery) in a diary. The diary was collected every two weeks and substituted with a new one. Diary data were checked for consistency and completeness and translated into English.

Name and cultivar of the crop, field size (as estimated by the farmer as well as measured), date of planting or sowing, and planting distance, were noted at sowing or planting time. After that, farmers provided daily records of amounts and costs of labour and material inputs for the particular crop. Labour was recorded as own labour or hired labour. For critical recording the data was disaggregated by activity: land preparation, planting, sowing, staking (tomato), irrigation, fertilization, crop protection, weeding, harvesting and others. Material inputs recorded were: seeds, transplants, pesticides, fertilizers, farm yard manure, stakes, irrigation water, packing material and others. At harvest, products were graded and quantities and price per unit were noted. Crates, bags and heads were converted to metric units of weight using a measured average weight per bag, crate or head.

For the exchange rate with US dollar (US$), the average exchange rate for 2011 of 1585 Tanzanian Shilling (TZS) per 1 US$ was used.

2.6 Variables

Crops differ considerably in growth duration and yield. In order to be able to compare variables per crop, values were converted to units per hectare (ha) per growing day (Gday). Variables calculated were:

Growth duration: Growth duration in the field is the period between sowing or transplanting in the production field, up to the last day of harvest. A day in the production field is one growing day (Gday).

Profit: Profit was calculated as return in TZS per ha per Gday in the production field (TZS/ha/Gday). Profit was defined as gross return minus production costs. Production costs included all inputs, such as seeds or transplants, costs of pesticides, fertilizers and hired labour. Own labour was excluded from production costs.

Yield: Yield was calculated in kilogram (kg) per ha per Gday in the production field (kg/ha/Gday).

Product price: Product price is the price the farmer received for his product in TZS per kg of product (TZS/kg).

Labour input: A distinction was made in hired labour and own labour. Labour input was calculated in hours (h) spend per hectare (ha) per growing day (Gday) in the production field (h/ha/Gday). Labour included land preparation, sowing or transplant production, transplanting, irrigation, fertilizer application, crop protection, weeding and others.

Fertilizer application: Fertilizer application was considered, (i) from an economic point of view and expressed as TZS spend on inorganic fertilizers and farm yard manure per ha per Gday in the production field (TZS/ha/Gday), and (ii), for a number of crops with multiple data sets ($n \geq 6$), inorganic fertilizer application was analysed as application of nutrients in kg per ha (kg/ha).

Crop protection: Crop protection was considered, (i) from an economic point of view and expressed as TZS spend on crop protection per ha per Gday in the production field (TZS/ha/Gday), and (ii), for a number of crops with multiple data sets ($n \geq 6$), crop protection is discussed in terms of number and type of insecticide, fungicide and herbicide applications.

2.7 Data analysis

To analyse which factors determine profitability of vegetable production, we used linear and non-linear regression analysis. Data were studied as individual crop data, as averaged per crop, and as averaged per crop and area. Because of sometimes non-normal distribution of variables (skewness and kurtosis significantly differed from zero), the analysis was also carried out with response data transformed to square root or ^{10}Log. We used multiple linear regression analysis to analyse the combined effect of variables on profit. Statistical analysis was done using the GenStat 12 program (Payne *et al*., 2009).

2.8 Feedback on data

On June 11, 2012, a workshop was held in Arusha with the farmers who had participated in the study. At the workshop the farmers received a reader with results per crop in the form of a balance sheet (Appendix). A preliminary analysis of the data of the study was presented. A plenary discussion was held with the farmers, discussing the relevance of the collected data to the farmers and what the farmers had learned during the study.

3 Results

3.1 General

One of the thirty farmers prematurely ended participation in the study and was replaced by another farmer.

Temperature in 2011 followed a normal pattern (Figure 2). A dry period occurred from June to August.

A total of 65 individual crop data sets were collected (Table 2; Everaarts and de Putter, 2015). Six crops had only one data set, while another six crops had six or more data sets collected. Cabbage and potato were the crops with the highest number of data sets, 11 and 9 respectively. Collection of data sets per crop was not equally distributed across the three areas. Of only two crops, kale and tomato (staked), data sets were collected in all three areas.

Average total farm size was 0.86 ha, while the average area under vegetable production per farm was 0.53 ha. Most of the plots of which data were collected were smaller than 4,500 m^2 (Figure 3), while planting of crops showed a peak in April.

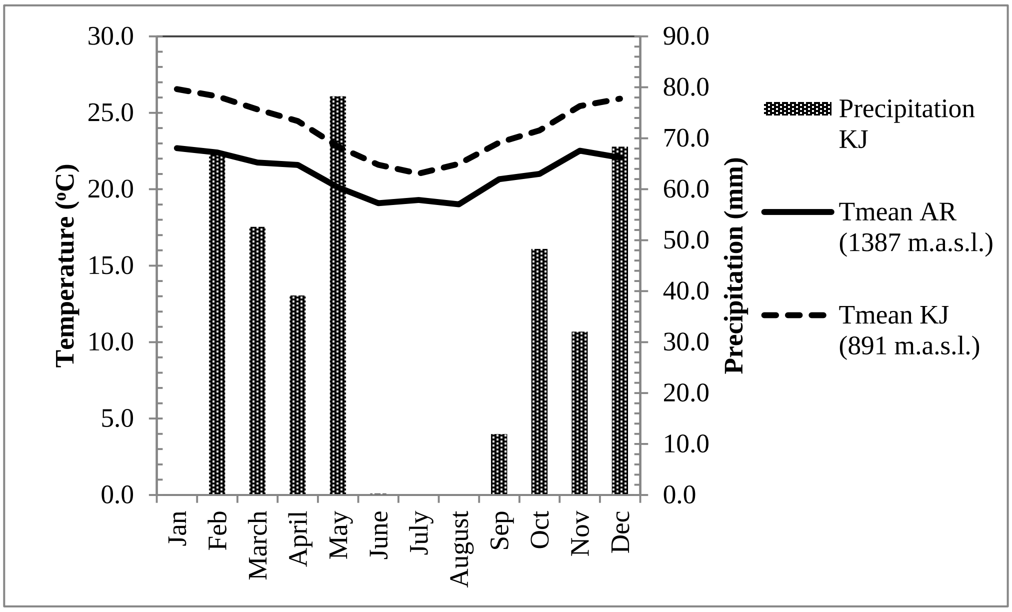

Figure 2. Mean monthly temperature and total monthly precipitation in the study area in 2011 (AR = Arusha Airport; KJ = Kilimanjaro Airport, see Figure 1).

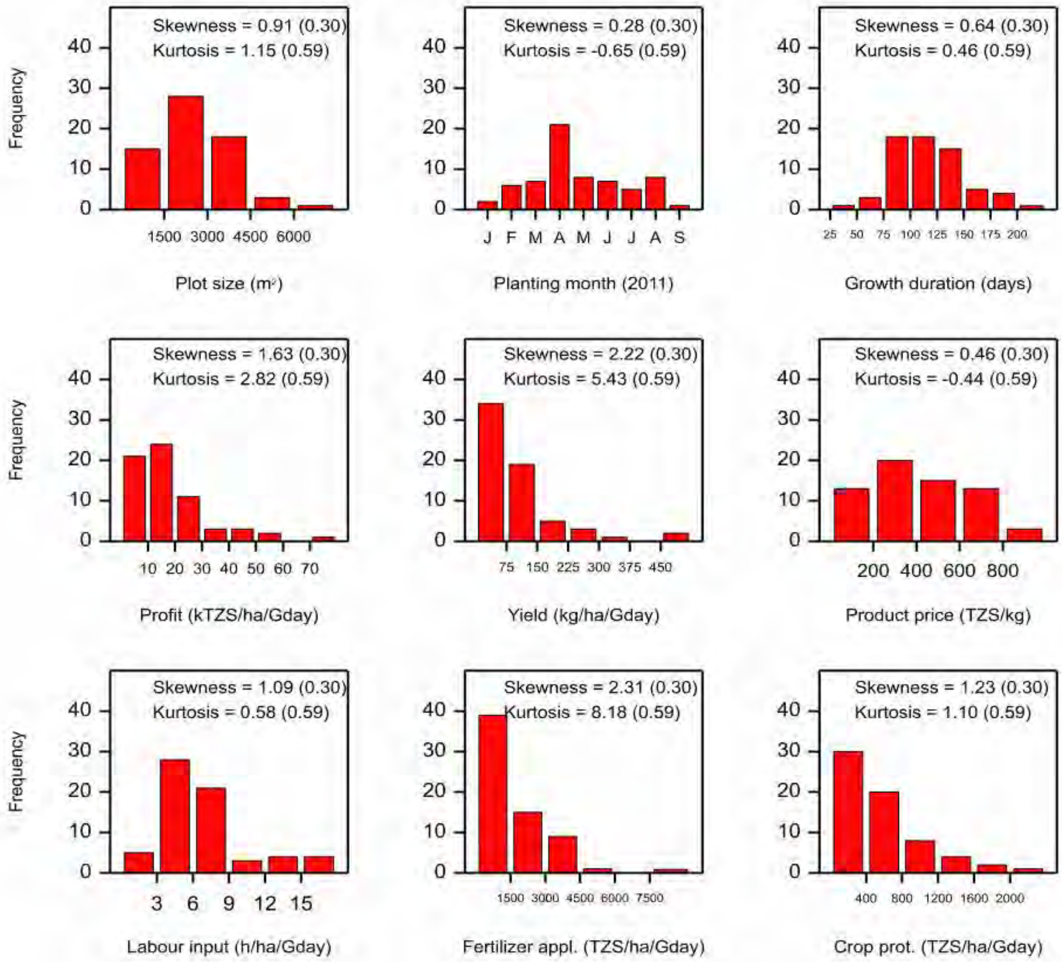

Figure 3. Frequency distribution of data and variables of the 65 individual data sets (values between brackets denote Standard Error; TZS = Tanzanian Shilling; kTZS = 1000 Tanzanian Shilling; Gday = growing day in the production field).

Table 2. Number of crop data sets collected per area.

Family Species	Crop	Area Kioga	 Usa River	 Nduruma	 Total
Apiaceae					
Daucus carota	Carrot	1	6		7
Asteraceae					
Lactuca sativa	Lettuce		1		1
Brassicaceae					
Brassica carinata	Ethiopian mustard		2	1	3
Brassica oleracea var. *acephala*	Kale (Sukuma wiki)	4	2	1	7
Brassica oleracea var. *botrytis*	Cauliflower		1		1
Brassica oleracea var. *capitata*	Cabbage	7	4		1
Brassica oleracea var. *italica*	Broccoli		1		1
Brassica rapa spp. *pekinensis*	Chinese cabbage		2		2
Cucurbitaceae					
Cucumis sativus	Cucumber			2	2
Liliaceae					
Allium cepa var. *cepa*	Onion	1		1	2
Malvaceae					
Abelmoschus esculentus	Okra			1	1
Solanaceae					
Solanum aethiopicum	African eggplant	1		3	4
Solanum lycopersicum	Tomato - Staked	1	4	1	6
Solanum lycopersicum	Tomato - Non-staked			6	6
Solanum melongena	Eggplant		1		1
Solanum tuberosum	Potato	8	1		9
Solanum villosum	African nightshade	1			1
	Total	24	25	16	65

Table 3. Duration of growth in the production field, profit, yield product price, labour input and costs of fertilizer application and crop protection of vegetables cultivated in the Arusha region (n = number of data sets per crop; total n = 65 ; TZS = Tanzanian Shilling; 2011: 1 U$ = 1587 TZS; Gday = growing day in the production field; SE = standard error of the mean).

Family Crop	Sown (S) Trans-planted (T)	n	Growth duration (days)		Profit (TZS/ha/Gday)		Yield (kg/ha/Gday)		Product price (TSZ/kg)		Labour input (h/ha/Gday)		Fertilizer application (TZS/ha/Gday)		Crop protection (TZS/ha/Gday)	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Apiaceae																
Carrot	S	7	161	7	17,100	6,761	86	23	292	33	6.4	0.8	1,253	445	486	134
Asteraceae																
Lettuce	T	1	82		9,721		23		655		6.9		1,171		359	
Brassicaceae																
Ethiopian mustard	S	3	121	54	12,254	4,310	17	12	820	181	2.9	0.7	168	88	88	57
Kale (Sukuma wiki)	T	7	94	6	18,640	3,336	35	5	705	33	6.1	1.2	1,239	414	286	129
Cauliflower	T	1	120		19,691		49		508		5.9		1,095		336	
Cabbage	T	11	109	5	16,516	3,680	245	40	141	35	6.0	0.5	2,142	386	674	140
Broccoli	T	1	97		1,040		8		709		2.9		1,327		52	
Chinese cabbage	T	2	64	2	10,338	522	33	10	630	42	7.7	1.3	1,396	217	380	179
Cucurbitaceae																
Cucumber	S	2	113	1	40,635	29,990	88	65	634	28	9.5	6.1	2,638	2,322	864	542
Liliaceae																
Onion	S	2	140	5	39,415	20,001	104	33	459	59	12.3	3.6	1,335	17	575	439
Malvaceae																
Okra	S	1	173		9,046		19		641		2.8		440		179	
Solanaceae																
African eggplant	T	4	162	8	2,835	1,089	43	3	193	9	4.6	0.3	980	86	390	126
Tomato - Staked	T	6	113	7	23,628	4,091	85	11	439	30	12.7	1.2	1,844	542	1,210	237
Tomato - Non-staked	T	6	132	1	27,857	4,477	94	6	378	42	9.3	1.3	1,488	482	1,004	218
Eggplant	T	1			8,764		17		705		3.3		586		402	
Potato	Seed potato	9	103	6	15,410	3,230	86	13	310	17	5.6	0.7	2,706	905	449	102
African nightshade	S	1	87		22,272		26		970		4.7		287		103	
		Average	121		17,362		62		541		6.4		1,300		461	

3.2 Growth duration

Most crops had a growth duration between 75 and 150 days, while the average for all crops was 121 days (Table 3).

3.3 Profit

Profit was non-normally distributed (skewness and kurtosis significantly differed from zero). Most crops had a profit between zero and 20,000 TZS/ha/Gday. Two crops, cucumber and onion had especially high profits. Average profit for all crops was 17,362 TZS/ha/Gday.

3.4 Yield

Yields per hectare per growing day in the field were non-normally distributed and varied considerably between crops. Most of the yields were between zero and 150 kg/ha/Gday. Tomatoes, potatoes, carrots and cucumber had comparatively high yields between 85 and 95 kg/ha/Gday. Cabbage, a crop of which a particularly high percentage of total crop weight is harvested, had the highest yield per hectare per growing day in the field: 245 kg/ha/Gday.

3.5 Product price

Product prices were normally distributed and varied mostly between 200 and 800 TZS per kg.

3.6 Labour

Most of the labour input ranged between three and nine h/ha/Gday. Together with onions, tomatoes and cucumber required a comparatively high number of hours of labour per hectare per growing day, with staked tomatoes having the highest labour input of all crops. For all crops, on average 6.4 hours of labour were spent per hectare per growing day in the field. Within these hours, on average 1.3 h/ha/Gday were spent on irrigation of crops. Most of the labour input was hired labour. For all crops on average 89 per cent of labour input was hired labour.

3.7 Fertilizer application

Highest costs of fertilizer application were made with potatoes, cucumber, cabbage and tomatoes. These costs were between 1,488 to 2,706 TZS/ha/Gday. For most of the crops, however, costs of fertilisers were between zero and 1,500 TZS/ha/Gday.

In the most frequently recorded crops nitrogen, phosphorus and potassium application in the form of inorganic fertilizers varied considerably between areas, and given the sometimes high standard errors, also between plots in an area (Table 4). For staked tomatoes the nitrogen application ranged from 41 to 154 kg/ha, while phosphorus and potassium applications were from 0 to 48 and from 0 to 22 kg/ha, respectively. Especially in Nduruma, phosphorus and potassium applications appeared to have been low.

Table 4. Nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) application (kg/ha) with inorganic fertilisers in the most frequently (n≥6) recorded crops in Kioga, Usa River and Nduruma (SE = standard error of the mean; see Table 2 for number of data sets per area).

Family	Kioga						Usa River						Nduruma					
Crop	N		P_2O_5		K_2O		N		P_2O_5		K_2O		N		P_2O_5		K_2O	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Apiaceae																		
Carrot	1	-	1	-	11	-	32	7	30	10	64	5						
Brassicaceae																		
Kale (Sukuma wiki)	60	13	58	27	35	21	27	12	14	1	28	3	10	-	5	-	9	-
Cabbage	48	8	42	11	11	6	93	37	54	34	64	48						
Solanaceae																		
Tomato - Staked	41	-	48	-	0	-	41	12	21	12	22	20	154	-	0	-	0	-
Tomato - Non-staked													80	26	2	1	4	3
Potato	66	28	45	16	17	17	50	-	52	-	5	-						

Table 5. Crop protection chemicals used per hectare and per ton of harvested product in the most frequently (n≥6) recorded crops (SE = standard error of the mean).

Family		Fungicide		Insecticide		Herbicide		Total		Fungicide		Insecticide		Herbicide		Total	
Crop		Active ingredient (g/ha)								Active ingredient (g/t harvested product)							
	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Apiaceae																	
Carrot	7	774	245	77	31	1056	338	1907	394	61	21	6	3	92	39	160	43
Brassicaceae																	
Kale (Sukuma wiki)	7	724	359	194	81	0	-	918	431	294	167	67	33	0	-	361	198
Cabbage	11	1230	259	484	109	0	-	1713	329	54	12	20	6	0	-	74	17
Solanaceae																	
Tomato - Staked	6	3278	506	456	185	0	-	3734	592	340	104	43	11	0	-	430	107
Tomato - Non-staked	6	2533	531	565	245	0	-	3098	658	209	47	45	19	0	-	254	57
Potato	9	1974	610	147	47	0	-	2122	624	387	57	17	6	0	-	229	58
Average		1666		319		161		2146		186		31		14		159	

3.8 Crop protection

Costs of crop protection were lower as compared to costs of fertiliser application. Most of the costs of crop protection were less than 800 TZS/ha/Gday. Tomatoes formed an exception, with comparatively high costs of crop protection. The high costs in tomato are primarily due to fungicide application, which application was the highest among the most frequently recorded crops (Table 5). Cabbage and tomato scored highest with the use of insecticides, but due to the high yield, cabbage scored low with active ingredients in gram per ton of harvested product. The sometimes high standard errors indicate considerable variation in fungicide and insecticide use between plots. The use of herbicides was only recorded in the production of carrots. Mixing of pesticides before application was not common and mostly concerned one insecticide and one fungicide.

Most of the active ingredients of fungicides applied are of the mancozeb type (Table 6). Most of the active ingredients of the insecticides used belong to the carbamates, organochlorines and organophosphates, with an exception for cabbage on which only pyrethroïds were applied. The insecticide most used in a range of crops, is the organochlorine endosulfan. Herbicides used in carrots were paraquat dichloride and glyphosate before sowing and linuron in a pre-emergence application.

Table 6. Type of fungicides and insecticides used in the most frequently (n≥6) recorded crops.

	Fungicides (active ingredient, % of total use)			Insecticides (active ingredient, % of total use)			
Family Crop	Mancozeb	Metalaxyl	Other	Carbamates, Organochlorines, Organophosphates	Pyrethroids	Neonicotinoid	Abamectine
Apiaceae							
Carrot	92	1	7	71	13	15	1
Brassicaceae							
Kale, Sukuma wiki	58	6	36	96	1	2	1
Cabbage	94	5	1	0	89	11	0
Solanaceae							
Tomato - Staked	65	2	34	67	21	12	0
Tomato - Non-staked	94	6	0	63	22	15	0
Potato	97	1	2	94	5	1	0
Average	85	3	12	82	11	6	1

3.9 Total costs

An analysis of the composition of total costs of production showed that by far the highest single cost in vegetable production in the Arusha region was the cost of hired labour (Table 7). For costs of planting material, potato scored high because of the high costs of seed potatoes. As shown earlier (Table 3), costs of crop protection were lower than the costs of fertilizer application.

Table 7. Costs of inputs and hired labour as a percentage of total production costs (n = number of data sets per crop; total n = 65).

Family Species	n	Costs of production (% of total production costs) Planting material	Hired labour	Fertilizer application	Crop protection	Others
Apiaceae						
Carrot	7	11	56	18	7	9
Asteraceae						
Lettuce	1	5	48	23	7	17
Brassicaceae						
Ethiopian mustard	3	22	56	15	6	1
Kale (Sukuma wiki)	7	4	69	19	4	3
Cauliflower	1	26	45	22	7	0
Cabbage	11	20	44	24	8	4
Broccoli	1	21	37	29	1	11
Chinese cabbage	2	34	28	16	6	17
Cucurbitaceae						
Cucumber	2	16	46	13	7	19
Liliaceae						
Onion	2	21	56	13	5	4
Malvaceae						
Okra	1	15	67	13	5	0
Solanaceae						
African eggplant	4	6	65	18	7	5
Tomato - Staked	6	5	62	13	10	11
Tomato - Non-staked	6	3	64	17	12	4
Eggplant	1	2	70	17	11	0
Potato	9	41	30	20	4	5
African nightshade	1	5	78	10	4	3
	Average	15	54	18	6	7

3.10 Effects of variables on profit

The largest effect of a single variable on profit was found with non-linear regression of profit against yield, taking the three areas into account: 54.6 percentage of variance was accounted for (Table 8). Profit in Nduruma increased with higher yields, while profits levelled off early in Kioga, with the relation between profit and yield in Usa River in between the two others (Figure 4). With crop yield data averaged per area, percentage variance accounted for was only slightly smaller, 49.3 per cent, indicating that yield per crop was much more important than area. With transformed data for crop means, the percentage variance accounted for, 52.2 per cent, was considerably reduced to 29.2 per cent when area was taken into account, again indicating that average yield per crop was more important than area.

With crop means, labour input as a single factor accounted for 54.2 per cent of variance in profit, which is comparable to the 52.2 per cent of variance accounted for in profit with regression on yield with crop means. The percentage variance accounted for decreased when area was taken into account, showing that labour input per crop was more relevant than area. Profit increased with an increase in labour input per crop (Figure 4).

Regression of profit on planting date showed a consistent positive effect of area on the percentage of variance accounted for, but the significance was comparatively low (P=0.02).

Only one significant regression between profit and product price was found, showing different relationships for the three areas.

Regression of profit on costs of crop protection gave the highest percentage variance accounted for with crop means. Profit per crop increased with an increase in costs of crop protection, but the correlation was less strong as compared to that with labour input or yield.

The lowest and least significant correlation with profit was found for costs of fertilizer application.

With multiple linear regression analysis, using crop means, the highest percentage of variance accounted for in profit, 64.4 per cent, was found with non-transformed data of a subset of three variables: labour input, yield and product price. Labour input alone explained 54.2 per cent of this variance.

Table 8. Highest percentage variance (R_{adj}^2) accounted for and significance (*P* value) of regression analysis of profit (TZS/ha/Gday) on planting date, yield, product price, labour input, costs of fertilizer application and costs of crop protection (TZS = Tanzanian Shilling; Gday = growing day in the production field).

	Planting date (day number)		Yield (kg/ha/Gday)		Product price (TZS/ha/Gday)		Labour input (h/ha/Gday)		Fertilizer application (TZS/ha/Gday)		Crop protection (TZS/ha/Gday)	
	R_{adj}^2	*P*	R_{adj}^2	*P*	R_{adj}^2	*P*	R_{adj}^2	*P*	R_{adj}^2	*P*	R_{adj}^2	*P*
All data (n=65)	23.9[2]	<0.01	26.1[4]	<0.01	-	-	37.3[1]	<0.01	-	-	16.7[2]	<0.01
All data, three areas (n=65)	28.1[1]	<0.01	54.6[3]	<0.01	29.4[5]	<0.01	37.6[1]	<0.01	13.9[3]	0.03	18.1[1]	<0.01
Crop means (n=17)	19.4[1]	0.04	52.2[5]	<0.01	-	-	54.2[1]	<0.01	-	-	30.3[1]	<0.01
Crop/area means (n=27)	28.3[2]	<0.01	29.2[5]	<0.01	-	-	44.7[1]	<0.01	-	-	21.1[2]	<0.01
Crop/area means, three areas (n=27)	31.6[1]	0.02	49.3[3]	<0.01	-	-	41.5[1]	<0.01	-	-	-	-

[1]Linear; [2]Linear, square root transformation; [3]Non-linear; [4]Non-linear, square root transformation; [5]Non-linear, Log_{10} transformation.

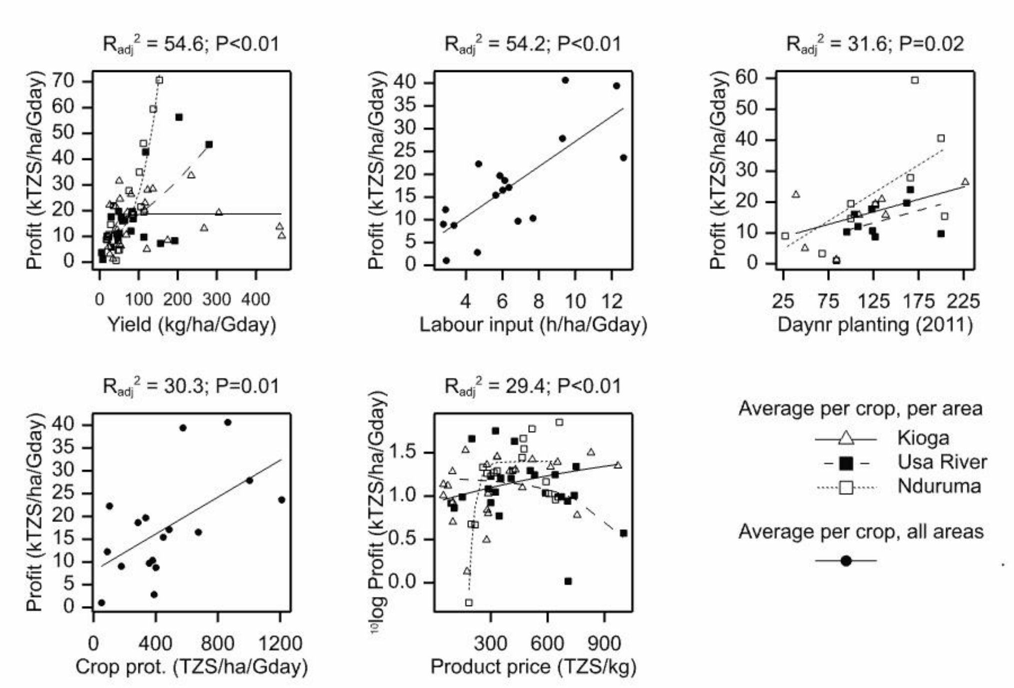

Figure 4. Regressions with the highest percentages of variance accounted for between profit and yield, labour input, planting date (day nr.), costs of crop protection and product price (Table 5; TZS = Tanzanian Shilling; Gday = growing day in the production field).

3.11 Feedback on data

Farmers in general stated that they learned a lot from the investigation. They had gained a better understanding and awareness of the costs of inputs and labour on their farm. The illustration of the cash flow in crop production after planting (Figure 5) was considered highly instructive. Many indicated that they intended to continue daily recording and to monitor their cash flow. The general picture that emerged from the discussions with the farmers is that they manage the farm on a day to day basis, getting income from livestock as well, while the income that is available, is mostly spend on the most urgent matter of the day. In this situation it is difficult at any moment to accumulate enough cash to do a major investment. Sometimes farmers sell chicken or a goat to be able to buy fertilizers or hire labour.

Major obstacles to higher crop and farm profitability brought forward by the farmers, were lack of cash to purchase inputs, the dependence on middlemen (who operate as a consolidated group, offering low prices) for selling their products and the lack of access to safe and affordable credit for their farming operation, or for starting a small side business (e.g. a shop).

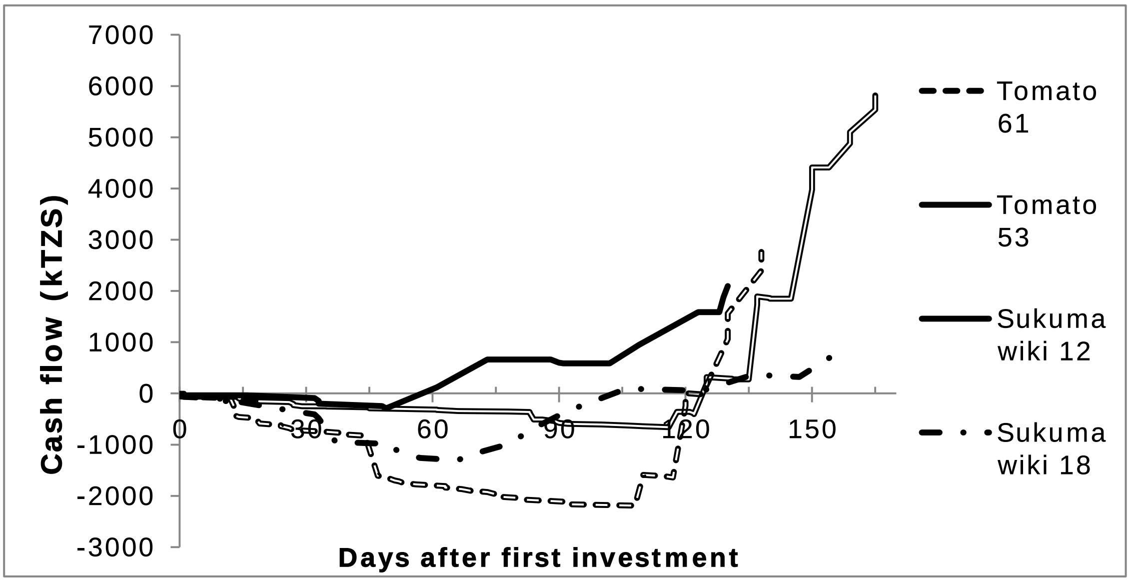

Figure 5. *E*xamples of cash flow with production of tomato (Data set no. 61= high initial costs; Data set no. 53 = low initial costs) and Sukuma wiki (Data set no. 18 = high initial costs; data set no. 12 = low initial costs) (kTZS = 1000 Tanzanian Shilling).

4 Discussion

4.1 Profit

Profit appeared primarily correlated with labour input and yield level of the crop. Product price, planting date and crop protection all had less influence, while fertilizer application had the lowest correlation. The relation between profit and yield appeared to be especially strong in Nduruma and Usa River, but less so in Kioga. This is primarily the result of the unequal distribution of crops across areas. The high profits of the cucumber and onion crops, that were grown in Nduruma only, positively influenced the regression. However, the percentage of variance accounted for when using mean crop yields, independent of area, was only slightly less.

Profit appeared to be higher with crops with a higher input of labour and a higher yield level. Nevertheless for a few crops with a comparatively low yield (kg/ha/Gday), like Ethiopian mustard and African nightshade, profit was compensated for by high product prices. Farmers aiming for high profits should concentrate on crops like tomatoes, onions and cucumber, which however, require high labour inputs.

4.2 Labour

Average labour input per crop ranged from three to thirteen hours h/ha/Gday, while the average for all crops was 6.4 h/ha/Gday. This is considerably less than the amount of labour spent per hectare per day in Asian countries, like Vietnam, where field vegetable production plays an important role in the economy of rural areas (Huong *et al.*, 2013a). In Northern Vietnam for most vegetable crops labour input was between 24 to 72 h/ha/Gday (three to nine d/ha/Gday), with an average input across crops of 64.8 h/ha/Gday (Huong *et al.*, 2013b). Labour requirements, however, are influenced by the system and method of production and by the yield level, and as such are difficult to compare directly. Nevertheless the large difference in labour input between the two countries suggests that labour input in field vegetable production in the Arusha region has scope to increase with intensification of production, offering employment opportunities, in this case especially for those depending on casual labour.

The data from the Arusha region show that with an average area of vegetable production of 0.53 hectare, an average of 3.4 hours of labour are spent a day. An amount that would seem to fit within the amount of labour available in an average five member household. Labour requirement on a vegetable farm, however, usually is characterised by peak demands (soil preparation, sowing/planting, irrigation, harvesting) and needs to fit in with other labour requiring household economic activities. On the other hand as crop production on the farm is divided across several plots, involving different crops at various stages of production, peak labour demands per plot might be manageable for a five member household.

Labour was the highest single cost in crop production. This is because on average for all crops 89 per cent of labour input was hired labour. During the discussions with the farmers, it did not become clear why so much labour was hired labour. Apparently the farmers involved in the study gave preference to other activities that were worthwhile in terms of income, social standing or leisure. It could also be that livestock at the farm required trusted labour by the farmer himself, or by family members, which was compensated for by hiring outside labour for the vegetable plots.

If labour is available within the household, farmers could increase their profits by working on vegetable production themselves. When all labour comes from within the household, the average profit per crop would increase from 17,362 to 21,773 TZS/ha/Gday. Without substituting hired labour for own labour, the introduction of drip irrigation would save most on labour for watering the crops and thereby increase profits.

In the Arusha region at present the situation apparently is such that traditional practices, necessities or other income earning opportunities dictate own labour, or time, for a large part to be spend outside vegetable production. Especially in the Kioga area, it may be necessary, and possibly more attractive, to spend time on skills and labour intensive milk production and marketing from stall-fed dairy cows (Hillbom, 2011).

The labour on the vegetable farms offered to outsiders, likely forms an important source of employment and income for people in the rural areas of the Arusha region who depend solely on casual labour.

4.3 Fertilizer application

No officially documented crop specific fertilizer application recommendations for the locally common broadcast application of fertilizers are available for the region. However, when taking tomato as an example, fertilizer recommendations per hectare for this crop include 120 kg N and 60 kg P_2O_5 for Tanzania (Kamhabwa, 2014), or 80-180 kg N, 96-240 kg P_2O_5 **(**80-200 kg P) and 96-240 kg K_2O (80-200 kg K), as well as 25 t of farm yard manure, for tropical Africa in general (Grubben and Denton, 2004). For potato 200 kg N and 60 kg P_2O_5 per hectare are recommended (Kamhabwa, 2014). In view of these recommended amounts, the amounts of fertilizer applied for tomato and potato as recorded in our study are low to very low, especially for phosphorus and potassium.

Suboptimal application of fertilizer is likely to apply to the other crops as well. Apart from the absence of reliable recommendations, at the feedback workshop farmers complained about the high prices of inorganic fertilizers and their lack of daily cash to buy fertilizers. For these reasons fertilizer gifts may be lower than required for good crop nutrient supply. With higher application of fertilizers, the costs of fertilizers would increase but the direct effect of these costs on profit would probably be limited, while likely increased yield levels would result in higher profits.

No recent broad scale, measured soil fertility data are available for the study area. The results of a soil fertility survey in a comparable mountainous area with vegetable production, the Western Usambara Mountains, suggest that soil fertility constraints may occur (Ndakidemi and Semoka, 2006). In such a situation, co-operation between farmers and soil fertility scientists, including local fertiliser application trials, will help to increase farmers' knowledge and appreciation of local soil fertility issues (Mowo *et al*, 2006). In case of nutrient deficiencies, such efforts would likely result in better, and economically justified, nutrient application.

4.4 Crop protection

The types of fungicides used mostly are mancozeb, a so-called contact fungicide, and metalaxyl, a systemic fungicide. Mancozeb has a preventive mode of action only and therefore should be complemented with the use of curative fungicides, such as metalaxyl, once a disease has infected a crop. Both active ingredients, however, are in most cases already combined in the products farmers use.

Metalaxyl is classified as highly sensitive to developing disease resistance (Brent and Hollomon, 2007) and the use of metalaxyl by vegetable farmers in Tanzania might not be effective anymore in controlling downy mildew and late blight, due to prolonged indiscriminate use of this fungicide in a broad range of vegetables. *Phytophthora infestans* populations in central, eastern and southern African countries consists of two major clonal lineages only (Pule *et al*., 2013) and resistance of late blight (*Phytophthora infestans*) to metalaxyl in potato and tomato has been shown in Tanzania, Burundi, Kenya and Uganda (Olanya *et al*., 2001). Even in regions where metalaxyl was applied at moderate levels, an unexpectedly high rate of resistance was found (Mukalazi *et al*., 2001).

The types of insecticides most frequently used are the carbamates, organochlorines and organophosphates. These insecticides are broad spectrum insecticides that control a range of insects in vegetable crops. A study carried out in 2005 amongst coffee and vegetable farmers in Arumeru district confirms the use of these insecticides (Lekei *et al.*, 2014). In general, however, these broad spectrum insecticides are more toxic than more specific insecticides, like the pyrethroïds. The insecticide used in most crops was the organochlorine endosulfan. This insecticide is highly toxic to humans and to the environment in general. The continued use of this insecticide illustrates again the urgent need for better information on the use of less toxic insecticides in particular and less toxic pesticides in general (Everaarts *et al.,* 2014). Comprehensive multiple level interventions are needed to reduce farmers' exposure and health risks (Lekei *et al.*, 2014; Ngowi *et al.,* 2007; Nonga *et al.,* 2014).

Ngowi *et al*. (2007) reported that a third of vegetable farmers interviewed in Northern Tanzania, indicated to mix pesticides before application, mostly up to a maximum of three. In our study mixtures were not often applied. In case of application of mixtures, in general only one insecticide and one fungicide were mixed.

Average total pesticide use for the most frequently recorded crops (Table 5) was 2.1 kg active ingredient per hectare. It is difficult to say whether this is low or high, as no data were found concerning active ingredient use under comparable production conditions. In our study, for tomatoes, staked and non-staked, total pesticide use amounted to 6.2 kg or l formulated product per hectare. IPM trained tomato farmers in Northern Tanzania (including the Arumeru district) used 13.6 kg or l formulated product per hectare per season, in addition to using biological products, while non-IPM tomato farmers used 13.1 kg or l per hectare per season (Musebe *et al*., 2014). These data suggest that total pesticide use among the farmers in our study is comparatively low.

Assuming a positive relationship between effectiveness of control of pests and diseases and costs of crop protection, it is wise to invest in better, and environmentally sound, crop protection, as profit per crop is likely to increase with an increase of costs of crop protection.

4.5 Income and the opportunity to invest in hybrid seeds and modern equipment

It should be borne in mind that variables are expressed in units per hectare, while the average area of vegetable production in the study was 0.53 hectare. Assuming that the selection of crops in the present study is a representative one for the Arusha region and assuming that crops are grown on three hundred days of the year, this would mean that with the average profit of 17,362 TZS/ha/Gday, a farmer with 0.53 hectare of vegetables would earn around 7,500 TZS per day throughout the year. The income per day would increase to about 9,000 TZS/day, if the farmer concentrated on potatoes, cabbage and tomatoes only. According to the farmers participating in the study 6,000 to 10,000 TZS is needed per day for a household of a family of five. This is in line with the outcome of the Tanzania Household Budget Survey (National Bureau of Statistics, 2014), in which the basic daily need for a household of five persons, two adults and three children, amounts to 4,256 TZS per day.

Seeds of hybrid vegetable cultivars usually are more expensive than open pollinated cultivars. Taking tomato as an example, presently seeds of an open pollinated tomato cultivar locally cost 3,170 TZS per 1,000 seeds, while seeds of a hybrid cultivar cost 57,060 TZS per 1,000 seeds (Everaarts and de Putter, 201X). At 27 thousand plants per hectare this would mean an additional seed cost of 1,455,030 TZS per hectare or 11,830 TZS per growing day.

In general the use of modern equipment like drip irrigation may improve yields (Everaarts and de Putter, 2009) and increase profits (Woltering *et al.*, 2011), although successful introduction depends strongly on the right institutional support (Kulecho and Weatherhead, 2006; Venot *et al.*, 2014; Woltering *et al.*, 2011). The use of drip irrigation systems will also save water, which is important, as water in the area is becoming increasingly scarce due to population growth (Hillbom, 2012b). Apart from potentially increasing yields and saving water, labour (hired) costs of the present furrow irrigation system may be reduced by using drip irrigation, making this method therefore an interesting opportunity to be considered by the local farmers.

Based on local data, a drip installation for a 0.53 hectare vegetable farm costs 2,400,000 TZS, a motor pump costs 300,000 TZS and a water reservoir (10 x 10 x 3 m) costs 6,000,000 TZS. The total investment would be 8,700,000 TZS. With a depreciation period of 5 years, the costs per year would be 1,740,000 or 4,767 TSZ per day. Fuel costs are estimated at 1,800 TZS per day, resulting in a total cost of 6,567 TZS per day.

Assuming that the use of hybrid cultivars and drip irrigation do indeed increase profits under the local conditions, the data on extra costs of hybrid seeds and drip irrigation equipment for a farm with 0.53 hectare of vegetable production in relation to the average daily income (7,500 TZS per day), illustrate that at best only a gradual introduction of hybrid seeds and drip irrigation on limited areas on the farm would seem to be possible, when the use of hybrid seeds and drip irrigation has to be financed with income from vegetable production alone. This is apart from the reported difficulties of accumulating enough cash to do the actual purchase. The situation suggests that companies wanting to sell hybrid seeds and modern production equipment would be wise to offer affordable credit in one form or another to the farmers.

Nevertheless, despite the higher seeds costs, recent experience in tropical Asian countries has shown, that hybrid vegetable cultivars are rapidly adopted, because of higher production and profits (Bastakoti, 2009; Basuki *et al*., 2009; Dagupen and Pasolo, 2009).

4.6 General

Activities of vegetable producers are influenced by the local ecological and social situation, as well as by national economic and political issues (Lynch, 1999). Arusha region farmers sell vegetables at farm gate or market the vegetables within the village, at local markets, at markets in Arusha or even to Dar es Salaam (Hillbom, 2012a). Selling vegetables at the market delivers a higher profit, but selling at farm gate saves time and eliminates the risk of losing the money and time invested in taking the product to the market. Improving market institutions may help farmers to increase profits (Hillbom, 2012a).

As reported by the farmers in our study, the absence of affordable credit in the Arusha region is a major obstacle for developing and consolidating farming and marketing operations, affecting broader issues such as land and soil conservation in the area as well (Kajembe *et al.*, 2005). Provision of credit has also been recommended to enable farmers to participate in profitable export marketing channels (Mgeni and Temu, 2010).

Nevertheless, although local developments induce farmers to intensify and diversify production, and credit facilities may help them to do so, due to increasing population pressure non-agricultural activities and paid employment outside agriculture are likely to become more and more important for the welfare of the people of the region, as was shown for a comparable, neighbouring region on the slopes of Mt. Kilimanjaro (Soini, 2005).

5 Conclusions

Daily income from a 0.53 hectare vegetable farm operation ranges between an average of 7,500 TZS per day to around 9,000 TZS per day if the farmers concentrate on major crops, like potatoes, cabbage and tomatoes, only. Given the reported need of around 6,000 to 10,000 TZS per day for expenses of a five person household, the income from an average vegetable farming operation in the Arusha region would cover all or a major part of the household expenses. However, little money would be left for investment in hybrid seeds and modern production equipment, when vegetable farming is the only source of income.

On average 89 per cent of labour input in vegetable production is hired labour, constituting 54 per cent of the average production costs. Income from vegetable farming would increase if hired labour would be substituted for by own labour.

Given the small margin between income from vegetable farming and household needs, and the reported difficulties in accumulating cash or obtaining affordable credit, companies wanting to sell hybrid seeds and modern vegetable production equipment, would be wise to offer affordable credit to stimulate their trade. At the feedback workshop farmers stated that they would very much welcome such an opportunity.

Yield levels would likely increase with an increase in fertiliser application. Comprehensive efforts are needed to replace especially toxic insecticides with less harmful ones.

To elucidate why in the Arusha region a high percentage of the labour in vegetable production is hired labour, further research is needed on the nominal or appreciated value of all activities within the vegetable farming household.

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Appendix

Example of balance sheet. Data set no. 26: Tomato (staked) production in Nduruma. Price, revenue, income and costs are in Tanzanian Shilling.

Data set no.	26		
Crop	Tomato	Staked	
Cultivar	Tanya		
Acreage	1	ha	
Measurement	2000	m2	
Area	Nduruma		
Start date	12-3-2011		
Sowing date	13-3-2011		
Transplant date	10-4-2011		
Last harvest date	15-7-2011		
Plants	2.8	pl/m2	
Production	10840	kg	270 Crate

	Harvest date	Amount	Unit	Unit price	Revenue per	Income
Income	19-6-2011	10	crate	18,000	180,000	3,620,000
	26-6-2011	30	crate	16,000	480,000	
	26-6-2011	5	crate	8,000	40,000	
	5-7-2011	50	crate	14,000	700,000	
	5-7-2011	20	crate	5,000	100,000	
	6-7-2011	40	crate	14,000	560,000	
	6-7-2011	10	crate	5,000	50,000	
	14-7-2011	55	crate	17,000	935,000	
	14-7-2011	20	crate	6,000	120,000	
	15-7-2011	25	crate	17,000	425,000	
	15-7-2011	5	crate	6,000	30,000	

Item	Item	Amount	Unit	Unit price	Costs per item	Costs per	Total costs
Planting	Seeds	500	g	85	42,500	42,500	2
Crop protection	Attakan - C	1000	ml	40	40,000	138,350	8
	Karate 5 EC	2350	ml	21	49,350		
	Linkonil 500	2500	ml	12	30,000		
	Ridomil Gold 68 WG	500	g	32	16,000		
	Volar mz	150	g	20	3,000		
Fertilization	Urea 46-0-0	335	kg	948	317,500	317,500	18
Others	Tractor plough rental	5	fee	15,000	75,000	172,500	10
	Pull cart rents	25	fee	3,500	87,500		
	Transport	5	fee	2,000	10,000		
Own labour	Total	25	hr				
	Crop protection	10	hr				
	Others	15	hr				
Hired labour	Total	1535	hr			1,080,000	62
	Land preparation	10	hr	2,500	25,000		
	Sowing	5	hr	1,000	5,000		
	Irrigation seedbed	75	hr	833	62,500		
	Bed preparation	30	hr	1,333	40,000		
	Transplanting	45	hr	1,333	60,000		
	Transplanting + fertilization	20	hr	2,000	40,000		
	Staking	195	hr	462	90,000		
	Gap filling	10	hr	2,000	20,000		
	Irrigation field	310	hr	718	222,500		
	Fertilization	45	hr	1,000	45,000		
	Crop protection	100	hr	1,250	125,000		
	Weeding	170	hr	441	75,000		
	Bird control	60	hr	750	45,000		
	Harvesting	460	hr	489	225,000		
Total costs						1,750,850	
Profit						1,869,150	

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PPO/PRI report 653

Plant researchers of Wageningen UR aim to utilise plant properties to help solve issues concerning food, raw materials and energy. They are devoting their knowledge of plants and their up-to-date facilities to increasing the innovative capacity of our clients. In doing so, they work on improving the quality of life.

The mission of Wageningen UR (University & Research centre) is 'To explore the potential of nature to improve the quality of life'. Within Wageningen UR, nine specialised research institutes of the DLO Foundation have joined forces with Wageningen University to help answer the most important questions in the domain of healthy food and living environment. With approximately 30 locations, 6,000 members of staff and 10,000 students, Wageningen UR is one of the leading organisations in its domain worldwide. The integral approach to problems and the cooperation between the various disciplines are at the heart of the unique Wageningen Approach.

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Report 653

Bij Wageningen UR proberen plantonderzoekers de eigenschappen van planten te benutten om problemen op het gebied van voedsel, grondstoffen en energie op te lossen. Zo worden onze kennis van planten en onze moderne voorzieningen ingezet om de kwaliteit van leven in het algemeen en de innovatiekracht van onze opdrachtgevers in het bijzonder te vergroten.

De missie van Wageningen UR (University & Research centre) is ‘To explore the potential of nature to improve the quality of life’. Binnen Wageningen UR bundelen 9 gespecialiseerde onderzoeksinstituten van stichting DLO en Wageningen University hun krachten om bij te dragen aan de oplossing van belangrijke vragen in het domein van gezonde voeding en leefomgeving. Met ongeveer 30 vestigingen, 6.500 medewerkers en 10.000 studenten behoort Wageningen UR wereldwijd tot de aansprekende kennisinstellingen binnen haar domein. De integrale benadering van de vraagstukken en de samenwerking tussen verschillende disciplines vormen het hart van de unieke Wageningen aanpak.