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

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1 SUMMARY

An analysis was made of the inputs, costs and profit of vegetable production in Arusha region, Tanzania. The aim was to establish the financial capability of vegetable producers to invest in improved production techniques use of hybrid seeds and drip irrigation. The average income from vegetable production was like 17,362 Tanzanian Shilling per hectare per growing day (TZS/ha/Gday). This amount is equivalent to around 7,500 TZS (4.73 USD) per day for 0.53 ha, which is the average area of vegetable production in the study area. After deduction of estimated daily expenses of a five-member household, the remaining earnings would only make a gradual introduction of hybrid seeds and drip irrigation possible. Farmers have complained of lack of access to affordable credit. Thus companies supplying hybrid seeds and improved 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 price. Average labour input per crop ranged from 3 to 13 h/ha/Gday. The average for all crops was 6.4 h/ha/Gday. About 89% of labour spend, was hired labour, constituting 54% of the average total production costs. Average cost of fertilizer application and crop protection were 18% and 6% respectively, of total production costs. Farmers complained about high costs of inorganic fertilizers, which may be the reason for low amounts applied. Most of the active ingredients of fungicides applied are of the mancozeb type, while insecticides belong to the organochlorines and organophosphates. Herbicide use was low, limited to carrot production only.

2 INTRODUCTION

In Tanzania vegetable products form a significant part of the daily diet, while their production is a valuable economic activity, providing employment and income (Weinberger and Msuya, 2004; Weinberger and Lumpkin, 2005; Porter *et al.*, 2010). The area under vegetable production 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 tropical Asia, vegetable production per hectare has in recent years 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). It is not clear whether local vegetable producers will be able to afford the more expensive seeds and have the opportunity to invest in improved production methods, as few documented data are available on profit and cash flow of vegetable producers in Tanzania. This study presents results of an analysis of profitability, labour input, fertilizer application and crop protection in vegetable production in the Arusha region, Tanzania.

3 MATERIALS AND METHODS

3.1 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 region has a bimodal rainfall pattern, with a short rainy season from October to November and a long one from April to May. The average annual rainfall 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°C in December and 21°C in June. The soils used for vegetable production in the area generally are chromic Luvisols and ochric Andosols (Jones *et al.*, 2013). They are 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).

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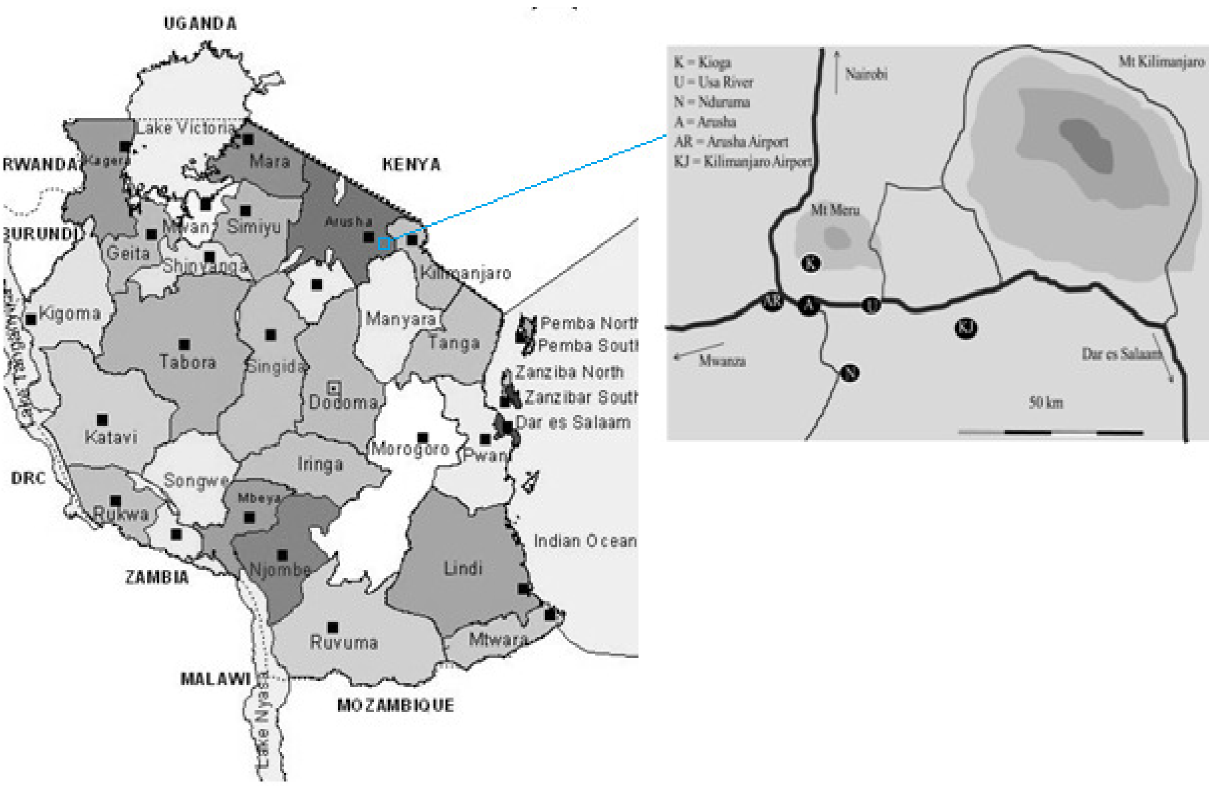

Figure 1: Map of Tanzania - regions, showing the location of Arusha city and the study areas (Kioga, Usa River and Nduruma)

3.2 Selection of vegetable producing areas: Initially five vegetable producing areas in the region were visited in September 2010. During the visits the topography, altitude and size of the production areas were recorded, 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 the visits three areas were selected for data collection. The selected areas constituted of the three villages of Kioga, Usa River and Nduruma in the Arumeru district (Figure 1). The villages are located at 5, 15 and 18 km from Arusha city, at altitudes of 1,690, 1,235 and 1,030 m.a.s.l., respectively. The villages are generally easily accessible, characterized by existence of large plots of food and vegetable crops. Water for irrigation is generally available throughout the year except in the Nduruma village where vegetable crops production mostly depends on rainfall. Livestock including Dairy cows, Sheep and Goats are kept at the farms. The average temperature and precipitation in 2011 is presented in Figure 2.

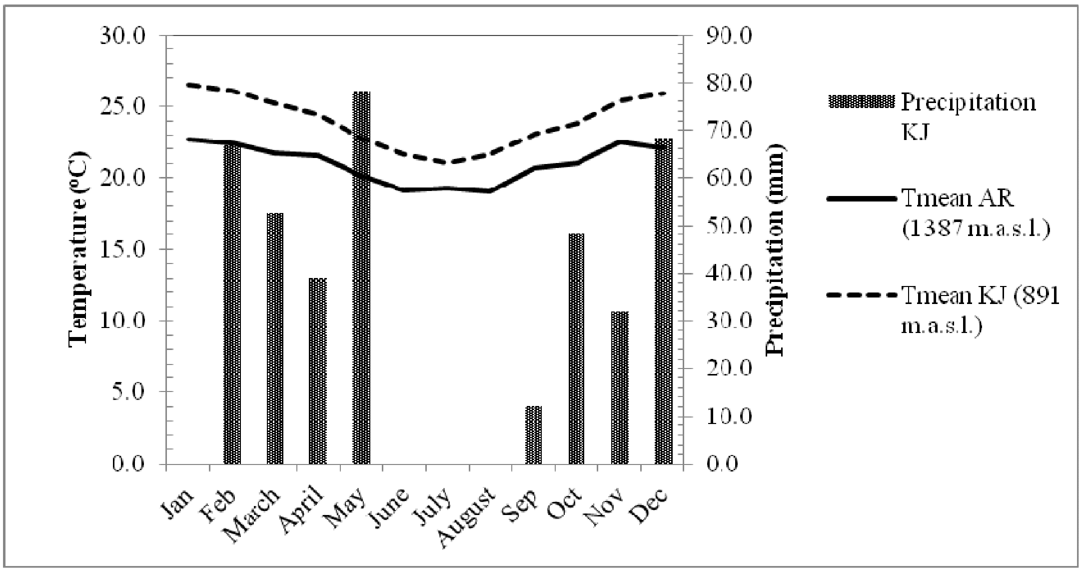

Figure 2: Mean monthly temperature and total monthly precipitation in the study area in 2011 (AR = Arusha Airport; KJ = Kilimanjaro Airport, see Figure 1).

3.3 Selection of farmers: Through the network of a horticultural trade and production company in Arusha, 15 professional vegetable producers from each of the three areas were selected and invited to participate in the study based on the following criteria:

(i) For farm income and financing of vegetable crop production, the farmer should rely largely part on vegetable production (contract farming, involving loans and inputs was excluded);

(ii) Vegetable plots at the farm should be at least 0.2 ha for major vegetable crops and at least 0.1 ha for minor crops;

(iii) The farmer should be younger than fifty years, as to be considered an active producer;

(iv) Should be a commercial vegetable producer with at least five years of experience;

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

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

The selected farmers were invited to a one-day inception workshop in Arusha, during which the aim of the study and the proposed method of data collection were presented. After group discussions most farmers became interested to participate, some declined while others appeared to lack the necessary critical attitude to participate. This led to registration of ten interested farmers from each village as participants in the study. Follow up visits at their respective villages and farms were conducted to train them on data recording.

3.4 Method of data collection: For one year (January to December, 2011), the farmers made notes daily, describing all activities, inputs, yield and income of a particular vegetable plot in a diary. The diaries were collected every two weeks and substituted with new ones.Name and cultivar of the crop, field size, date of planting/sowing and spacing, were recorded. The farmers provided daily records of amounts and costs of labour and all material inputs for the particular crop. Labour was recorded as own labour or hired labour, disaggregated by activity. At harvest, products were graded; quantities and price per unit were recorded.

3.5 Data collected: Variables recorded were the following:

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

(ii) Profit: Profit was calculated as return in Tanzanian Shilling (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.
(iii) Yield: Yield was calculated in kilogram (kg) per ha per Gday in the production field (kg/ha/Gday).
(iv) Product price: Was recorded as the price the farmer received in TZS/kg of product.
(v) Labour input: A distinction was made between hired labour and own labour. Labour input was calculated in hours (h) spent per ha/Gday in the production field (h/ha/Gday). Labour included land preparation, sowing or transplant production, transplanting, irrigation, fertilizer application, crop protection and others.
(vi) Fertilizer application: Was recorded as costs of inorganic fertilizers and farmyard manure expressed as TZS/ha/Gday. For crops with multiple data sets ($n \geq 6$), the data was recorded as application of nutrients in kg/ha.
(vii) Crop protection: Consisted of the cost of pesticides expressed as TZS/ha/Gday, while for crops with multiple data sets ($n \geq 6$), the data were also collected in terms of number and type of insecticide, fungicide and herbicide applications.
At the end of the study, a workshop was held in Arusha with the farmers who had participated, to discuss in the relevance of the collected data and what the farmers had learned.
3.6 Data analysis: To identify factors which determine profitability, linear and non-linear regression analysis were done. Data were analysed on individual crop basis, averaged per crop and per crop and area. In cases of non-normal distribution of variables (skewness and kurtosis significantly different from zero), the analysis was also carried out with response data transformed to square root or ^{10}Log. Multiple linear regression analysis was used to analyse the combined effect of variables on profit. The statistical analysis was done using the GenStat 12 program (Payne *et al*., 2009).

4 RESULTS

4.1 General: A total of 65 individual crop data sets were collected (Table 2). Cabbage and potato were the crops with the highest number of data sets, 11 and 9 respectively. The data sets per crop were not equally distributed across the 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 from which data were collected were smaller than 4,500 m^2 (Figure 3). Planting of crops showed a peak in April, with most crops having a growth duration between 75 and 150 days. The average for all crops was 121 days (Table 3).

4.2 Yields and Product Prices: 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 from 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). Product prices were normally distributed and varied mostly between 200 and 800 TZS per kg (0.13 and 0.50 USD per kg).

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		11
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

4.3 Production Inputs: Most of the labour input ranged between three and nine h/ha/Gday. Together with onion, tomato- 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. Highest costs of fertilizer application were incurred for potato, cucumber, cabbage and tomato. These costs were between 1,488 to 2,706 TZS/ha/Gday (0.94 USD to 1.71 USD/ha/Gday). For most of the crops, however, costs of fertilisers were between zero and 1,500 TZS/ha/Gday.

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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

Family Crop	Sown (S) Trans-planted (T)	n	Growth duration (days) Mean	SE	Profit (TZS/ha/Gday) Mean	SE	Yield (kg/ha/Gday) Mean	SE	Product price (TZS/kg) Mean	SE	Labour input (h/ha/Gday) Mean	SE	Fertilizer application (TZS/ha/Gday) Mean	SE	Crop protection (TZS/ha/Gday) 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	

(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).

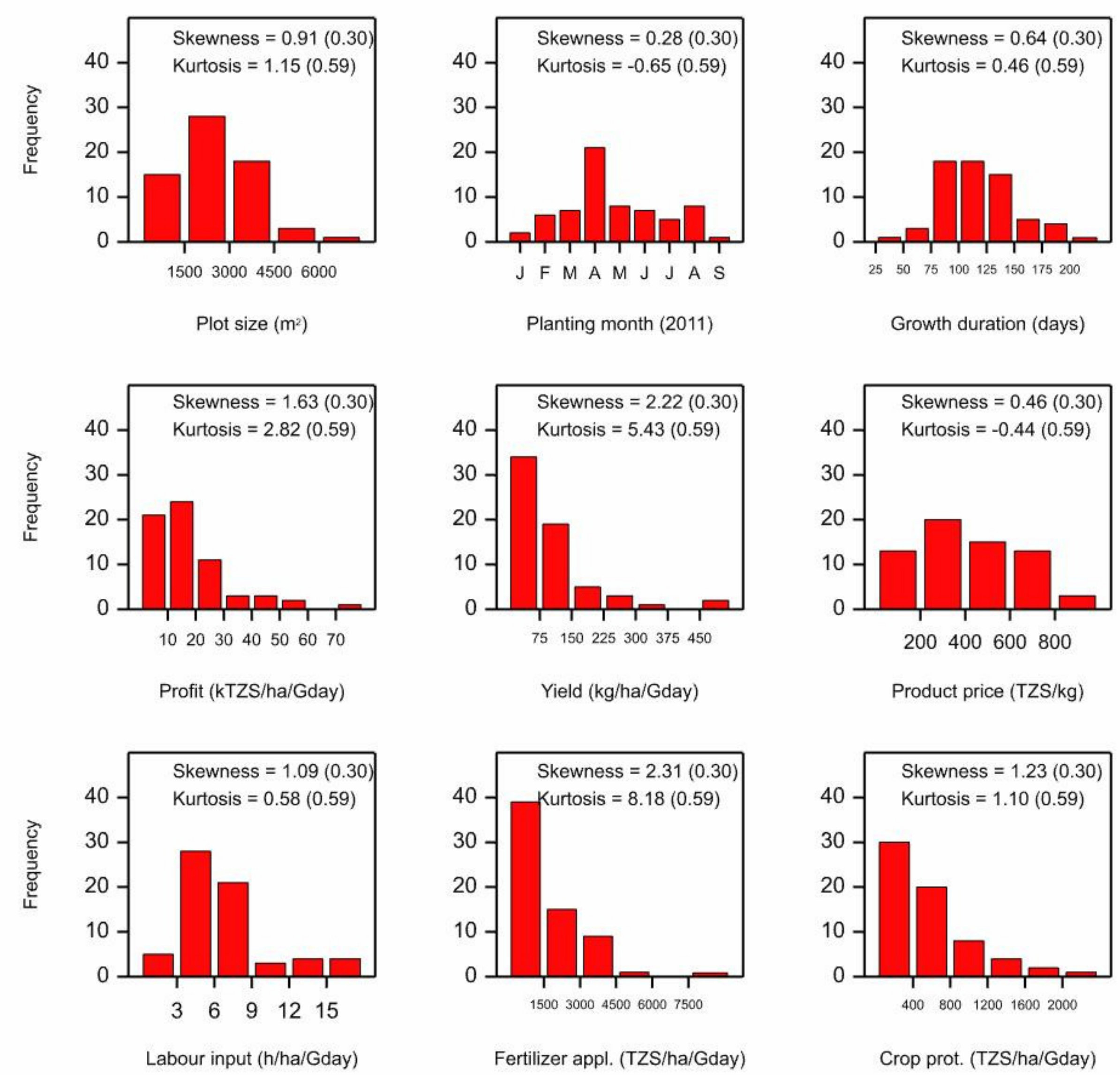

Figure 3: Frequency distribution of data and variables of the 65 individual data sets (values between brackets denote Standard Error; TZS = Tanzanian shilling;
kTZS = 1000 Tanzanian Shilling; Gday = growing day in the production field).

In the most frequently recorded crops; nitrogen, phosphorus and potassium application in the form of inorganic fertilizers varied considerably between areas, showing sometimes high standard errors, including between plots in an area (Table 4). For staked tomatoes 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. 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. This is attributed primarily to fungicide application, which 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 relative to active ingredients in g/t of harvested product.

The sometimes-high standard errors indicated considerable variation in fungicide and insecticide use between plots. Herbicides use was only recorded in the production of carrot. 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.

4.4 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 potato. As shown earlier (Table 3), costs of crop protection were lower than the costs of fertilizer application.

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 Crop	Kioga						Usa River						Nduruma					
	N		P_2O_5		K_2O		N		P2O5		K2O		N		P2O5		K2O	
	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 Crop		**Fungicide**		**Insecticide**		**Herbicide**		**Total**		**Fungicide**		**Insecticide**		**Herbicide**		**Total**	
		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	

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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

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Table 7: Costs of inputs and hired labour as a percentage of total production costs and profit (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
Asteraceac						
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

4.5 Effects of variables on 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. 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% of variance was accounted for (Table 8). Profit in Nduruma increased with higher yields, while profits levelled off early in Kioga. The relation between profit and yield in Usa River lied between the two others (Figure 4). With crop yield data averaged per area, percentage variance accounted for, was only slightly smaller (49.3%), indicating that yield per crop was much more important than area. With transformed data for crop means, the percentage variance accounted for (52.2%), was considerably reduced to 29.2% 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% of variance in profit, which is comparable to the 52.2% of variance accounted for in profit with regression on crops mean yields. 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. On the other hand, 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%, was found with non-transformed data of a subset of three variables: labour input, yield and product price. Labour input alone explained 54.2% of this variance.

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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

	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)**	
	Radj2	P	Radj2	P	Radj2	P	Radj2	P	Radj2	P	Radj2	P
All data (n=65)	23.92	<0.01	26.14	<0.01	-	-	37.31	<0.01	-	-	16.72	<0.01
All data, three areas (n=65)	28.11	<0.01	54.63	<0.01	29.45	<0.01	37.61	<0.01	13.93	0.03	18.11	<0.01
Crop means (n=17)	19.41	0.04	52.25	<0.01	-	-	54.21	<0.01	-	-	30.31	<0.01
Crop/area means (n=27)	28.32	<0.01	29.25	<0.01	-	-	44.71	<0.01	-	-	21.12	<0.01
Crop/area means, three areas (n=27)	31.61	0.02	49.33	<0.01	-	-	41.51	<0.01	-	-	-	-

[1]Linear; [2]Linear, square root transformation; [3]Non-linear; [4]Non-linear, square root transformation; [5]Non-linear, Log_{10} transformation, [6]1USD = 1587 TZS.
(TZS = Tanzanian Shilling[6]; Gday = growing day in the production field).

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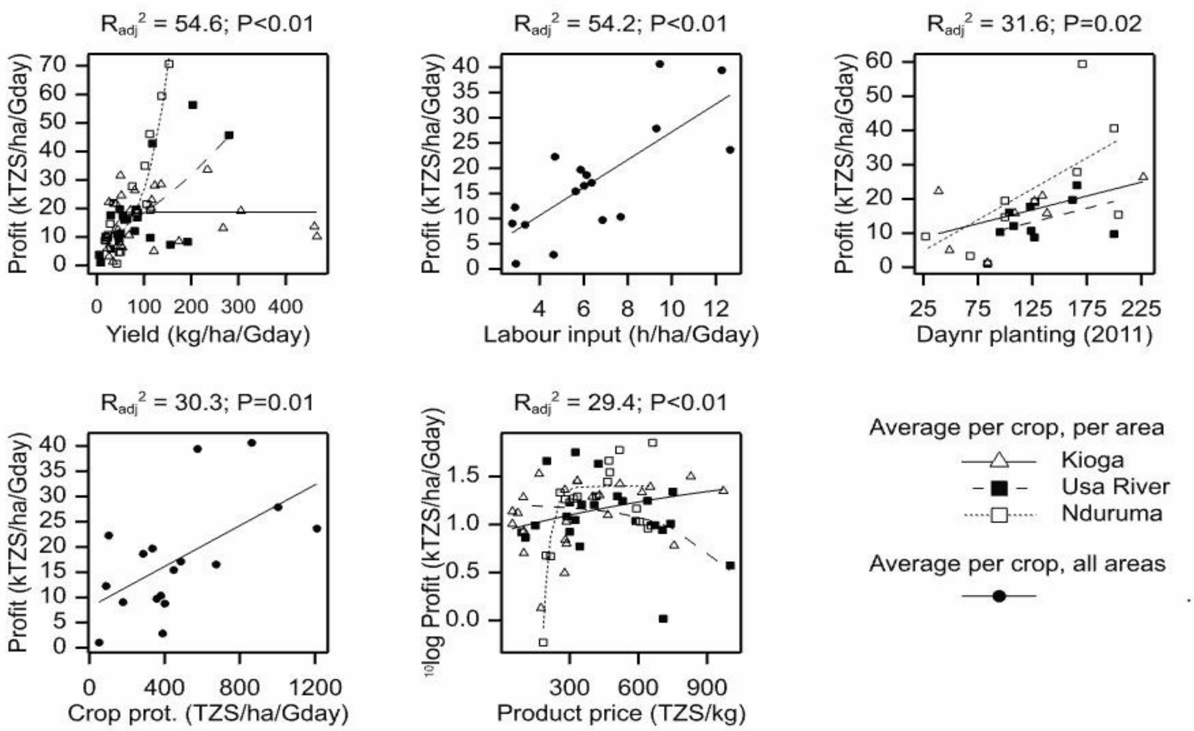

Figure 4: Regressions with the highest percentages of variance accounted for between profit and yield, labour input, planting date (day nr.), costs of crop protection and product price (Table 5; TZS = Tanzanian Shilling; Gday = growing day in the production field).

4.6 Feedback on data: At the end of the study, preliminary data were presented at a feedback workshop. 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 with 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 spent 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.

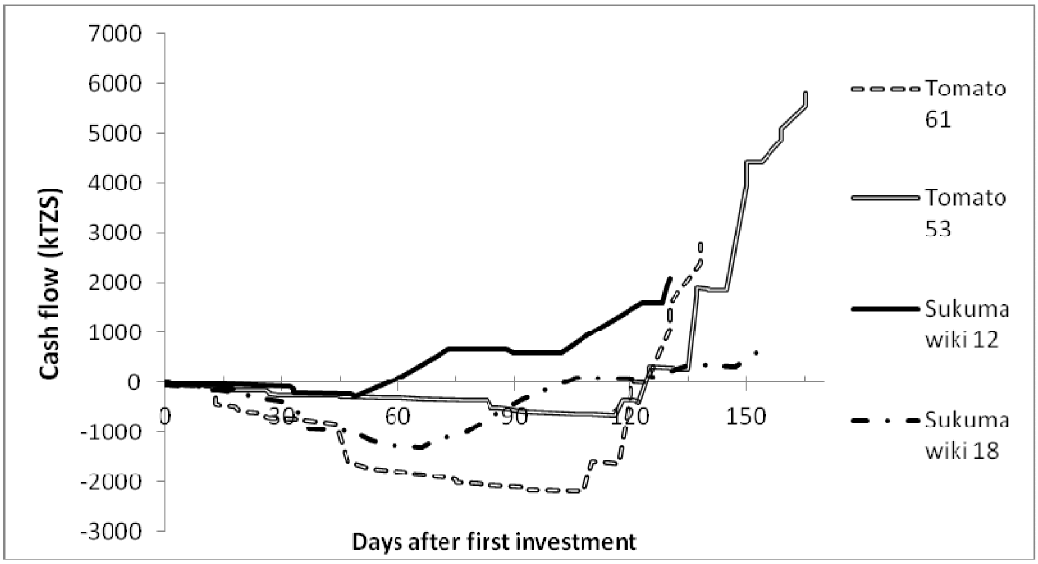

Figure 5: Examples of cash flow with production of tomato (Data set no. 61= high initial costs; Data set no. 53 = low initial costs) and Sukuma wiki (Data set no. 18 = high initial costs; data set no. 12 = low initial costs) (kTZS = 1000 Tanzanian Shilling).

5 DISCUSSION

5.1 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.

5.2 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 results 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, is usually 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% of labour input was hired labour. During discussions with farmers, it did not become clear why so much labour was hired. 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 (10.94 to 13.72 USD/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. The current situation in the study area is apparently 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 who depend solely on casual labour.

5.3 Fertilizer application: No officially documented crop specific fertilizer application recommendations for vegetables are available for the region. However, when taking tomato as an example, fertilizer recommendations per hectare 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 this study are low to very low, especially for phosphorus and potassium. Suboptimal application of fertilizer is likely to apply to the other vegetables as well. Apart from the absence of reliable recommendations, at the feedback workshop farmers complained of high prices of inorganic fertilizers and their lack of daily cash. For these reasons, fertilizer application may be lower than the requirement for good crop nutrient supply. With higher application of fertilizers, the costs of fertilizers would increase but their direct on profit would probably be limited, while the likely increased yield levels would result in higher profits. No recent soil fertility analysis data are available for the study area. Data for a comparable mountainous area in 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.

5.4 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). Hence, it 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 consist of two major clonal lineages only (Pule *et al*., 2013). Its resistance 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 pyrethroids. Endosulfan (Organochlorine) is used in most crops. The insecticide is highly toxic to humans and to the environment in general. Continued use of this insecticide illustrates again the urgent need for better information on the use of 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 this study, mixtures were not often applied. In case of application of mixtures, in general only one insecticide and one fungicide were mixed. Average total pesticides 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 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 /ha/season (Musebe *et al*., 2014). These data suggest that total pesticide use among the farmers in our study is comparatively low. Where there is a positive relationship between effectiveness of control of pests 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.

5.5 Income and the opportunity to invest in hybrid seeds and modern equipment: 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 (10.94 USD/ha/Gday), a farmer with 0.53 ha of vegetables would earn around 7,500 TZS/day (4.73 USD/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 (3.85 to 6.30 USD) 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/day (2.7 USD/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 (2 USD) per 1,000 seeds, while seeds of a hybrid cultivar cost 57,060 TZS (36 USD) per 1,000 seeds. At 27,000 plants/ha this would mean an additional seed cost of 1,455,030 TZS (916.8 USD) per hectare or 11,830 TZS (7.45 USD)/Gday, equivalent to 6,270 TZS (3.95 USD) per 0.53 ha. In general the use of equipment like drip irrigation may improve yields (Everaarts and de Putter, 2009) and increase profits (Woltering *et al*., 2011), although their 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, 2012). Apart from potentially increasing yields and saving water, labour (hired) costs of the present furrow irrigation system may be reduced by using drip irrigation. This makes this method an interesting opportunity to be considered by the local farmers. Based on available data, a drip installation for a 0.53 ha of vegetable farm costs 2,400,000 TZS (1,512.3 USD), a water pump costs 300,000 TZS (189 USD) and a water reservoir (10 x 10 x 3 m) costs 6,000,000 TZS (378.1 USD). The total investment would be 8,700,000 TZS (5,482 USD). With a depreciation period of 5 years, the costs per year would be 1,740,000 (1,096 USD) or 4,767 TSZ (3.0 USD) per day. Fuel costs are estimated at 1,800 TZS/Day, resulting in a total cost of 6,567 TZS/Day (4.14 USD). 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/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, if the use of hybrid seeds and drip irrigation has to be financed with income from vegetable production alone. 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 Asia 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).

6 CONCLUSIONS

Daily income from a 0.53-hectare vegetable farm operation ranges between an average of 7,500 TZS/Day to around 9,000 TZS/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/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 improved production equipment, when vegetable farming is the only source of income. On average 89% of labour input in vegetable production is hired labour, constituting 54% 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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