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Scoping study of horticulture smallholder production in the Central Rift Valley of Ethiopia

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Report 495

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Executive summary

Introduction
To shape its support to the Ethiopian horticultural sector, the Embassy of the Kingdom of the Netherlands in Addis Ababa has requested the Ethiopian Horticulture Producers Exporters Association (EHPEA) in collaboration with Wageningen UR to develop the program 'Promoting Innovations for Smallholder Horticulture in Ethiopia (SmallVeg)' specifically focussing on the needs of smallholder horticulture. To design and to provide input to this program, two scoping studies have been carried out in the Central Rift Valley, which is one of the major smallholder horticultural production areas in Ethiopia.

This report presents the results of the study on current horticultural management and performances of smallholders in the Central Rift Valley. The objective of the study was to describe and analyze current management practices for better understanding of productivity and associated socio-economic and environmental performances of small-holders. The collected information and analyses of data serve as baseline information, teaching material and the identification of R&D needs and management options for further testing in SmallVeg.

The study monitored the day-to-day management in onion and tomato plots of horticulture smallholders in two districts (*woredas*) in the Central Rift Valley, i.e. Dugda and Adami Tulu Jido Kombolcha. Using farm logbooks the daily management operations were recorded by farmers including registration of labor requirements (divided into family and hired, and gender), use and costs of inputs (e.g. fertilizers and pesticides), and the amount and price of produce sold after harvest operations. This information allows estimating detailed crop socio-economic indicators such as cost-benefit ratios, unit cost price and labor productivity. Additional field observations (e.g. plant densities), measurements (e.g. soil analyses and water use), general household information and spatial information (e.g. distances to markets) complement the inventory of crop management of these smallholders, and allow more in depth analyses of the observed economic and agronomic performance.

Results
In total 37 commercial horticulture farmers participated in the study. Despite the fact that our sample farmers were above-average educated and trained, our results suggest that their agronomic and socio-economic performances are far from optimal and also the large variation in performance among farmers indicates at possibilities for improvements in productivity, profitability and environmental footprint.

Remarkably is that sample farmers under- or overestimate their plot size on average with 25%. This bias is not systematic, i.e. about half of the farmers over-estimated and the other half underestimated the size of their plots. Hence, in reality the plot size is 25% larger or smaller than the farmers think it is. This incomplete knowledge hinders the adequate following up on advices with respect to good agricultural practices involving input amounts per unit of area such as fertilizer recommendations.

Smallholders heavily rely on onion and tomato production, which creates a market risk but also bears the potential risk of building up soil borne diseases that will negatively impact on yields and profit in the mid and long-term.

Currently, improved plant material is hardly used by smallholders while most seed used by farmers is locally multiplied and of uncertain quality. The current method of raising transplants in a field bed nursery leads to high seed losses and uneven plant size. In addition, the average age at which seedlings are transplanted from the seedbed to the field is too old, which increases susceptibility to the so-called 'transplanting shock' and reduces final yield.

Average higher onion yields in Adami Tulu Jido Kombolcha (24.8 t ha^{-1}) compared to Dugda (17.3 t ha^{-1}) were associated with lower nitrogen fertilizer use (162 kg N ha^{-1} *vs.* 242 kg N ha^{-1}). Average higher tomato yields in Dugda (31.6 t ha^{-1}) compared to Adami Tulu Jido Kombolcha (16.3 t ha^{-1}) were associated with higher nitrogen fertilizer use in Dugda (186 kg N ha^{-1} *vs.* 120 kg N ha^{-1}). These yield levels are on average more than twice as high as observed in other studies in the Rift Valley, but large variations in yield and N input have been observed among farmers and within both districts: minimum and maximum tomato yields in our sample were 5.9 and 52.5 t ha^{-1}, respectively, while these for onion were 9.0 t ha^{-1} and 57.5 t ha^{-1}.

Especially factors related to seedling age, fertilization, irrigation, and crop protection showed a positive correlation with observed yields which can be explained based on production ecological insights.

In general, farmers applied much more N and P than the average recommended rates (89 kg N ha^{-1}; 80 kg P_2O_5 ha^{-1}), which was further evidenced by the relatively high N and P soil fertility status of the farmer plots. The applied fertilizer rates suggest that current formal but generic recommendations need to be properly validated for prevailing soils in this region (and other regions). Especially, in onion the frequency and timing of fertilizer application need improvement to prevent nutrient losses to the environment, to reduce costs of farmers and to increase yield with the same or even less fertilizers. The role of potassium as possible yield-limiting factor remains unclear, especially in relation to the high soil sodium concentrations found across the study region. Potassium fertilizers are expensive in Ethiopia and access is limited for smallholders. Evidence-based information on the potential impact of potassium fertilization on horticulture crop yields in Ethiopia is lacking.

There is little variation in the types of used fungicides and insecticides, which is probably associated with the price; the old and most frequently used pesticides such as the broad spectrum organophosphates and pyrethroids as well the mancozeb are relatively cheap. The frequent and prolonged use of some insecticides and fungicides may result in the resistance of plagues and diseases. The high frequency of application of some pesticides suggests that plagues and diseases are already increasingly resistant against currently used pesticides, but further research is needed to confirm this.

The socio-economic performance indicators were strongly distorted by the extremely high output prices during the monitoring period: Onion prices averaged 7.7 Birr kg^{-1} and were more than twice as high as the long-term monthly average price (3.1 Birr kg^{-1}), while average tomato prices (4.1 Birr kg^{-1}) were also much higher than the long-term monthly average price (2.7 Birr kg^{-1}). Based on these high prices, profits from tomato and onion were in Dugda almost the same (80,000 Birr ha^{-1}), but in Adami Tulu Jido Kombolcha profit of onion was four times higher than in tomato (150,000 Birr ha^{-1} *vs.* 40,000 Birr ha^{-1}). Overall profits of onion in both districts were about one-third higher than in tomato: average profit of onion farmers was 110,000 Birr ha^{-1} *vs.* 60,000 Birr ha^{-1} for tomato farmers. In general, cost-benefit ratios were more favorable in onion (0.38) than in tomatoes (0.53); this means that each invested Birr gave a return of 2.6 Birr in onion, while in tomato only 1.9 Birr.

Analyses showed that especially farmers producing low yields (<10 t ha^{-1}) may face problems to reach an economic break-even point at long-term average price levels. Obviously, also farmers with higher yields run into problems if prices drop below the long-term average price levels. As indicated before, other studies have observed much lower yields than in our study, which implies that our results possibly provide a too optimistic view on the agronomic and economic performance of horticulture smallholders, the latter caused by the extreme high product price level during our monitoring campaign.

Horticultural production is very labor intensive and represents the largest cost component for small holders; up to 40% of the costs are spent on hiring labor. However, returns to labor are high, i.e. average labor productivity in onion was 210 Birr labor day^{-1} *vs.* 140 Birr labor day^{-1} in tomato. This compares very favorable to daily wage rates such as common in greenhouses, i.e. about 25 Birr labor day^{-1}. However, also here the extreme high output prices provide a disturbing factor. The determined labor productivities can be considered as upper limits under observed management, yield levels and prices.

We found remarkable differences in the labor use and provision between Dugda and Adami Tulu Jido Kombolcha. Dugda farmers rely much more on externally hired labor than farmers in Adami Tulu Jido Kombolcha who use more family labor. Several reasons may explain this difference. First, the Meki area has a longer tradition in smallholder vegetable production than Adami Tulu Jido Kombolcha. Associated with this history is the more developed labor market and transport sector (horse carts) to transport daily wage earners to the fields. Second, the horticulture production area is more concentrated in Dugda and closer to a labor pool (Meki) facilitating the transport of daily laborers. Third, the Meki horticultural sector is more dominated by businessmen often from other areas who are forced to use hired labor, because they have no other choice. These differences result in higher costs for hired labor in Dugda than in Adami Tulu Jido Kombolcha.

Recommendations

- To secure the sustainable development of commercial smallholder horticulture in the Central Rift Valley, there is an urgent need for crop diversification and the design of crop rotations that are economically viable and sound from an agronomic point of view.
- Since crop genetics are one of the most important yield determining factors testing and demonstration of improved varieties in collaboration with the private seed sector is urgently needed to identify varieties that are adapted to the local conditions and economically viable. This activity, however, cannot be considered in isolation and needs to be done in close collaboration with the next point:
- Improvements in nurseries and seedbeds are required for raising seedlings of improved (hybrid) seed. Without improvements the loss of seedlings during the nursery stage and early crop establishment will be too high to economically use improved (and more expensive!) seed. Centralization and specialization, for example through nurseries of farmer cooperatives or managed by specialized farmers are options to reduce nursery costs.
- Better understanding is required on the relationship between nitrogen inputs and crop yields taken into account prevailing soil fertility. Current fertilizer recommendations are generic, while soil differences are not accounted for, which may result in recommendations that are too low to attain targeted yield levels, or too high resulting in avoidable physical and economic losses. Also the role of potassium as possible yield limiting factor in horticultural production needs further attention also related to the high soil sodium concentrations found.
- More awareness and knowledge of development agents and farmers is needed on the use of pesticides, i.e. types, frequency of applications, scheduling, proper pest and diseases identification, and diagnostics in relation to the type of pesticides, etc. This could prevent early resistance against pesticides, reduce environmental pollution, increase yields, reduce costs and avoid consumer and occupational health risks.
- Inadequate water management results in nutrient losses, creates favorable environments for pests and diseases and is a direct cost factor (fuel for pumps). Earlier attempts to promote more water-efficient application methods (i.e. drip systems) all failed in the region for various reasons. However, a more efficient use of water needs to remain high on the R&D agenda also in relation to the increasing competition for irrigation water, soil salinity and energy costs, which most likely will increase in the future.
- Last but not least, more systematic record keeping by farmers of their management and performance during multiple seasons allows to monitor progress of farmers and to provide feedback to farmers during longer periods. Such information also provides excellent material to coach and advice other farmers and to discuss in farmer groups as learning material and benchmarking.

1. Introduction

It is estimated that only 5% of the more than 3.7 million hectare of potentially irrigable land in Ethiopia is being irrigated (Awulachew *et al.*, 2007). This potential was already acknowledged in the first Sustainable Development and Poverty Reduction Program (SDPRP) of the Ethiopian Government in 2002 in which small scale irrigation was one of the main focus areas (WB, 2002). Further ambitions to develop irrigated horticulture for smallholders were formulated in the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) and the Agricultural Development Led Industrialization (ADLI; FDRE, 2006). Major efforts of these policies were focused on developing irrigation infrastructure for small farmers. Much less emphasis was paid to capacity building, commercialisation and sustainability aspects of irrigated smallholder agriculture. As a consequence smallholder horticulture (vegetables and fruits) has expanded very rapidly over the last decade, however, largely uncontrolled and unguided as value chains are poorly developed and organized, while productivity and resource efficiency are low.

The Ethiopian Growth and Transformation Plan (2010/11 – 2014/15) stresses the leading role of agriculture for the economic and social development of the country. The Growth and Transformation Plan (GTP) includes ambitious objectives for the horticultural sector in terms of production and productivity gains including the further commercialisation and diversification of smallholder farmers.

The Netherlands has supported the development of the Ethiopian horticultural sector since 2007. Initially, the support focused primarily on the floriculture production and exports. The development of the fruit and vegetable sub-sectors (export-oriented and domestic markets) also became part of the Dutch-Ethiopian cooperation since 2010/2011. The Embassy of the Kingdom of the Netherlands (EKN) in Addis Ababa has the intention to continue its support to the viable, competitive and sustainable development of the Ethiopian horticultural sector that contributes to the ambitions of the GTP. To shape its support to the Ethiopian horticultural sector, the Dutch Government has requested the Ethiopian Horticulture Producers Exporters Association (EHPEA) in collaboration with Wageningen UR to develop the program 'Promoting Innovations for Smallholder Horticulture in Ethiopia (SmallVeg)' specifically focussing on the needs of smallholder horticulture. To design and to provide input to this program, two scoping studies have been carried out in the Central Rift Valley, which is one of the major smallholder horticultural production areas in Ethiopia.

The first scoping study focused specifically on the horticulture value chains and markets in this region (Stallen *et al.*, 2012). Objectives of that study were to gain insight in existing types and quality of service provision to horticulture smallholders and the functioning of vegetable value chains, vegetable marketing and actors involved along the value chains. This information allowed identifying bottle necks and constraints in supply chains as well as opportunities for further development in the input provision system, production and marketing.

The second scoping study of which the results are presented in this report focused specifically on the production aspects of horticulture smallholders. The objective of this scoping study was to analyze current horticultural management for better understanding of actual productivity and associated socio-economic and environmental performance of horticulture smallholders. The collected information and analyses of data serve as baseline information, teaching material and the identification of management options for further development and testing in SmallVeg.

The main part of this study consisted of the monitoring of the day-to-day management in onion and tomato plots of 40 horticulture smallholders in two districts (woredas) in the Central Rift Valley. Using farm logbooks the daily management operations were recorded by farmers including labor requirements (e.g. hired and family labor; gender division), use and costs of the type of inputs (e.g. fertilizers and pesticides), and the amount and price of produce sold after harvest operations. This information allows estimating detailed crop socio-economic indicators such as cost-benefit ratios, unit cost price and labor productivities. Additional field observations (e.g. plant densities), measurements (e.g. soil analyses and water use), general household information and spatial information (e.g.

distances to markets) complement the inventory of crop management of these smallholders, and allow more in depth analyses of the observed economic and agronomic performance.

1.1 Outline of report

Chapter 2 provides an introduction to the study area, i.e. the two districts in the Central Rift Valley, providing information on the climatological conditions, prevailing soil types, population and farming systems including issues related to land tenure and recent developments. Chapter 3 provides the analysis of the onion and tomato cultivation of smallholders. This chapter begins with describing the material and methods used to collect and analyse the data followed by a description of the main characteristics of the involved farmers and their households. The results are subdivided into an assessment of the agronomic management and the resulting socio-economic performance characteristics of the monitored plots. Chapter 4 discusses the agronomic and socio economic results in a broader context and identifies key issues for research and development, which may be addressed in future stages of SmallVeg and by other stakeholders.

2. General description of the study area

2.1 Location

The study has been carried out in two districts, Dugda and Adami-Tulu Jido Kombolcha of the Central Rift Valley in Ethiopia (Figure 2.1). Frequently, both districts are named after their district capitals, i.e. Meki in Dugda and Ziway in Adami-Tulu Jido Kombolcha, and in this report we will therefore refer to 'Meki-Ziway' as our study area. This region is one of the major horticultural areas in the Central Rift Valley as well as Ethiopia thanks to its favourable climate and soils, availability of fresh water resources, and its proximity to Addis Ababa. The Capital, approximately 150 km northeast of Meki-Ziway serves as the major market for the produced vegetables (Stallen *et al.*, 2012). Dugda (95,945 ha) is located east and north of Lake Ziway, the largest fresh water resource in the Central Valley, and Adami-Tulu Jido Kombolcha (142,295 ha) west and south of this lake reaching up to Lake Abyata, a highly saline lake. See Jansen *et al.* (2007) for a comprehensive assessment of land and water resources in the Central Rift Valley.

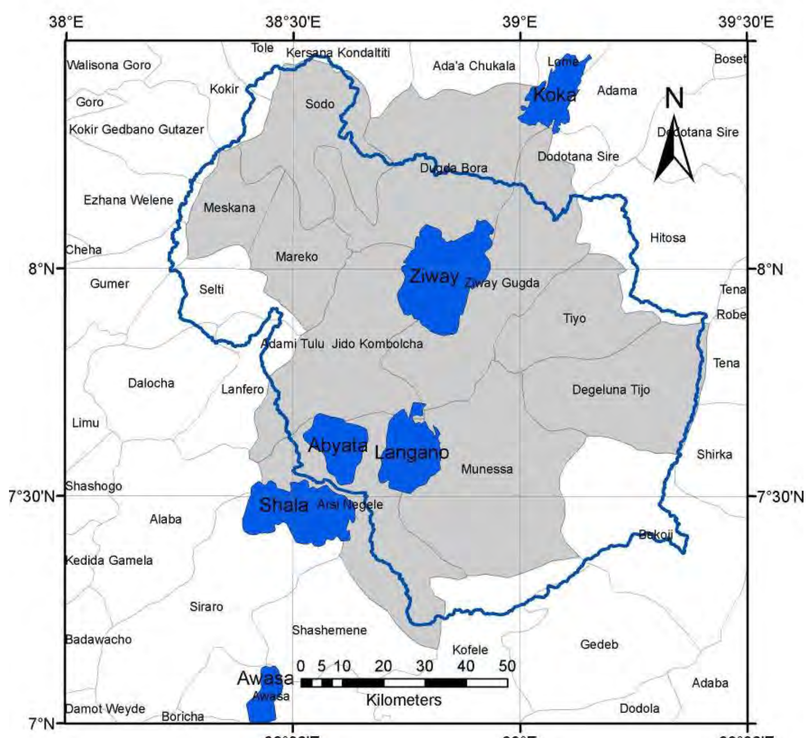


Figure 2.1. Districts Dugda and Adami Tulu Jido Kombolcha in the Central Rift Valley (Jansen et al., 2007).

The Meki-Ziway area is an administrative part of Oromia state while its altitude varies between roughly 1500 and 1800 m above mean sea level.

2.2 Soil types

The soil type distribution in the communities where onion and tomato plots have been monitored is shown in Table 2.1. The Andisols and Fluvisols are the predominant soil types in most communities. The Solonetz soil type of Desta Abijata is clearly different from the soils in the other communities. Andosols are generally well to excessively drained, deep to very deep; very dark grey to brown, medium and coarse textured dominantly sandy loam (MoWR, 2007). Fluvisols are soils developed from recent alluvial deposits, and they are moderately deep to very deep, imperfectly to well drained, fine to medium textured soils. Solonetz soils are well drained, very deep, medium and coarse textured soils characterized by very alkaline pH and high exchangeable sodium content. See for the major soil characteristics Appendix I.

Table 2.1. Soil type distribution among the different communities where monitored plots were located (ha).

District - Community	Andosol	Solonetz	Fluvisol	Cambisol	Luvisol	Total
Adami Tulu Jido Kombolcha						
Desta Abijate		6,581				6,581
Dodicha	2,002					2,002
Edo Kejela	1,413		396		319	2,128
Halaku	4,671			1,713		6,383
Lilika Choleme	1,833		13		973	2,819
Dugda						
Bekele Grisa	1,618		667			2,285
Burka Denbel/Debrabge	1,422		253		45	1,721
Derara Dalecha	1,431		917			2,348
Graba Korke Adi	933		127		1,868	2,928
Welda Kelina			2,167			2,167

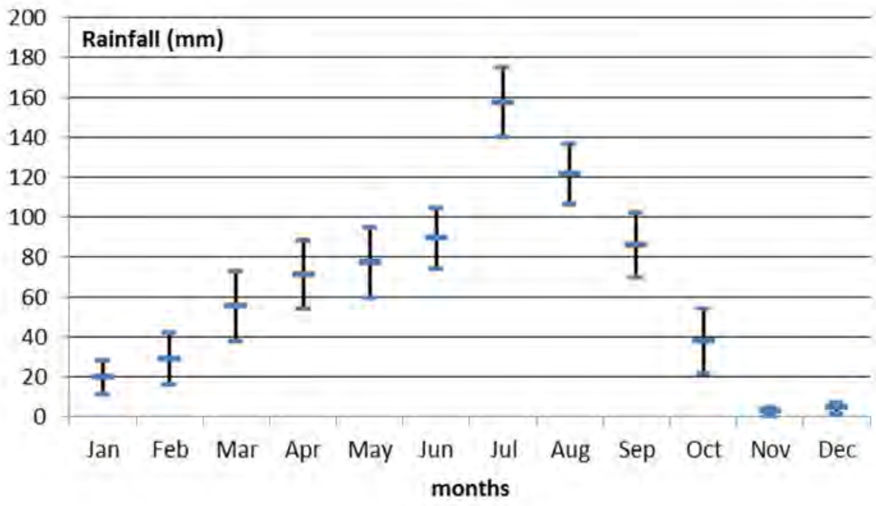
2.3 Climate

2.3.1 Rainfall

Daily rainfall data are available from the period 1960-2009 for Ziway (40 years) and 1966-1990 for Meki (25 years). These data have been compiled and analyzed on monthly basis (Figure 2.2).

The average annual rainfall in Ziway (748 mm) is a bit lower than in Meki (798 mm). The 95% confidence interval of rainfall in Ziway varies between 900 and 560 mm, and in Meki between 1,006 and 590 mm.

The intra annual distribution of rainfall is very similar in both woredas: Rainfall steadily increases from January till June, and rainfall peaks abruptly in July after which it declines again steadily till October. Hardly any rainfall is expected in November and December. Recent studies show that the amount of rainfall in the Central Rift Valley has not changed in the past 30 years (Kassie *et al.*, 2012).



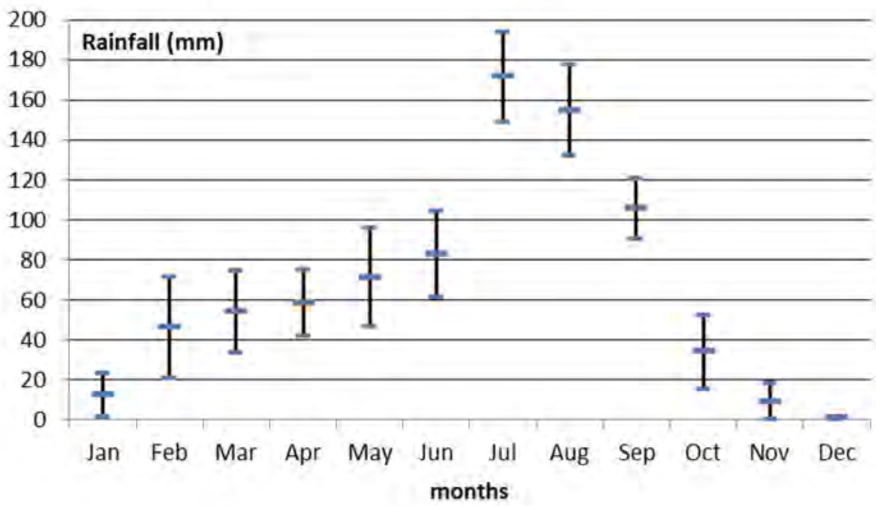


Figure 2.2. Average monthly rainfall with 95% confidence intervals for Ziway (above) and Meki (below).

2.3.2 Temperature

Fairly complete data of the monthly minimum and maximum temperature are available for Ziway from the period 1984-2007 (24 years). Daily minimum and maximum temperature data are available from the period 1996-2008 (13 years). First, these data have been compiled and analysed on annual basis (Figure 2.3).

In general, maximum temperatures fluctuate roughly between 27 and 28 °C with an outlier in 1994 due to missing values. Minimum temperatures vary roughly between 12 and 16 °C.

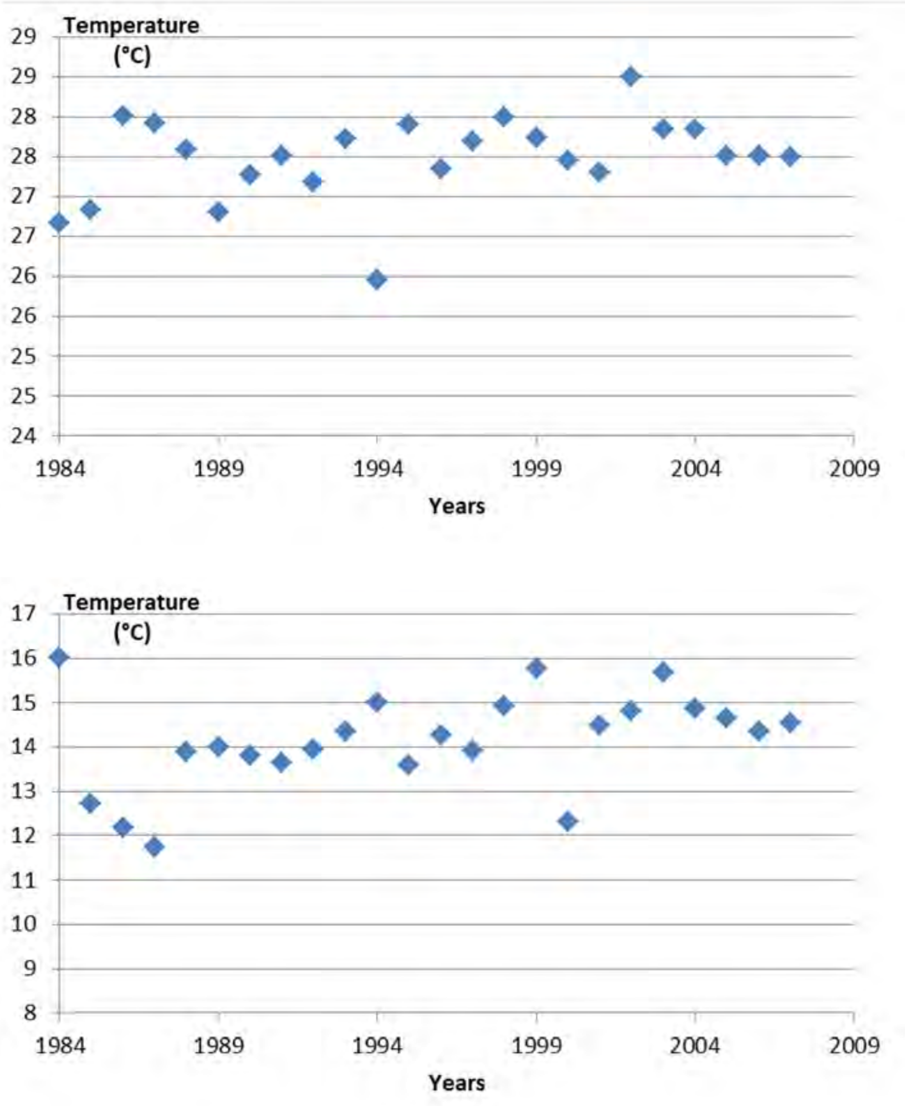


Figure 2.3. Average annual maximum (above) and minimum (below) temperature in Ziway (see text).

Figure 2.4 shows that average monthly maximum temperatures can go as high as 30 °C (June), but then quickly drop to values around 25 °C during the rainy season in July and August. Maximum temperatures quickly increase again to values of approximately 27 °C in October. Minimum temperatures follow a different pattern. Highest minimum temperatures (16 °C) are recorded in April-June, but then they steadily decrease to lowest values of approximately 11 °C in December. The lowest daily minimum temperature in the period 1996-2007 was 4.4 °C (in February), suggesting that the risks for frost are negligible in the study area and that most horticultural crops can be grown provided that water is available. The highest daily maximum temperature in the same period was 34 °C.

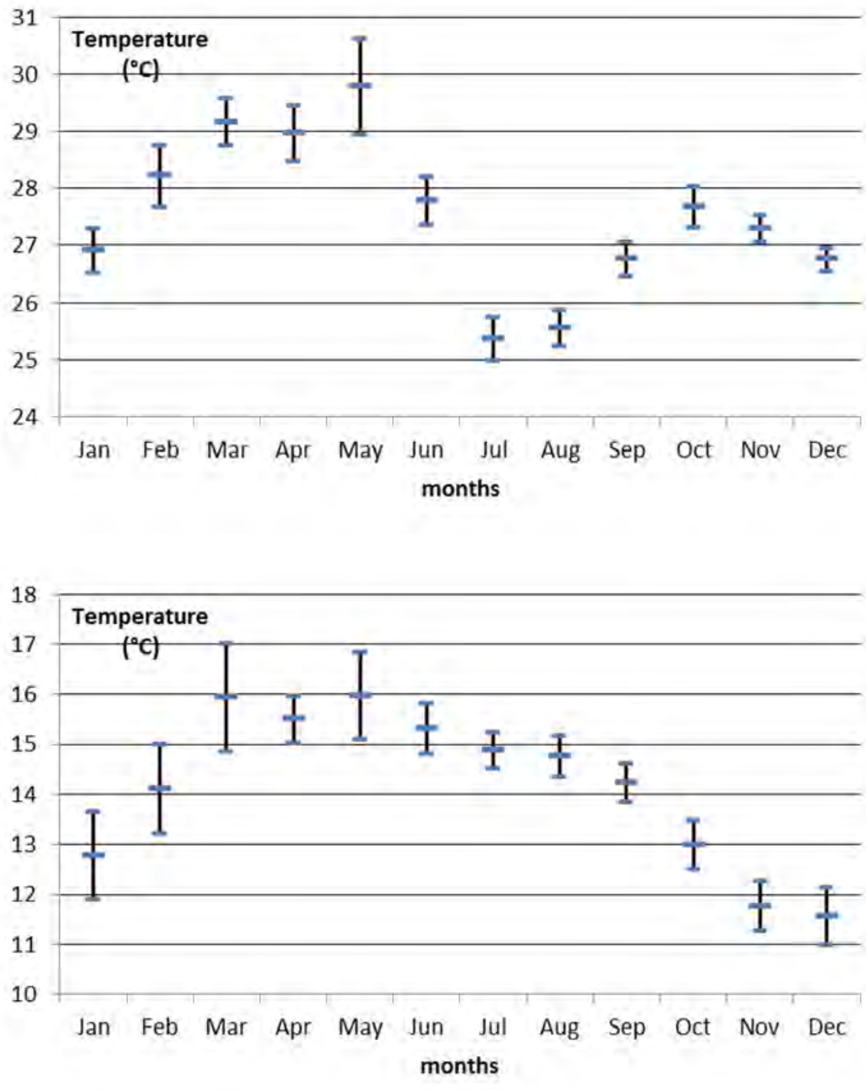


Figure 2.4. Maximum (above) and minimum (below) monthly temperatures in Ziway for the period 1984-2007.

2.3.3 Crop water balance

The crop water balance compares the rainfall and reference evapotranspiration (ETo). A positive balance indicates that rainfall exceeds ETo and that rainfall in general will be sufficient to meet crop water demand. A negative balance indicates that rainfall is insufficient to meet the crop water demand. Additional water from the soil water stock or irrigation is in the latter case required to realise production potentials. Monthly ETo has been estimated using the Penman Monteith method (Monteith, 1965). Figure 2.5 illustrates the development of monthly ETo and rainfall for two years. While ETo is relatively stable varying roughly between 150 and 200 mm per month, rainfall fluctuates much more resulting in a deficit situation during a major part of the year. Commonly, only in one or two months (July and August) rainfall exceeds ETo resulting in a surplus water balance in the Central Rift Valley.

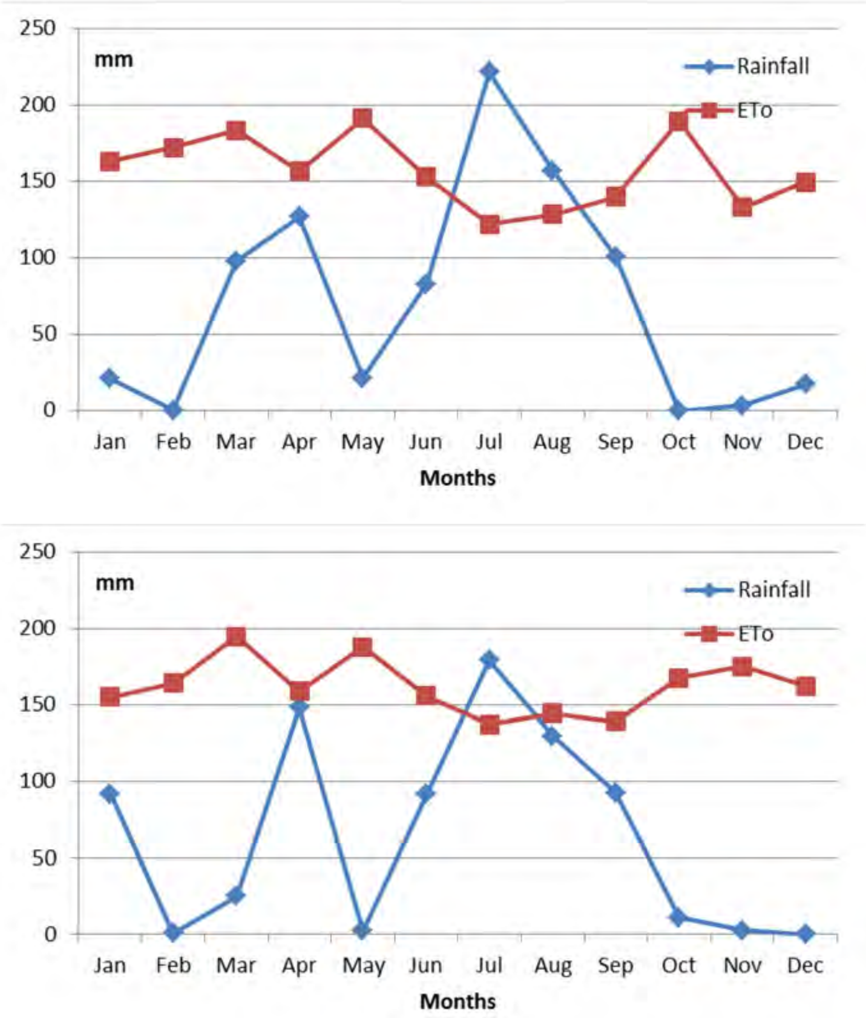


Figure 2.5. Monthly rainfall and reference evapotranspiration (ETo) in 2003 (above) and 2004 (below) in Ziway.

2.4 Population

The total population of Dugda and Adami Tulu Jido Kombolcha is shown in Table 2.2. Adami Tulu Jido Kombolcha has a population density of 1.1 persons per hectare, while in Dugda it is 1.5 according official district statistics. However, reliable population registration is lacking in Ethiopia and especially the urban population of Adami Tulu Jido Kombolcha (Ziway city) seems greatly underestimated compared to Dugda. Figure 2.6 and 2.7 show the population structure of Dugda and Adami Tulu Jido Kombolcha, respectively. These figures show that the population is predominantly young.

Table 2.2. Population of Dugda and Adami Tulu Jido Kombolcha according to district statistics.

	Adami Tulu Jido Kombolcha			Dugda		
	Male	Female	Total	Male	Female	Total
Rural	67,668	67,410	135,078	55,671	52,964	108,635
Urban	12,121	11,337	23,458	18,844	17,370	36,214
Total	79,789	78,747	158,536	74,515	70,334	144,849

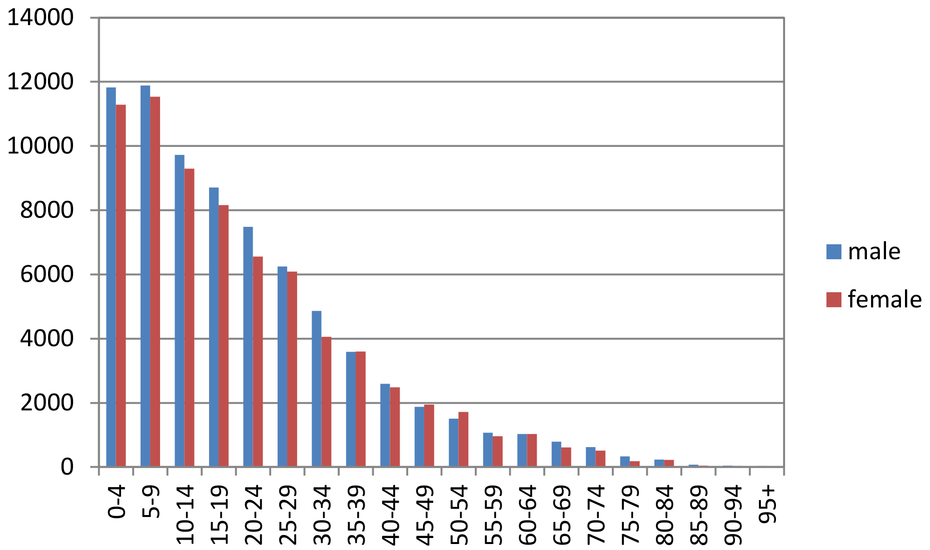


Figure 2.6. Population age cohorts of 5 years and per sex of Dugda (source: CSA, 2007).

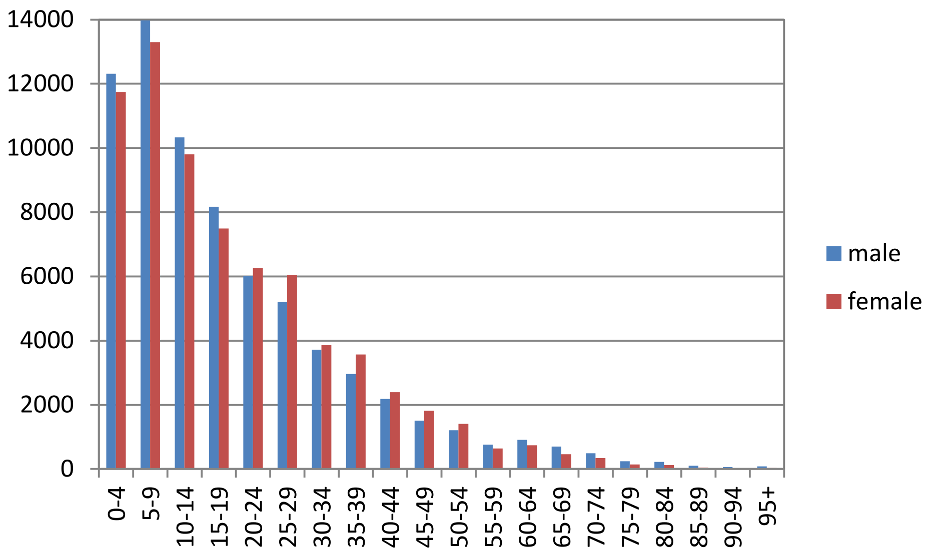


Figure 2.7. Population age cohorts of 5 years and per sex of Adami Tulu Jido Kombolcha (source: CSA, 2007).

The plots for monitoring the cultivation of tomatoes and onions were located in five communities in each district. Population data of these communities are presented in Table 2.3. Data of Table 2.3 and Table 2.2 are not consistent which may be related to the different sources and reference year.

Table 2.3. Population characteristics in the districts Adami Tulu (AT) and Dugda (Du) and the five communities where monitored plots were located (source: CSA, 2007).

	Population	Households	Houses	Persons per household	M/f ratio
AT Urban	20,756	5,339	5,209	3.9	
AT Rural	120,341	23,640	22,784	5.1	
Edo Gojola	2,906	603	559	4.8	1.0
Lilika Choleme	3,970	786	776	5.1	1.0
Haleku	2,285	424	416	5.4	1.0
Desta Abjata	3,070	652	614	4.7	1.0
Du urban	35,501	9,630	9,298	3.7	
Du rural	108,419	22,092	21,512	4.9	
Derara Dalecha	4,035	790	768	5.1	1.0
Welda Qelina	5,197	1,060	1,033	4.9	1.1
Bekele Grisa	4,317	864	850	5.0	1.1
Graba Korke ada	4,375	932	908	4.7	1.0

A slightly higher percentage of the population in Adami Tulu Jido Kombolcha attended school than in Dugda (Table 2.4). Both districts show expected differences in school attendance between the urban and rural population: higher school attendance in urban areas. Differences between male and female school attendance were larger in the past and suggest currently more gender equality in schooling, though small differences remain.

Table 2.4. Percentage of the population > 5 yrs. never attending, currently attending school or attended school in the past (source: CSA, 2007).

	Never attended school		Currently attending school		Attended school in the past	
	Male	Female	Male	Female	Male	Female
Dugda	26.5	31.6	10.6	9.3	14.3	7.6
Urban population	10.5	17.2	18.8	17.3	22.9	13.3
Rural population	32.2	36.7	7.7	6.5	11.3	5.6
Adami Tulu Jido Kombolcha	21.9	31.0	13.1	9.7	15.2	9.2
Urban population	11.0	18.1	17.6	14.0	23.1	16.1
Rural population	23.9	33.3	12.3	8.8	13.7	7.9

In both Dugda and Adami Tulu Jido Kombolcha about 70-75% of the population is economically active, in rural areas participation rates are higher than in urban areas, and also participation rates of the male population are higher than the female part of the population (Table 2.5). Official unemployment rates in rural areas are much lower (< 2%) than in the urban areas (9% and up).

Table 2.5. Economically active part of the population expressed as % of the total population > 10 years, and unemployment rates of the economically active population (source: CSA, 2007).

	Active (%)		Inactive (%)		Unemployment rate (%)	
	Male	Female	Male	Female	Male	Female
Dugda	41.3	30.2	10.4	18.1	3.1	4.6
Urban population	35.1	23.2	17.5	24.2	9.3	15.3
Rural population	43.6	23.9	7.7	15.8	1.1	1.7
Adami Tulu Jido Kombolcha	40.8	37.8	9.1	12.4	3.8	3.9
Urban population	31.8	22.9	20.3	25.0	18.8	26.2
Rural population	42.6	40.8	6.8	9.9	1.5	1.3

2.5 Farming systems and land use

The predominant smallholder farming system in Meki-Ziway is a mixed system consisting of rain fed crops and livestock. Major rain fed crops are maize, wheat, barley, teff and haricot bean. Livestock serves multiple purposes, ranging from providing draught power, milk, and manure to savings. Especially in the direct neighborhood of Lake Ziway, land use in the Central Rift Valley has changed considerably during the last 30 years from once a semi-pastoralist area to the current intensively cultivated rain fed crop land (Jansen *et al.* 2007). Associated with the semi-pastoralist land use in the recent past, average land holding sizes are relatively large (2-3 ha) compared with those in other parts of Ethiopia such as the Southern Nations, Nationalities and People's Region and Tigray where the population density is much higher (Tesfaye Shirefaw, 2008; Adimassu *et al.*, 2012).

Average rain fed crop yields in Adami Tulu Jido Kombolcha vary between 1 and 1.5 t ha^{-1} for wheat, 2 and 2.5 t ha^{-1} for maize, 0.5 and 1 t ha^{-1} for teff and 1 and 2 t ha^{-1} for haricot beans. Related with the low yields is the low use of fertilizers. Based on survey data, 40% of the rain fed farmers do not use any fertilizer, while over 50% of the users apply less than 50 kg DAP (Di-ammonium Phosphate) and urea per ha (Tesfaye Shirefaw, 2008).

Especially during the last decade irrigated agriculture has expanded rapidly in the Meki-Ziway region: State farms were privatized and new foreign investors were attracted through the provision of favorable loans and tax holidays. Especially, the Sher greenhouse complex in Ziway producing flowers for export has resulted in new employment opportunities for the local population and migrants. But also other foreign investors (e.g. Castel winery) and local investors have obtained irrigated land from privatized state farms or developed new irrigated land and provide new employment opportunities.

Major investments in irrigation infrastructure by national and regional governments and non-governmental organizations (NGO) have been made within the context of the poverty reduction strategy of the Federal Government. Communal (grazing) land or rain fed crop land has been supplied with irrigation infrastructure and the land has been redistributed among local farmer communities. The dominant model of irrigation development is the small scale irrigation scheme in which farmers share one large pump and each farmer has the usufruct of irrigated plots varying in size between approximately 0.25 and 0.5 ha. Such schemes differ in size but most schemes range from 10 to 100 ha (Rodriguez de Francisco, 2008). Farmers in such irrigation schemes are organized in Water User Associations (WUA), which is a prerequisite to receive support from donors for the irrigation infrastructure (pump, scheme design, weirs, etc.). Farmers usually provide own labor for developing the schemes. A recent development is that individual smallholders begin with irrigated horticulture using small pumps and shallow dug wells. The pumps are individually owned, shared within a group of farmers, or rented.

As a result of the investments in irrigation infrastructure and the diversification and commercialization of rain fed farmers the irrigated area in Meki-Ziway has increased rapidly during the last ten years (Figure 2.8). The area under irrigation is estimated to have increased roughly 10 times of which the majority is managed by smallholders.

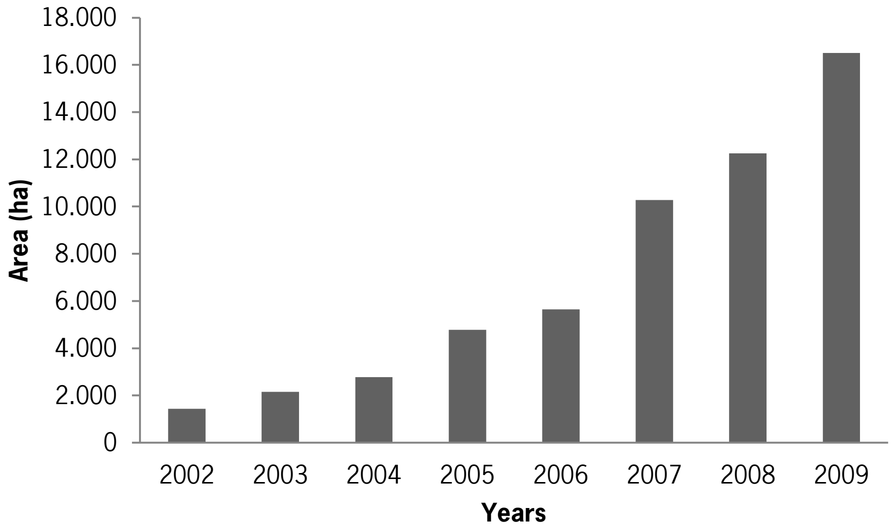


Figure 2.8. Development of irrigated area in the Meki-Ziway area between 2002 and 2009 (source: local districts statistics).

2.6 Land tenure and tax

The Ethiopian Constitution of 1994 sets the national framework for land policy including the concept of public land ownership and the impossibility to sell or transfer land use rights (FDRE, 1995). The Ethiopian Constitution asserts state ownership of land. There are no private property rights in land and farmers only receive usufruct rights to plots of land without transfer rights, such as sale or mortgage. This limits farmers in obtaining credit for inputs and technologies.

Ethiopia's land policy has been further clarified by Proclamation No. 89/1997, 'Rural Land Administration.' This law defines the scope of individual land use rights and states that such rights can be leased and bequeathed. The land rights themselves cannot be sold or exchanged, but private property improvements to the land can be sold or exchanged.

The 1997 Proclamation also delegates responsibility for land administration to regional governments including the assignment of holding rights and the distribution of landholdings. Consequently, regional governments can endorse laws or regulations related to land rights. For example, land rental is permitted, but restrictions remain on land transfers. Yet, land tenure in Ethiopia remains an ambiguous topic as interpretation of the Constitution varies by officials at different locations and administration levels. In addition, despite the decentralization of land administration to regional governments, the formulation of land policy still rests with the federal government. Local government officials are reluctant to develop laws and policies that have not been sanctioned by the federal government. The apparent resistance from policy to the leasing out of irrigated land is because of the risk that smallholders will consume the received financial benefits (for the land lease) quickly and become food insecure later in the year.

In general, leasing out of irrigation land is not allowed in WUA-managed irrigation schemes. According to WUA regulations it is only possible when a member is unable to work on his/her plot due to health-related and financial problems (Mengistu Assefa, 2008). Approval for leasing is needed from the executive committee of WUA. According to the bylaws of the WUAs every member is allowed to leave the association but s/he has to leave the irrigated land to the WUA. The WUA gives permission to individuals from the same community (*Kebele*) to exchange land with the WUA member who leaves the scheme. The enforcement of such bylaws is often weak, and therefore different formal and informal lease and sharecropping constructions have developed in most schemes. This resulted, for example, in situations that most female beneficiaries in an irrigation scheme were not female-headed households, but the wives of other male beneficiaries (Paas, 2010).

Lack of capital to purchase inputs (e.g. seed, fertilizers, pesticides) is one of the most important reasons for farmers to lease their land to others, i.e. WUA members or outsiders. Sometimes, all farmers in schemes lease their land to (local) 'investors', who has the financial capacity to buy fuel, seeds and other inputs required to begin cultivation. In such cases, the labor of farmers is often rented in again by the investor for doing the field work. Farmers can be compensated through receiving a part of the harvest or cash payments (rent price for the land and wage labor). Also individual farmers within irrigation schemes can hire somebody doing the actual crop management, while the farmer pays the inputs and the benefits at harvest are shared.

Since shortly, these forms of (informal) land leasing constructions are forbidden with the penalty to loose usufruct of the irrigated plot. Innovative constructions, however, are being developed to by-pass this law. For example, affluent people buy the inputs for a farmer while benefits at the harvest are shared (in cash or part of the harvest). At this stage it is unknown how this new law will be enforced.

Recently, and associated with the improved availability of small and cheap irrigation pumps there is a rapid increase of individual farmers who start irrigation in the Meki/Ziway. Either using surface water or shallow groundwater individual farmers are now able to access water to irrigate horticulture crops. Also here, as in irrigation schemes, various informal lease and share cropping constructions are apparent. Also the renting out and shared use of these small pumps are new phenomena including the theft of pumps.

Tax payments of farmers are collected by the district revenue office under supervision of the district land use office. Taxes are not related to household assets such as the number of livestock as the Meki-Ziway area is not a pastoralist area any longer, but related to land size and income (Table 2.6). Income from irrigated land is assumed to be higher than from rain fed land resulting in higher income taxes for irrigated land. Tax payments are collected once a year beginning in October during approximately two months. Because the land size is often not exactly known and registered land taxes may be negotiable in some communities depending on the committee members in charge of collecting taxes.

Table 2.6. Income and land use tax for rain fed and irrigated land (Birr ha^{-1}). Source: district offices.

Land size (ha)	Rain fed land			Irrigated land		
	Land use	Income	Total	Land use	Income	Total
≤ 0.5	15	Exempted	15	15	30	45
0.5 – 1	20	20	40	20	40	60
1 – 2	30	35	65	30	55	85
2 – 3	45	55	100	45	75	120
3 - 4	65	70	135	65	90	155
4 - 5	90	100	190	90	120	210
≥ 5	120	140	260	120	160	280

3. Analysis of onion and tomato cultivation

3.1 Material and methods

3.1.1 Methods

In February 2012, 40 smallholders were selected in Meki-Ziway to gain insight in the cultivation methods and the agronomic, environmental and socio-economic performance of tomato and onion production. The selection was done using a stratified sampling method. Five communities per district (Dugda and Adami Tulu Jido Kombolcha) were selected based on the presence of horticultural smallholders, and per community two onion plots and two tomato plots were selected. Additional selection criteria were that the farmer produced a surplus of tomato or onion for commercial purposes, and that farmers were literate as they needed to keep a daily logbook of the management.
In total 40 farmers were selected, resulting in 20 onion farmers and 20 tomato farmers which were equally divided over the two districts Dugda and Adami-Tulu Jido Kombolcha. In this report results from 36 farmers are presented, 20 from Dugda and 17 from Adami-Tulu Jido Kombolcha (Table 3.1). Shortly for the actual monitoring three farmers decided to cultivate another crop than onion and tomato.

Table 3.1. Number of onion and tomato farmer fields per district (wereda) and community (kebele).

District - Community	Onion	Tomato	Total
Adami Tulu Jido Kombolcha	7	10	17
Desta Abijate		2	2
Dodicha	1	2	3
Edo Kejela	2	2	4
Halaku	2	2	4
Lilika Choleme	2	2	4
Dugda	10	10	20
Bekele Grisa	2	2	4
Burka Denbel/Debrabge	2	2	4
Derara Dalecha	2	2	4
Graba Korke Adi	2	2	4
Welda Kelina	2	2	4
Total	17	20	37

In February two workshops with farmers and government development agents were held, one in Ziway and one in Meki, to explain the background of the data collection and the method to collect and record the data. The workshops were also used to modify proposed recording methods, and to incorporate issues in the collection of data relevant for the study region based on discussions with farmers and development agents.

All physical inputs and labor used for the crop cultivation were recorded, including the associated costs, the produced quantity and the price received for the marketed produce. For each management activity the date and description of activity was recorded by the famers. In addition to information on management practices, farmers also recorded fees or other costs associated with crop cultivation such as renting costs of oxen or tractors, irrigation fees, transport fees, broker fees, market taxes etc. Every two weeks the logbooks were collected by development agents (DA) and submitted to project staff in Meki and Ziway who checked the data on accuracy and completeness. The information was further checked and analysed by the authors of this report. Atypical data were double checked with responsible farmers.

In addition to the collection of management data, also general information was collected of the farmers (e.g. level of education, experience in tomato or onion production), farm household (e.g. number of family members, gender composition), total farm size and assets (e.g. landownership, permanent staff).

The soil of each plot was sampled within seven days after the last harvest. Sampling depth was 20 cm for onion and 25 cm for tomato. Per plot about 20 to 25 soil cores were taken to make one large sample. This sample was split in two sub samples of which one was submitted on the same day of the sampling to Jije laborglass laboratory in Addis Ababa to determine the content of mineral nitrogen, NO_3 and NH_4+. The other sub sample was kept cool in a refrigerator for five months to five days depending on the harvest date. These samples were analysed on general soil fertility characteristics. Since the samples were analysed by Altic in the Netherlands, they were sent in batches to the Netherlands. A first batch with about half of the samples was submitted to Horticoop on August 1, 2012 and a second batch on September 13, 2012.

A GIS survey has been carried out by a local consultant to measure with GPS the cultivated fields, distance from farm to field, distance from field to nearest market (Meki or Ziway) and the geographic location of the fields. The measured field size by this method was used to convert figures recorded on field base to hectare. See Figure 3.1 for a map with the locations of the various fields across the Meki-Ziway region.

In addition to the frequency of irrigation, associated labor requirements and energy costs for all plots, irrigation water input has been measured using flumes for a selected number of plots. In these selected plots flumes during one irrigation event were placed in the water inlet to the plots. Using the approach described by Beshir Keddi Lencha (2008) the amount of water applied during this event was calculated.

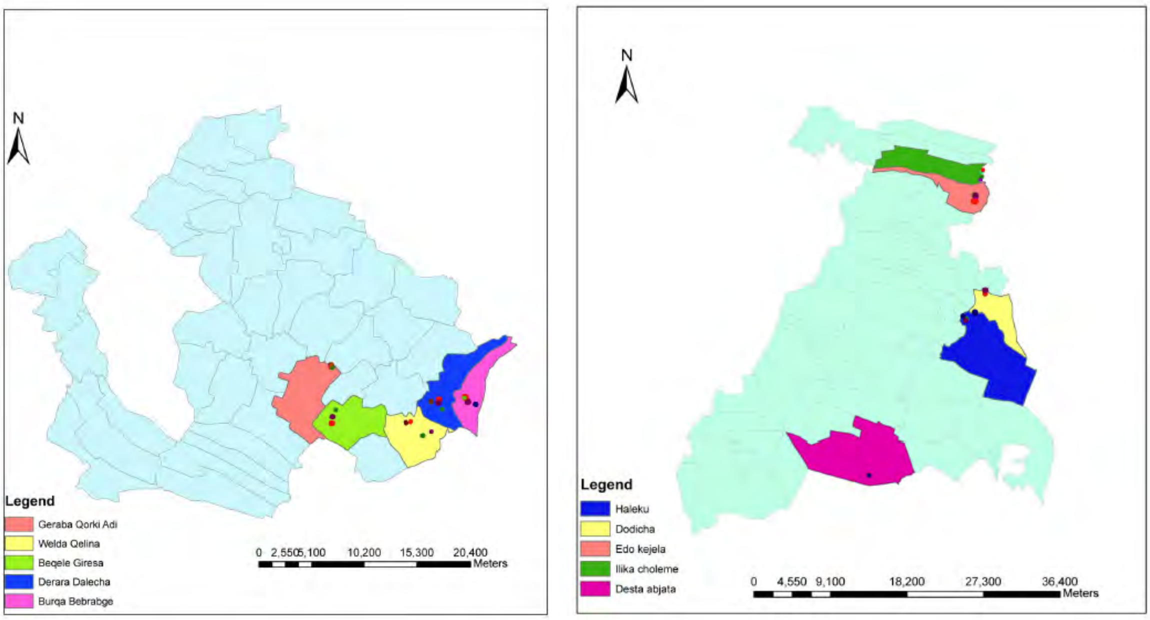


Figure 3.1. Map of Dugda (left) and Adami Tulu Jido Kombolcha (right) with locations of the monitored plots.

3.1.2 Data collection

Used materials were described by farmers in terms of type (e.g. Urea 46-0-0, Mancozeb 80%WP), amount used, unit (e.g. liter or kilogram), price per unit, and total costs.

Labor input was recorded according to the type of labor (hired, permanent staff or family labor), gender (male or female), number of persons involved, amount of labor, and paid wages.

Harvesting of vegetables is most often not a one-time operation in horticulture production, but rather a sequence of events during a certain harvesting period. Since the harvested produce is commonly sold directly after each harvest operation, market prices and harvested amounts vary during the entire harvesting period. To enable the calculation of the total crop revenues farmers recorded harvest dates, sold quantity in kilograms, actual produced kilograms, and price per kilogram or per crate for each harvest operation. Traditional produce is packed and sold in crates of 50 to 60 kg. Selling agreements can be based on crate or kg. In case of crates the number of crates was counted, the price per crate and an average weight of 55 kg per crate (according farmers estimate). In case of kilogram agreements, a fixed price per kilogram is agreed upon between famer and buyer, and each filled crate is weighed. Buyers subtract standard 10 kg per crate from the weight to account for the weight of the crate. During the survey empty crates were weighed which showed that empty crates weigh on average 6 kg, i.e. for each crate the buyer receives a discount of 4 kg. To accurately estimate the production per harvest, we have accounted for this difference, which implies in general that the marketed amount (as paid by the buyer) is lower that the physical amount.

In order to evaluate the agronomic practices N, P_2O_5 and K_2O content of all applied fertilizers was recorded and the type of active ingredient (A.I.) and its concentration of pesticides were recorded as given by the product labels. With this information the total amount of applied nutrients and the amount of A.I. per fungicide and insecticide was calculated per crop.

3.1.3 Data analyses

Since the field size as given by the farmers may deviate from the measured field size using GPS (section 3.1.1), we used the measured field size in the data analyses.

Agronomic indicators
The total yield of tomato and onion was determined using the method described in section 3.1.2.

The total amount of nitrogen fertilizers was calculated based on the number of fertilizer applications, fertilizer amount and composition. N use efficiency is calculated as kg produce per kg N applied.

For pesticides the number of applications was determined from transplanting till last harvest. Spray intervals were calculated by dividing the period from the first application till the last application by the number of applications. Total spray volumes were calculated by multiplying the maximum amount observed during a single spraying.

We are not able to estimate the water use efficiency due to the unavailability of actual rainfall data during the report writing. Alternatively, we calculate evapotranspiration under standard conditions using the CROPWAT model (FAO, 2012) and the irrigation water use of a selection of plots and we show the long-term rainfall during the growing season as an indication of the actual rainfall.

A correlation analyses was performed with on the one hand the agronomic yield of tomato and onion and on the other hand the variables listed in Table 3.2. These variables have been grouped according the major management events and general farm characteristics: crop establishment, fertilization, crop protection, irrigation, labor, costs and general farm characteristics. The analyses allows to identify which variables correlated most with the observed yield performance of tomato and onion without being able to establish always causal relationships.

Table 3.2. Variables (and units) correlated with the observed agronomic yield of tomato and onion.

Crop establishment	Fertilization	Crop protection	Irrigation	Labor	Costs	Farm characteristics
Seedling age (days)	N amount (kg ha^{-1})	Number of sprays	Fuel (l ha^{-1})	Labor hours (h)	Seed costs (Birr ha^{-1})	Distance to field (m)
Field period (days)	P_2O_5 amount (kg ha^{-1})	Amount insecticide (kg AI ha$^{-1)}$	Irrigation labor hours (hr ha^{-1})	Female labor hours (h)	Fertilizer costs (Birr ha^{-1})	Distance to paved road (m)
Seeds (g ha^{-1})	Number of N applications	Amount fungicide (kg AI ha^{-1})	Number of irrigations	Family labor hours (h)	Crop protection costs (Birr ha^{-1})	Distance to main market (m)
Plant density (number ha^{-1})	First N application (day)	spray volume (l ha^{-1})	Irrigated land % of total land	Share female labor (%)	Irrigation power costs (Birr ha^{-1})	Measured field size (ha)
	soil NH_4/NO_3 ratio	Interval fungicide application (days)		Share family labor (%)	Other costs (Birr ha^{-1})	Farmers age
	N mineral soil after harvest (kg Nmin ha^{-1})	Interval insecticide application (days)		Average wage (Birr day^{-1})	Real Labor costs (Birr ha^{-1})	Education level (years)
	EC (onion only)	Day of first spray (Day after planting)		Number of permanent labor	Total costs (Birr ha^{-1})	Experience of grower (years)
	SAR (onion only)	Day of last spray (DBH)		Permanent labor costs (birr month^{-1})		Number of cows
	pH (onion only)			Permanent labor hours (h ha^{-1})		Number of oxen
						Number of goat/sheep

Socio-economic indicators

Economic indicators are expressed using the local currency Ethiopian Birr, of which the exchange rate was approximately 23 Birr per Euro at the time of writing this report.

Gross income is the summation of the sold produce multiplied with their prices at each harvest date.

Costs of production were grouped into the costs associated with seed or seedlings, fertilizers, crop protection, energy (for irrigation) and others. These costs only include material costs and no labor costs.

Since the input of family labor in the production may obscure profit calculations, profit was calculated in two ways. First, *actual* profit was calculated based on the gross income minus non-labor costs and the costs for hired labor (actual labor input). Second, *real* profit was calculated in which all labor input including family labor is accounted for using the average wage paid to hired labor (real labor input). Actual profit is always higher than real profit; the former provides the financial returns to family labor, while the latter profit takes into account the opportunity cost of family labor.

Total labor requirements were calculated, while also the share of family labor and female labor was calculated. Family labor comprised the time worked by all family members. Female labor includes labor provided by hired female labor as well as labor of female household members.

The cost price consists of total costs based on real labor input divided by the marketable yield, and it gives an indication of the economic efficiency of production. In addition, labor productivity is calculated, i.e. the actual profit divided by the total labor input while assuming 8 hours per labor day.

3.2 Main characteristics of farmers

Farmers in both districts were on average 34.4 years old (Table 3.3). Farmers in Dugda were on average 5 years older than the farmers in Adami Tulu Jido Kombolcha, but had on average 1.8 years less experience with horticulture. Also the educational level in Dugda was lower than in Adami Tulu Jido Kombolcha. An educational level of 8 means that the elementary school has been finished; while a level of 10 means that the first two years of secondary school have been finished.

The average household comprises of 5.3 persons of which 2.4 were 18 years or older. Households comprised on average 2.9 male family members and 2.4 females. Household composition did not much differ between both districts.

Table 3.3. Average age, educational level and years of experience with horticulture and number of household (hh) members of participating farmers.

Household characteristic	Adami Tulu Jido Kombolcha	Dugda	Mean
Age	31.8	36.6	34.4
Maximum education level	8.3	6.8	7.5
Years of horticultural experience	6.6	4.8	5.7
Number of male hh members 18 years or older	1.8	1.3	1.5
Number of male hh members <18 years	1.3	1.5	1.4
Number of female hh member 18 years or older	1.2	0.9	1.1
Number of female hh members < 18 years	1.4	1.5	1.5
Total hh members	5.7	5.3	5.5

Fields were often not located near the homestead or house of farmers (Table 3.4) as in both districts most of the farmers live in cities or villages near the main road. On average farmers have to travel 2.9 km to their fields. Farmers in Adami Tulu Jido Kombolcha travel a bit less than their colleagues in Dugda. The most extreme case is a farmer whose plot is 11.1 km from his house. Transport is mostly done by foot in Adami Tulu Jido Kombolcha, in Dugda it is done by bicycle or (rental) cart. Only few farmers own a motorbike or horse. Fields in Adami Tulu Jido Kombolcha are closer to paved roads than those in Dugda. The nearest market for farmers in Adami Tulu Jido Kombolcha is Ziway while this is Meki for farmers in Dugda. Farmers in Dugda are closer to their market on average 6.8 km, while farmers in Adami Tulu Jido Kombolcha are more than 10 km away from their market.

Fields were on average 0.43 ha, in Dugda they were on average twice as large as those in Adami Tulu Jido Kombolcha. Remarkable is the inaccurate knowledge of farmers of the size of their fields. GPS measurements of the plots indicated that they are on average 27% different from the information of farmers, and in one extreme case the plot was even 212% larger. There is no systematic over or underestimation of the plot size, 15 farmers underestimated the size of their plot, while 17 farmers overestimated the size. Similar differences between farmers estimate and measurement of plots have been observed in two smallholder irrigation schemes (Paas, 2010), and this phenomena seems, therefore, wide spread.

Table 3.4. Distance from the field to the farm, nearest paved road and nearest main market and measured field size with GPS and difference with farmers estimate in Adami Jido Kombolcha, Dugda and the mean of both districts.

	Adami Tulu Jido Kombolcha				Dugda		
	Mean	Average	Minimum	Maximum	Average	Minimum	Maximum
Distance farm to field (km)	3.1	3.0	1.3	6.9	3.1	0.3	11.1
Distance plot to nearest paved road (km)	3.8	1.8	0.1	5.6	3.0	0.1	8.3
Distance plot to nearest main market (km)	8.4	10.2	5.1	30.0	6.8	2.4	11.5
Measured field size (ha)	0.43	0.27	0.08	0.51	0.57	0.21	1.04
Difference with farmers estimate (%)	26.4	33.1	0.0	212.5	20.8	2.5	56.3

Land holdings of farmers in Adami Tulu Jido Kombolcha are a bit larger then in Dugda, while latter farmers also rent less land (Table 3.5). In contrast, livestock holdings of Dugda farmers are larger than in Adami Tulu Jido Kombolcha. The highest costs for rented land and permanent staff are in Dugda suggesting tighter rental land and labor markets in this district. Based on the total land holding (own and rented land), the percentage land under irrigation per farm is on average 33 and 52% in Adami Tulu Jido Kombolcha and Dugda, respectively, suggesting greater horticultural specialization in Dugda.

Table 3.5. Farm characteristics of selected farmers in terms of land use, animals and permanent labor use in Adami Tulu Jido Kombolcha, Dugda and the mean of both districts.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Own land (ha)	3.2	2.1	2.6
Rented land (ha)	2.1	1.7	1.9
Renting fee (birr ha-1)	2,764	3,583	3,284
Number of cows	9.2	11.4	10.3
Number of goat/sheep	1.9	11.4	6.8
Number of oxen	0.6	3.6	2.3
Number of permanent labor staff	1.9	3.7	2.8
Average wage of permanent labor staff (birr hr-1)	2.5	4.0	3.4
Percentage of land under irrigation (%)	33.4	51.5	43.6

Irrigation farmers are either operating in a scheme where the irrigation infrastructure is a joint operation or they irrigate their fields on individual basis (Table 3.6). When operating individually, farmers mostly pump water from a river, i.e. the Meki or Bulbula River, or from Lake Ziway. A third method is by digging a borehole and using groundwater for irrigation. In Adami Tulu Jido Kombolcha the predominant irrigation system is the scheme, while in Meki individual irrigation systems using water from boreholes and the Meki River are the predominant systems.

Table 3.6. Irrigation systems for the recorded fields and percentage of land per farm under irrigation. Percentage of land per farm under irrigation per crop and district and separated per irrigation source.

	Onion	Tomato	Mean
Adami Tulu Jido Kombolcha mean	34.5	32.6	34.5
Individual - Bulbula River	22.2	8.9	22.2
Individual - Lake Ziway	25.6	36.3	25.6
Irrigation scheme	82.4	60.7	82.4
Dugda mean	54.5	48.4	51.6
Individual - Borehole	53.8	57.7	55.6
Individual - Meki River	64.3	40.0	56.2
Individual - Lake Ziway	-	27.6	27.6
Irrigation scheme	40.0	21.9	30.9
Mean	47.0	40.5	43.6

3.3 Agronomic results

3.3.1 Crop yields

Farmers in Adami Tulu Jido Kombolcha had on average higher onion yields but lower tomato yields than farmers in Dugda. Onion yields in Adami Tulu Jido Kombolcha were on average 30% higher and tomato yields 50% lower than in Dugda. In Adami Tulu Jido Kombolcha, lowest yields for both onion and tomato are observed in Halaku, highest tomato yields in Dodicha (27.5 t ha^{-1}) and highest onion yields in Edo Kejela (37 t ha^{-1}). In Dugda, lowest yields for both onion and tomato are observed in Graba Korke Adi with respectively 15.1 t ha^{-1} and 23.2 t ha^{-1}. Burka Denbel and Welda Kelina showed the highest onion yields in Dugda with 21 t ha^{-1} and Burka Denbel and Derara Dalecha showed the highest tomato yields with respectively 41 and 42 t ha^{-1}. The average onion and tomato yields of all fields were 21.5 and 25.5 t ha^{-1}, respectively.

Table 3.7. Yield of onion and tomato per district and community (kg ha^{-1}).

	Onion	Tomato
Adami Tulu Jido Kombolcha	26,188	16,442
Desta Abijate	-	13,289
Dodicha	24,172	27,534
Edo Kejela	37,280	17,125
Halaku	12,130	9,941
Lilika Choleme	30,164	12,745
Dugda	18,551	33,699
Bekele Grisa	17,331	31,046
Burka Denbel/Debrabge	20,786	41,080
Derara Dalecha	18,140	42,126
Graba Korke Adi	15,052	23,198
Welda Kelina	21,446	31,047
Mean of both districts	21,696	25,525

3.3.2 Crop calendar and cropping period

Onion

For onion, the period of sowing, planting and harvesting was almost similar in Adami Tulu Jido Kombolcha and Dugda (Figure 3.2). Sowing was from the end of November till early February, transplanting from the end of January till mid-April while the harvest period was from the end of April till the end of July.

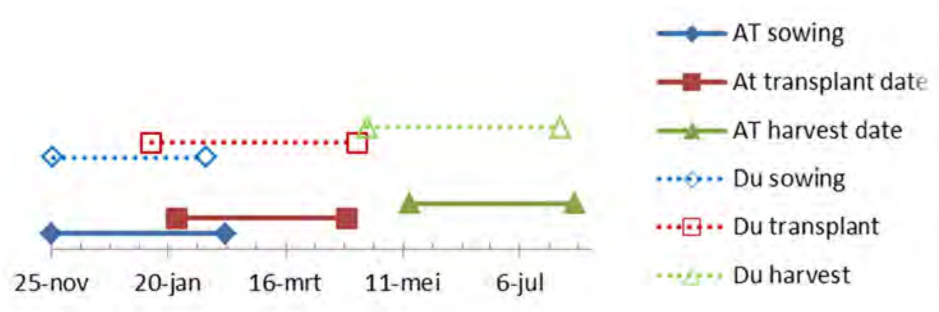


Figure 3.2. Sowing, transplant and harvest period of onion in Adami Tulu Jido Kombolcha (AT) and Dugda (Du).

The time from sowing till transplanting of onion was on average about two months (Table 3.8). Between Adami Tulu Jido Kombolcha and Dugda was a week difference in the transplant period. In both districts were large differences among farmers, i.e. about a month between the shortest and longest transplant period. The longer the transplant period the more labor is required for care and irrigation of the seedlings. The time from transplanting till harvest (field period) was on average 96 days and was for both districts the same. In Adami Tulu Jido Kombolcha the difference between the shortest and longest period was smaller than in Dugda where the difference was 40 days.

Table 3.8. Number of days from sowing till transplanting (transplant period), transplanting till the last harvest (field period) and from sowing till the last harvest (crop period) for onion in Adami Tulu Jido Kombolcha and Dugda.

		Adami Tulu Jido Kombolcha			Dugda		
	Mean	Average	Minimum	Maximum	Average	Minimum	Maximum
Transplant period	65	68	58	83	61	40	72
Field period	96	95	88	111	96	80	122
Crop period	160	164	155	172	156	141	169

Tomato

Tomato cultivation by farmers in Dugda started somewhat later than in Adami Tulu Jido Kombolcha (Figure 3.3). Sowing in Adami Tulu Jido Kombolcha was from half January till early March while in Dugda it was from the end of January till early April. Due to a slightly shorter transplant period, the difference in transplanting date between the both districts was smaller. Nevertheless, differences in transplanting dates resulted also in a later harvest period in Dugda (half of July till early September) compared to Adami Tulu Jido Kombolcha (June till the end of July).

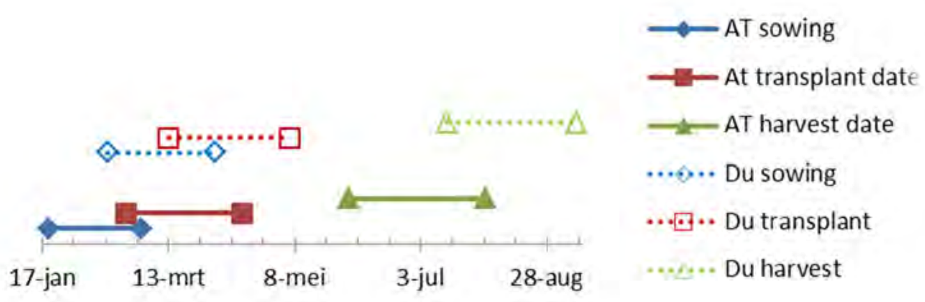


Figure 3.3. *Sowing, transplant and harvest periods of tomato in Adami Tulu Jido Kombolcha (AT) and Dugda (Du).*

The transplant period was about 37 days and similar in both districts (Table 3.9). In Adami Tulu Jido Kombolcha the transplant period varied between 25 and 65 days, in Dugda it varied between 27 and 52 days. In Adami Tulu Jido Kombolcha the field and crop period were about 5 days longer than in Dugda.

Table 3.9. *Number of days from sowing till transplanting (transplant period), transplanting till the last harvest (field period) and from sowing till the last harvest (crop period) for tomato in Adami Tulu Jido Kombolcha and Dugda.*

		Adami Tulu Jido Kombolcha			Dugda		
	Mean	Average	Minimum	Maximum	Average	Minimum	Maximum
Transplant period	37	38	25	65	36	27	52
Field period	116	111	93	126	122	105	139
Crop period	153	149	124	185	158	142	170

3.3.3 Planting material and densities

Almost all farmers used locally multiplied (open pollinated) seeds, either multiplied by themselves or neighbor farmers or purchased in local shops or market places. See Stallen *et al.* (2012) for more information on horticulture seeds including the prices of improved varieties.

Soils in Adami Tulu Jido Kombolcha are sandier than in Dugda, which may be a reason that plant densities in the former are on average lower than in Dugda. Plant densities of onion in Dugda are even twice as high as in Adami Tulu Jido Kombolcha (Table 3.10). Plant densities of tomato seem to increase with the clay content of soils in Dugda. On clay-silt soils the plant density of tomatoes is about 5,000 higher than on sandy-loam soils, i.e. about 8% more plants compared to the average plant density of tomatoes.

Table 3.10. Soil type and plant density (plants ha^{-1}) per district per crop.

	Onion	Tomato
Adami Tulu Jido Kombolcha		
Sand		44,444
Sandy loam	550,476	53,968
Dugda		
Clay silt	1,074,074	71,970
Loam		68,519
Sandy loam	1,210,648	66,579
Mean	972,381	59,645

3.3.4 Nutrient management

Onion

Use of fertilizers in onion is restricted to Di-ammonium Phosphate (DAP containing 18% nitrogen and 46% phosphorus) and Urea (46% nitrogen). Nitrogen use is considerable higher in Dugda (242 kg ha^{-1}) than in Adami Tulu Jido Kombolcha (162 kg ha^{-1}) (Table 3.11). In Adami Tulu Jido Kombolcha the applied nitrogen varied between 120 and 275 kg ha^{-1}, which seems in line with onion crop demand. In Dugda, however, applications ranged from 72 to 420 kg ha^{-1}. As a result of the high nitrogen application rates and low yields in Dugda (Table 3.7) nitrogen efficiency, i.e. kg onion per kg applied N, was less than half of that in Adami Tulu Jido Kombolcha. Phosphorus use was higher in Adami Tulu Jido Kombolcha than in Dugda, but in both districts variation in DAP use is large.

Table 3.11. Use of N and P_2O_5 in onion, nitrogen efficiency, total number of applications with nitrogen fertilizer, and first day of N application after transplanting in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Applied N (kg ha^{-1})	162	242	209
Minimum use	120	72	
Maximum use	275	420	
N efficiency (kg onion per kg N)	183	87	127
Total number of N applications	2.7	2.5	2.6
First N application (days after transplanting)	14.9	17.3	16.3
P_2O_5 (kg ha^{-1})	144	125	132
Minimum use	0	0	
Maximum use	316	197	

Associated with the high nitrogen application the mineral soil nitrogen content after harvest (residual soil N) was high with 828 kg nitrogen per hectare in Dugda, but also in Adami Tulu Jido Kombolcha residual nitrogen was high with 776 kg ha^{-1} (Table 3.12). In both cases, residual nitrogen contained a high amount of ammonium nitrogen, i.e. on average 45 times higher than the amount of nitrate nitrogen in Adami Tulu Jido Kombolcha and 119 times higher in Dugda. The reason for these peculiar residual soil nitrogen contents (i.e. extreme high ammonium content) remains unclear.

Table 3.12. Yields, applied fertilizer nitrogen, residual soil nitrogen in 0.2 m soil layer and nitrogen ammonium-nitrate ratio in the residual soil nitrogen in onion fields of Adami Tulu Jido Kombolcha and Dugda.

	Yield (kg ha^{-1})	Applied N (kg ha^{-1})	N-min (kg ha^{-1})	$N\text{-}NH_4/N\text{-}NO_3$ ratio
Adami Tulu Jido Kombolcha	26,188	162	776	45
Dugda	18,551	242	828	119
Mean	21,696	209	807	88

Tomato
As in onion, DAP and Urea are the predominant nutrient sources in tomato. Only one farmer applied potassium fertilizer and one farmer applied 2.8 t manure ha^{-1}. Potassium was applied as K_2O fertilizer (35% K_2O) at a rate of 38 kg ha^{-1}. Potassium fertilizer is relatively expensive (26 Birr kg^{-1}) compared to Urea and DAP, which cost about 14 and 16 Birr kg^{-1}, respectively.

In Dugda nitrogen use was higher than Adami Tulu Jido Kombolcha (3.13). Nitrogen rates in tomato (155 kg N ha^{-1}) were on average lower than in onion (209 kg N ha^{-1}). Associated with the higher N rates in Dugda tomato yields were almost twice as high as in Adami Tulu Jido Kombolcha. Because of the higher yields nitrogen efficiency in Dugda was considerable higher than in Adami Tulu Jido Kombolcha. The frequency of nitrogen applications was much higher in Dugda which may be related to the higher overall nitrogen application. The first nitrogen application was approximately 10 days after transplanting of tomato seedlings in both districts.

Table 3.13. Use of N and P_2O_5 in tomato, nitrogen efficiency, total number of applications with nitrogen fertilizer, and first day of N application after transplanting in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Applied N (kg ha^{-1})	120	186	155
lowest use	47	77	
highest use	219	405	
N efficiency (kg tomato per kg N)	164	226	197
Total number of N applications	2.3	3.2	2.8
First N application (days after transplanting)	10.3	10.5	10.4
P_2O_5 (kg ha^{-1})	94	137	116
lowest use	26	34	
highest use	178	403	

Residual soil content was very high in tomato, twice as high as in onion, while fertilizer N rates were considerably lower in tomato (Table 3.14). As in onion very high nitrogen ammonium-nitrate ratios were observed in the tomato plots after harvest.

Table 3.14. Yields, applied fertilizer nitrogen, residual soil nitrogen and nitrogen in 0.25 m soil layer ammonium-nitrate ratio in the residual soil nitrogen in tomato fields of Adami Tulu Jido Kombolcha and Dugda.

	Yield (kg ha^{-1})	Applied N (kg ha^{-1})	N-min (kg ha^{-1})	N-NH_4/N-NO_3 ratio
Adami Tulu Jido Kombolcha	16,442	120	2,195	722
Dugda	33,699	186	1,834	388
Mean	25,525	155	2,060	596

3.3.5 Water management

Onion

Labor requirements for irrigation are relatively high compared to other activities (section 3.4.3), but it is more evenly distributed over the entire field period than most other activities, which are generally more constrained to short periods.

The share of irrigation labor input in total labor requirements in onion was about 9% (Table 3.15). Energy costs associated with irrigation varied between 0.2 and 0.5 Birr kg^{-1} in Adami Tulu Jido Kombolcha and Dugda, respectively. Despite the higher frequency of irrigation in Adami Tulu Jido Kombolcha, the costs per unit produce were lower because of the higher yields in Adami Tulu Jido Kombolcha.

Table 3.15. Labor requirements for irrigation in onion, its share in total labor requirements, energy costs for irrigation, number of irrigation events, and fuel or electricity use for irrigation in Adami Tulu Jido Kombolcha and Dugda.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Irrigation labor (hr ha^{-1})	374	320	343
Irrigation labor (% of total labor requirements)	8.3	9.0	8.7
Irrigation energy cost (Birr kg^{-1} onion)	0.2	0.5	0.4
Number of irrigation events	18.6	14.3	16.1
Fuel for irrigation (l ha^{-1})	374	432	412
Electricity for irrigation (kW ha^{-1})	1,901		1,901

Tomato

Irrigation characteristics such as water use and crop evapotranspiration (ETc) of tomato under standard conditions (FAO, 1998) of six selected tomato plots in Dugda are shown in Table 3.16. The irrigation window indicates the period in which the irrigation events have taken place. The irrigation frequency of the plots varied between 2.6 and 5.5 days. Because we do not have actual rainfall data during the field period it is not possible to estimate the water use efficiency accurately. Because irrigation stopped in all plots well before the last harvest, i.e. plot 6 received no irrigation during the last 48 days of its field period, there are indications that most plots received considerable amounts of rainfall.

Table 3.16. Results of water measurements in six tomato plots in Dugda.

Plot #	Irrigation system	Field period	Length of field period (days)	Irrigation events	Irrigation window	Irrigation volume (m^3 ha^{-1})	Standard ETc (m^3 ha^{-1})	Long term rainfall [a] (m^3 ha^{-1})
1	Individual	April 8 – August 3	117	32	April 10 –July 18	5,975	4,030	3,210
2	Individual	March 26 – August 4	131	16	April 2 – June 29	2,272	4,600	3,480
3	Individual	April 5 – July 22	108	25	April 1 – June 30	851	3,855	2,926
4	Scheme	March 25 – July 28	125	22	March 26 – June 24	3,487	4,350	3,220
5	Individual	March 13 – July 30	139	36	March 15 – June 18	6,817	5,000	3,530
6	Individual	April 19 – August 16	119	22	April 22 – June 29	2,974	3,900	3,390

[a] *Effective rainfall during the field period is based on long-term rainfall and using the USDA S.C. Method option in CROPWAT (2012). The effective rainfall assumes that part of the rainfall is lost through runoff and percolation, depending on the rainfall intensity.*

The share of irrigation labor in total labor requirements in tomato varied between 10% in Dugda and 15% in Adami Tulu Jido Kombolcha (Table 3.17). Despite the lower share of irrigation labor input in Dugda labor input related to irrigation was higher than in Adami Tulu Jido Kombolcha. The energy costs expressed per unit produce were similar in both districts with 0.3 Birr kg^{-1} tomato. As with onion, some irrigation equipment in Adami Tulu Jido Kombolcha uses electricity as energy source while all plots in Dugda rely on fuel. Remarkably is that the Dugda plots used twice as much fuel as the plots in Adami Tulu Jido Kombolcha.

Table 3.17. Labor requirements for irrigation in tomato, its share in total labor requirements, energy costs for irrigation, number of irrigation events, and fuel or electricity use for irrigation in Adami Tulu Jido Kombolcha and Dugda.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Irrigation labor (hr ha^{-1})	340	413	376
Irrigation labor (% of total labor requirements)	15.2	10.4	12.7
Irrigation energy cost (Birr kg^{-1} tomato)	0.3	0.3	0.3
Number of irrigation events	17.8	20.7	19.3
Fuel for irrigation (l ha^{-1})	273	505	409
Electricity for irrigation (kW ha^{-1})	2,939		2,939

3.3.6 Crop protection management

Onion

Crop management in onion mainly consists of the use of insecticides and fungicides, which usually are applied in combination. In Adami Tulu Jido Kombolcha, pesticides were applied on average 4.7 times, while in Dugda the frequency was higher with 6.7 times per growing season (Table 3.18).

Crop protection costs in Adami Tulu Jido Kombolcha are 0.3 Birr per kg onion due to a lower pesticide use and higher yield than in Dugda. Insecticide use in Dugda was 1.5 kg A.I. ha^{-1} higher than that in Adami Tulu Jido Kombolcha. Highest use was in Dugda with 10.1 kg A.I. ha^{-1}. Fungicide use in in Dugda was approximately 30%

higher than in Adami Tulu Jido Kombolcha. Highest use was in Dugda with 22.8 kg A.I. ha^{-1} while in Adami Tulu Jido Kombolcha it was 14.5 kg A.I. ha^{-1}.

Used water volume for applying pesticides was on average 800 l ha^{-1}, which is in line with the recommendations. In Adami Tulu Jido Kombolcha lower volumes were applied than in Dugda. The interval between pesticide applications seems high, especially for fungicides (9.4 days) because mancozeb, the predominantly used fungicide in the Central Rift Valley (Table 3.18) only is effective when it is applied before crop infection. Since most fungal diseases in onion have short cycles it is important to apply fungicides regularly. The period between the last application and harvest seems quite long (30 days) implying that the crop is not protected against fungal diseases during the last month.

Table 3.18. Crop protection costs in onion, number of pesticide applications, insecticide and fungicide use in kg active ingredient (A.I.) per hectare, volume of water used for spraying, interval between applications, first day of pesticide application after transplanting, and the last observed moment of pesticide applications before harvest in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Crop protection costs (Birr kg^{-1})	0.3	0.5	0.4
Number of pesticide applications	4.7	6.7	5.9
Insecticide use (kg A.I. ha^{-1})	5.2	6.7	6.1
Minimum	2.1	2.6	
Maximum	7.4	10.1	
Fungicide use (kg A.I. ha^{-1})	8.0	11.7	10.2
Minimum	3.2	3.9	
Maximum	14.5	22.8	
Spray volume (water l ha^{-1})	705	843	791
Interval fungicide use (days)	9.8	9.2	9.4
Interval insecticide use (days)	10.3	8.3	9.1
First spray (days after transplanting)	17.4	19.3	18.5
Shortest spray interval before harvest (days)	30.4	21.1	24.9

Almost all used fungicides are based on mancozeb sometimes complemented with metalaxyl in the formulated product (Table 3.19). Mancozeb is a preventive fungicide while metalaxyl (present in Mancolaxyl and other brand names) shows curative characteristics but is prone to resistance after prolonged use. The frequent use of metalaxyl in onion indicates that resistance of fungi may already have occurred. Curzate R contains cymoxanil and copper oxy chloride and both compound are effective in controlling mildew in onion. For that reason it is more efficient to apply Curzate than Kocide as the latter only contains Copper oxy chloride.

For the control of insects predominantly organophosphate (OP) insecticides are used such as profenophos, malathion, and dimethoate. Especially profenophos (Selecron and other brand names) is used in both Adami Tulu Jido Kombolcha and Dugda. Continuously use of OP insecticides may rapidly result in insect resistance. Endosulfan (Ethiosulfan and other brand names), which is used in Adami Tulu Jido Kombolcha, is an organochlorine insecticide that is globally phased out due to its high human toxicity. Also methomyl (Lannate), a carbamate insecticide, is highly toxic to humans and its use is restricted in many countries.

Table 3.19. Number of farmers using specific pesticides in onion in Adami Tulu Jido Kombolcha and Dugda.

	Adami Tulu Jido Kombolcha	Dugda	Total
Fungicides			
Curzate R WP		2	2
Mancozeb 80% / Ethiozeb 80% WP / Unizeb 80% WP	7	12	19
Mancolaxyl 72 WP / Matco 72 WP / Ridomil Gold MZ	4	13	17
Folicur 250 EC		1	1
Kocide 77%		1	1
Polonin	1		1
Insecticides:			
Agrothoate 40% EC		1	1
Applaud 40% SC		1	1
Ethiosulfan 35% EC / Indoselfent 35% EC / Salfane	4		4
Hilarat 5 EC	1	2	3
Lannate 90 SP		1	1
Nimbicidine 3 EC		1	1
Profit 720 EC / Selecron 720 EC	8	9	17
Prompt 100g l^{-1} EC		1	1

Tomato

The frequency of pesticide applications in tomato was considerably higher in Dugda than in Adami Tulu Jido Kombolcha, 11.5 *vs.* 4.3 times (Table 3.20). Associated with the higher use frequency, both the applied amount of insecticide and fungicide was higher in Dugda, for example, insecticide use was 7.3 kg A.I. ha^{-1} *vs* 1.8 kg A.I. ha^{-1}. In Adami Tulu Jido Kombolcha average fungicide use was three times lower than in Dugda, i.e. 4.7 kg A.I. ha^{-1} *vs.* 15.2 kg A.I. ha^{-1}. The maximum amount of fungicides applied in Dugda was 30.8 kg ha^{-1}.

Table 3.20. Crop protection costs in tomato, number of pesticide applications, insecticide and fungicide use in kg active ingredient (A.I.) per hectare, volume of water used for spraying, interval between applications, first day of pesticide application after transplanting, and the last observed moment of pesticide applications before harvest in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Crop protection costs (Birr kg^{-1})	0.3	0.4	0.4
Number of pesticide applications	4.3	11.5	8.1
Insecticide use (kg A.I. ha^{-1})	1.8	7.3	4.7
Minimum	0.3	0.1	
Maximum	4.9	27.8	
Fungicide use (kg A.I. ha^{-1})	4.7	15.2	10.3
Minimum	1.3	5.9	
Maximum	9.1	30.8	
Spray volume (water l ha^{-1})	696	1044	879.3
Interval fungicide use (days)	11.4	7.7	9.5
Interval insecticide use (days)	11.3	8.3	9.8
First spray (days after transplanting)	17.6	14.1	15.7
Shortest spray interval before harvest (days)	13.7	8.7	11.1

In tomato the difference in used water between the two districts volume was higher than in onion. In Adami Tulu Jido Kombolcha on average 700 l ha^{-1} was used while in Dugda it was more than 1000 l ha^{-1}. The spraying interval of fungicides was also high with on average 9.5 days between applications. The shortest spray interval before harvest (11 days) is much shorter than in onion (25 days) but some farmers stopped with spraying just before the first tomato harvest, which implies a much longer spray interval for the last harvest.

Because of the higher use of pesticides, pesticide costs per kg tomato were higher in Dugda (0.4 Birr kg^{-1}) then in Adami Tulu Jido Kombolcha (0.3 Birr kg^{-1}).

Common practice is to use a mix of fungicides and insecticides in tomato. As in onion, mancozeb and mancozeb with metalaxyl are the main fungicides used in tomato followed by Curzate (Table 3.21). Especially late blight (*Phytophthora infestans*) is known for its resistance against metalaxyl. In Ethiopia about 20% of the tested *P. infestans* isolates showed intermediate to complete resistance to late blight (Schiessendorfer, 2002).

In tomato, the predominantly used insecticide is endosulfan (brand name Ethiosulfan and others) followed by the pyrethroid lambda-cyhalothrin (brand name Hilarat or Karate) and Profenofos (Profit and others). These are broad spectrum insecticides with a high impact on beneficial insects as well. Highly toxic insecticides such as methomyl (Lannate) are also applied in tomato. One farmer still used the obsolete insecticide DDT.

Table 3.21. Number of farmers using specific pesticides in tomato in Adami Tulu Jido Kombolcha and Dugda.

	Adami Tulu Jido Kombolcha	Dugda	Total
Fungicides:			
Bayleton 25 WP	4	3	7
Botridion 500 SC		1	1
Curzate RWP	6	6	12
Ethiozeb 80% WP / Mancozeb 80%WP / Unizeb 80% WP	9	15	24
Fostonic 80 WP		1	1
Impulse 500 EC		1	1
Kocide 77%	2	1	3
Mancolaxyl 72 WP / Matco 72 WP / Ridomil Gold MZ /Agrolaxyl MZ 63.5 WP/ Goldstar 72 WP	6		
Noble 25 WP		3	3
Odeon 825 WG		1	1
Insecticides:			
Abalone 18 EC	1	2	3
Agro	1		1
Agro cuten	1		1
Agrothoate 40% EC / Ethiothoate 40% EC		5	5
Applaud 40% SC		1	1
DDT		1	1
Ethiodemetrine 2.5% EC		2	2
Ethiolathion 50% EC / Malathion	2	2	4
Ethiosulfan 35% EC / Indoselfent 35% EC / Thionex 35 EC	6	11	17
Ethiozinon 60% EC		1	1
Hilarat 5 EC / Karate 5 EC	4	6	10
Lannate 90 SP		1	1
Prempt 50-150 g l^{-1}		1	1
Profit 720 EC / Selecron 720 EC	2	5	7
Pyrinex 48 EC		1	1

3.3.7 Soil analysis

Table 3.22 shows the results of the soil analysis. Both Pw, which is a measure for quickly available P, and P-PAE, which is a measure of the soil P reserves have very favourable values. In the Netherlands, recommended values for Pw are 30 to 45 and for P-PAE between 1.1 and 2.1. Also the N supply is relatively high. These high values are associated with high N and P fertilizer rates in both onion (Table 3.11) and tomato (Table 3.13). The current rates are much higher than the recommended rates, which range between 73 and 105 kg N ha^{-1} and 69 and 92 kg P_2O_5 ha^{-1} depending on different information sources.

The K-HCl values are on average 7 to 10 times higher than the recommended values in the Netherlands (15-20 mg K_2O/100 g) suggesting that K supply is sufficient. However, also the Mg and especially Na concentrations are very high in the Meki-Ziway area, which may be associated with unsustainable irrigation practices. The recommended Na concentration for the Netherlands is 21-37 mg Na kg^{-1} soil, which is more than 10 times lower than found in the soils of Meki/ Ziway. High Na concentrations may result in displacement of Ca by Na from the soil matrices resulting in Ca leaching and deteriorating of the soil structure, but they also may result in various nutrient imbalances (e.g. related to K) and toxicity for sodium sensitive crops. Soil pH-KCl is relatively high with a mean of 7.5 while recommended soil pH-KCl in the Netherlands ranges between 6.6 and 7.5. Organic matter contents are relatively high associated with the characteristics of luvisols and andosols, the predominant soil types in Meki/Ziway (Table 2.1).

Table 3.22. Soil analysis results of the onion and tomato plots in Dugda and Adami Tulu Jido Kombolcha.

	unit	Average Onion	Onion – Adami Tulu	Onion - Dugda	Average Tomato	Tomato- Adami Tulu	Tomato - Dugda	Mean
Total N	mg N kg^{-1}	1,911	2,147	1,745	1,628	1,894	1,361	1,758
N supply [1)]	kg N ha^{-1} yr^{-1}	98	106	92	88	98	79	93
C	%	1.9	1.9	1.8	1.6	1.7	1.5	1.7
C/N		10.0	9.4	10.5	9.9	8.9	11.0	10.0
Pw	mg P_2O_5 l^{-1}	43	39	45	48	48	49	46
P-AL	mg P_2O_5/100 g	42	68	24	70	118	23	57
P-PAE	mg P kg^{-1}	2.4	2.6	2.2	4.6	5.7	3.5	3.6
K-HCl	mg K_2O/100 g	155	164	148	127	150	104	140
K	mg K kg^{-1}	440	447	435	350	379	320	391
Mg	mg Mg kg^{-1}	300	313	291	275	262	287	286
Na	mg Na kg^{-1}	620	491	710	330	349	311	463
pH-KCL		7.6	7.9	7.5	7.4	7.7	7.1	7.5
Organic matter	%	3.2	3.3	3.2	2.7	2.9	2.5	3.0
$CaCO_3$	%	0.91	1.91	0.21	0.78	1.37	0.19	0.84
Afslib [2)]	%	41	37	44	35	25	44	38
Lutum [3)]	%	21	19	23	18	13	22	19

[1)] *Measure for availability of mineral N after harvest.*

[2)] *Mineral parts smaller than 0.016 mm.*

[3)] *Clay particles in the top soil smaller than 2 um (< 8% sandy soil, 8-25% light clay, > 25% clay soil).*

3.3.8 Yield affecting factors

Correlations between on the one hand onion and tomato yields and measured variables associated with the production (section 3.1.3) are shown in Table 3.23. Especially factors related to fertilization, irrigation, crop protection and labor showed a positive correlation with observed yields and can be explained based on production ecological insights. But also household composition and age and experience of the farmer showed correlations with yield.

Table 3.23. Correlations of production characteristic variables with agronomic yield for onion and tomato (only shown are correlations > 0.4).

	Onion	Tomato
Seedling age		-0.55
Field period		0.86
Plant density		0.43
Fertilizer costs	0.73	0.81
Amount of P_2O_5 fertilizer	0.76	0.58
Amount of N fertilizer	0.71	0.87
Number of N applications	0.55	
First N application	-0.70	
Nmin soil after harvest		-0.48
Crop protection costs		0.69
Amount of insecticides	0.56	0.58
Amount of fungicides		0.89
Spray volume		0.67
Day of first spraying	-0.58	
Irrigation (energy) costs	0.42	0.54
Fuel use for irrigation	0.47	0.52
Irrigation labor input		0.53
Number of irrigations	0.48	
% Irrigation land (of total farm land)		0.43
Other costs	0.69	0.80
Labor costs	0.42	0.83
Total labor input	0.77	0.70
Female labor input	0.44	
Share of female labor input	0.50	
Family labor input		-0.41
Share of family labor input		-0.61
Age of farmer	-0.47	
Education level		-0.82
Male HH member < 18 yrs	-0.60	
Female HH member < 18 yrs		0.55
Total HH members		0.52
Total farm land	-0.54	-0.46
Total costs	0.55	0.76

In both crops, P_2O_5 and N rates and associated higher fertilizer costs are positively related to yield, i.e. higher rates result in higher yields, which is not surprisingly. However, in tomato a high Nmin content after harvest shows a negative correlation, which most likely is related to abundant vegetative growth resulting in a lower yield. In onion, a delay in N application (after transplanting) associates with lower yields. Also the number of N applications is positively related with higher onion yields, which could be explained by the relatively low N uptake of onion and the higher risk of leaching losses compared to tomato. Therefore, nitrogen management seems to be more critical than in tomato.

Crop protection costs are positively correlated with yield in tomato. In both crops a higher use of insecticides is positively correlated with yield, but only in tomato a higher fungicide use is positively correlated. Also the use of higher spray volumes in tomato is positively correlated with higher yields. With the current technique of knap sack spraying high water volumes are required to obtain a good coverage. However, with higher volumes also higher quantities of pesticides are required and improvement in spraying technique seems to be necessary to reduce pesticide use while still protecting the crop. The risk of quality loss in tomato is higher than in onion because of the vulnerability of tomato fruits to pests and diseases. Therefore, pesticide management in tomato is more important than in onion. In onion it is necessary to start as soon as possible with a spraying schedule to prevent diseases since the timing of the first spraying is negatively correlated with the yield.

Correlation of variables on irrigation management showed that more fuel (and associated higher costs) was positively related with yields of both onion and tomato. In onion the number of irrigations carried out was positively correlated with yield. Onions are probably more sensitive to water stress and a more frequent irrigation can prevent temporary drought conditions that lower yield. In tomato, irrigation labor and duration was positively correlated with yield. However, correlation coefficients of irrigation variables were much lower than for crop protection and especially nutrient management variables indicating the lower impact on yield.

In tomato, older seedling age correlated negatively with final yield. Roots of old seedlings are larger and will be more damaged during transplanting while also the larger leave apparatus will be more affected. Optimizing the seedling age at transplanting as well as the transplanting operation may reduce the transplanting shock and result in higher yields. Higher plant densities and the length of the field period (longer) are positively correlated with yield. Obviously, the length of the growing period is positively related with yield as more dry matter can be produced if the crop remains green and healthy.

Labor costs and input are positively correlated with yield. In onion cultivation more labor is done by female labor and consequently a higher share of female labor in the total labor was positively correlated with yield. Female labor is mostly used for weeding and cultivation of onion beds and might therefore have a positive effect on yield. Remarkably, a higher share of family labor in tomato cultivation was negatively correlated with yield. No explanation can be given for that.

The age of the farmers and, surprisingly also the level of education showed a negative correlation with onion and tomato yields, respectively. Because these correlations are only observed for one crop, results may be biased because of the small sample size. Also the family household composition shows various correlations with yield, which are not always easy to explain at first sight.

Yield of both onion and tomato were negatively correlated with the total cultivated land by the famer, which may be caused by the need of famers with much land to divert attention to other activities.

Other costs involve fees for renting tractors and ox ploughs but also costs of stakes. A higher investment in these items is positively correlated with yield.

3.4 Socio-economic results

3.4.1 Gross income and market prices

Onion

Marketed onion yield in Adami Tulu Jido Kombolcha was about 7 t ha^{-1} higher than in Dugda and also the average farm gate price was 0.8 Birr kg^{-1} higher than in Dugda (Table 3.24). These factors combined resulted in a 35% higher gross income in Adami Tulu Jido Kombolcha. However, gross income in Adami Tulu Jido Kombolcha varied much more than in Dugda, minimum gross income was six times as low as the maximum gross income, while in Dugda minima and maxima varied up to only four times.

Table 3.24. Marketed yield (mean, minimum and maximum in kg ha^{-1}), farm gate price (mean, minimum and maximum in birr kg^{-1}) and gross income (mean, minimum and maximum in Birr ha^{-1}) for onion in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Marketed yield (kg ha^{-1})	24,843	17,340	20,429
Minimum	9,445	9,076	
Maximum	57,438	25,600	
Farm gate price (Birr kg^{-1})	8.2	7.4	7.7
Minimum	7.5	4.8	
Maximum	9.0	8.8	
Gross income (Birr ha^{-1})	202,077	130,582	160,021
Minimum	70,838	45,379	
Maximum	459,500	225,280	

Farm gate prices showed a considerable variation over a relatively short period, they varied between 5 and 9 Birr kg^{-1} in de period May-July (Figure 3.4).

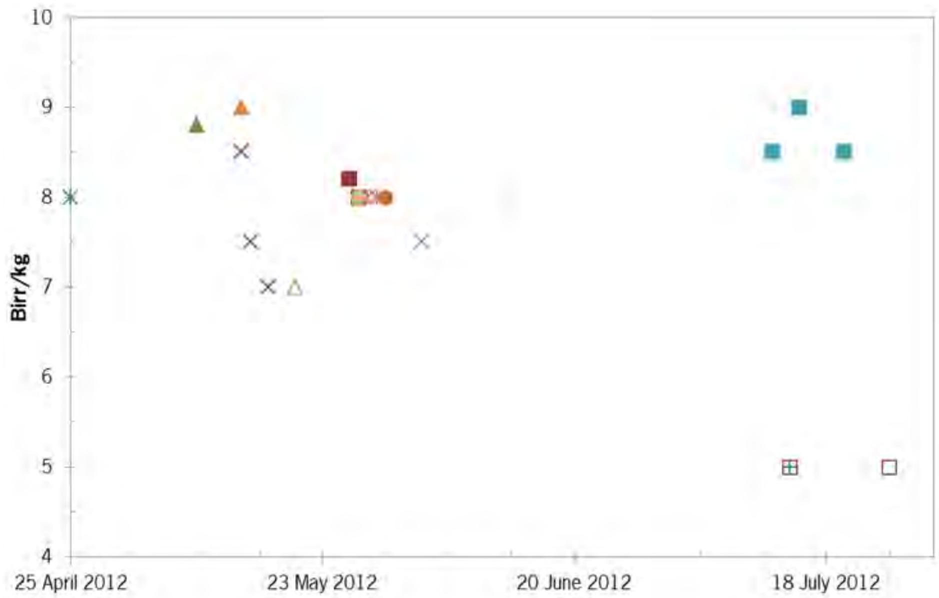


Figure 3.4. Farm gate prices of onion in Dugda and Adami Tulu Jido Kombolcha during May-July, 2012.

Tomato
Average prices, but especially yields of tomato were much higher in Dugda than in Adami Tulu Jido Kombolcha resulting in a gross income that was on average more than twice as high as in Adami Tulu Jido Kombolcha (Table 3.25). In general, differences between minimum and maximum gross incomes were larger than in onion: In Adami Tulu Jido Kombolcha there was a ten times difference, while in Dugda it was only six times.

Table 3.25. Marketed yield (mean, minimum and maximum in kg ha^{-1}), farm gate price (mean, minimum and maximum in birr kg^{-1}) and gross income (mean, minimum and maximum in Birr ha^{-1}) for tomato in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Marketed yield (kg ha^{-1})	16,335	31,563	24,350
Minimum	5,900	15,871	
Maximum	28,704	50,208	
Farm gate price (Birr kg^{-1})	3.6	4.6	4.1
Minimum	1.7	3.3	
Maximum	6.9	6.4	
Gross income (Birr ha^{-1})	62,141	149,619	108,182
Minimum	18,857	53,478	
Maximum	183,195	319,684	

Farm gate prices of tomatoes fluctuated more than those of onion, i.e. from 1.7 to 6.9 Birr kg^{-1}, but these prices covered a longer period April to September (Figure 3.5).

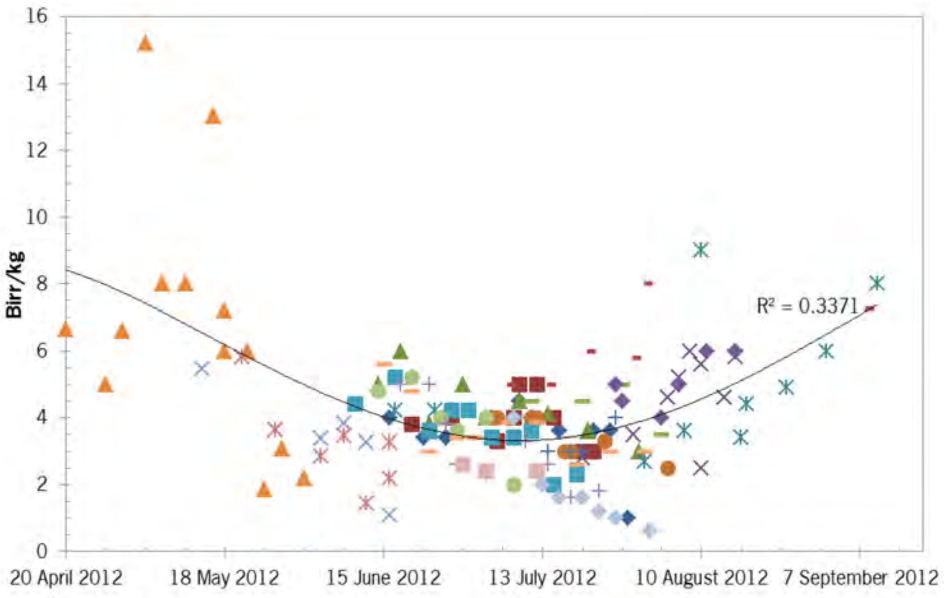


Figure 3.5. Farm gate prices of tomato in Dugda and Adami Tulu Jido Kombolcha during April-September, 2012.

3.4.2 Production costs and crop profit

Onion

Profits of onion in Adami Tulu Jido Kombolcha were higher than in Dugda mainly because of higher gross income as the production costs were not much different, i.e. 48,779 Birr ha^{-1} in Adami Tulu Jido Kombolcha and 51,385 Birr ha^{-1} in Dugda (Table 3.26).

Remarkable is the large variation in costs among the different cultivation components, for example, irrigation costs differ up to seven times across farmers (Table 3.26). The high variation in seed/seedling costs is caused by a failure of seedbed of some farmers, which had to buy seedlings. Other differences such as for pesticides and fertilizers are related to the different input use among farmers.

Table 3.26. Gross income, costs components and profit (mean, minimum and maximum in Birr ha^{-1}) of onion in Dugda and Adami Tulu Jido Kombolcha. Note that the minimum and maximum cost components not necessarily count up to total minimum and maximum costs as they relate to different plots.

	Adami Tulu Jido Kombolcha			Dugda		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Gross income (A)	202,077	70,838	459,500	130,582	45,379	225,280
Cost components:						
Seed/seedlings	5,693	1,800	10,688	6,815	2,564	15,300
Fertilizer	7,242	3,038	11,659	8,948	1,861	14,408
Crop protection	6,399	3,753	15,025	8,745	3,912	13,684
Irrigation (energy)	5,447	1,776	12,713	8,452	916	16,462
Other	2,343	692	5,943	1,173	120	2,072
Actual labor input	<u>21,655</u>	8,797	55,100	<u>17,252</u>	10,361	24,369
100% hired labor input	<u>25,363</u>	11,188	55,100	<u>17,847</u>	10,361	26,526
Total actual costs (B)	48,779	31,926	104,001	51,385	26,901	67,351
Total real costs (C)	52,487	34,317	104,001	51,980	26,901	67,351
Actual profit (A-B)	153,298	34,522	355,499	79,197	10,975	164,096
Real profit (A-C)	149,590	31,226	355,499	78,602	10,809	164,096

Real profit hardly differs from actual profit as most labor was provided by wage labor in practice, especially in Dugda. In both districts relatively little family labor is involved in onion production.

Tomato

In Dugda average actual profits (83,489 Birr ha^{-1}) from tomato are twice as high as in Adami Tulu Jido Kombolcha (37,798 Birr ha^{-1}), despite that associated production costs in Dugda are twice as high (Table 3.27). The difference in profit is mainly caused by a difference in gross income, which already was on average twice as high in Dugda.

Because more family labor was used in Adami Tulu Jido Kombolcha real costs are higher than in Dugda and the differences in real profits between both districts is a bit larger than in actual profits.

Table 3.27. Income, costs component and crop profit (mean, minimum and maximum in Birr ha^{-1}) of tomato in Dugda and Adami Tulu Jido Kombolcha. Note that the minimum and maximum cost components not necessarily count up to total minimum and maximum costs as they relate to different plots.

	Adami Tulu Jido Kombolcha			Dugda		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Gross income (A)	72,313	18,857	183,195	149,619	53,478	319,684
Cost component:						
Seed	1,124	476	4,000	2,695	543	12,594
Fertilizer	4,996	1,136	8,632	8,050	3,015	19,417
Crop protection	4,619	1,632	8,510	13,473	3,353	38,986
Irrigation (energy)	4,643	2,241	6,230	10,244	1,947	31,430
Other	2,873	95	7,911	10,099	1,816	15,548
Actual labor input	6,652	2,024	14,150	21,569	11,003	43,302
Real labor input	10,962	5,884	21,518	21,902	11,109	43,302
Total actual costs (B)	34,343	11,762	34,790	66,130	25,277	149,080
Total real costs (C)	28,654	15,836	37,864	66,463	25,383	149,080
Actual profit (A-B)	37,798	-7,390	159,804	83,489	6,486	251,088
Real profit (A-C)	33,487	-7,784	145,331	83,156	6,170	248,677

Onion and tomato

The cost components and their share in the total actual costs for onion and tomato are shown in 3.28. Total costs differ less than 10% between onion and tomato, and labor is the most important cost component in both crops, up to 38% of the total costs in onion and 31% in tomato. Seed/seedling costs in tomato are lower than in onion, in contrast with the costs for crop protection and other costs.

Table 3.28. Mean costs per component (Birr ha^{-1}) and share of cost components in actual total costs in onion and tomato in Dugda and Adami Tulu Jido Kombolcha.

	Onion		Tomato	
Costs:	Mean (Birr ha^{-1})	Share (%)	Mean (Birr ha^{-1})	Share (%)
Seed/seedling	6,353	13	2,134	5
Fertilizers	8,245	16	6,612	14
Crop protection	7,779	15	9,144	20
Irrigation (energy)	7,215	14	7,595	16
Other	1,655	3	6,348	14
Labor	19,065	38	14,503	31
Total	50,312	100	46,336	100

Because of the importance of labor in the total cost structure the following section analyses labor requirements in more detail.

3.4.3 Labor input

Onion

Onions in Adami Tulu Jido Kombolcha required considerable more labor than in Dugda, approximately 1,300 hours (Table 3.29). The share of labor provided by women in the total labor requirements is about 40 to 45%. As indicated in the previous section 3.4.2 more family labor was used in Adami Tulu Jido Kombolcha than in Dugda where only 3% of all labor was provided by the farmer or his family members. Average wages for hired labor was for both locations the same with 5.1 Birr hr^{-1} and ranged from 4 to 6 Birr hr^{-1}.

Table 3.29. Total labor input, labor provided by women, labor provided by family and average wages for hired labor in onion in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Total labor (hr ha^{-1})	4,963	3,613	4,169
Female labor (hr ha^{-1})	1,895	1,608	1,726
Share female labor in total labor (%)	40	45	41
Family labor (hr ha^{-1})	825	121	411
Share of family labor in total labor (%)	16	3	10
Average wages (Birr hr^{-1})	5.1	5.1	5.1
Minimum	3.9	4.0	3.9
Maximum	6.2	6.1	6.2

Table 3.30 shows the gender division of labor across the different field activities in onion in both districts. In Adami Tulu Jido Kombolcha women provided most labor at harvest and transplanting, while in Dugda it was at weeding and fertilization and transplanting, while no women were involved in the harvesting operations.

Table 3.30. Gender division of labor per activity in onion cultivation in Dugda and Adami Tulu Jido Kombolcha (% of total labor).

	Adami Tulu Jido Kombolcha		Dugda	
	Male	Female	Male	Female
Weeding/cultivation/fertilization	12	5	8	29
Crop protection	3	0	3	0
Harvest	8	16	18	0
Irrigation	7	0	8	0
Land preparation/ploughing	8	0	7	0
Crop maintenance	0	4	1	0
Field maintenance	13	4	2	0
Nursery activities	4	1	5	1
Transplanting	6	9	3	14
Total	60	40	56	44

Tomato

Tomatoes in Adami Tulu Jido Kombolcha required considerable less labor than in Dugda, approximately 1,500 hours (Table 3.31). On average, labor input in tomatoes is approximately 700 hr ha^{-1} lower than in onions.

Remarkably is the difference in the female labor between Dugda and Adami Tulu Jido Kombolcha. In the latter district 31% of labor input was provided by women while this was only 3% in Dugda. The same divergence is observed in the share of family labor, which is much higher in Adami Tulu Jido Kombolcha (36%) compared to only 2% in Dugda. Average wage rate in Dugda was with 5.4 Birr hr^{-1} 20% higher than in Adami Tulu Jido Kombolcha. Wages are paid either per hour of per completed activity; for example, harvesting can be paid per crate but also per hour. Because labor input both in physical and economic terms were recorded the different approaches can be compared.

Table 3.31. Total labor input, labor provided by females, labor provided by family and average wages for hired labor in tomato in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Total labor (hr ha^{-1})	2,698	4,214	3,496
Female labor (hr ha^{-1})	1,064	190	604
Share of female labor in total labor (%)	31	3	17
Family labor (hr ha^{-1})	1,103	64	556
Share of family labor in total labor (%)	36	2	16
Average wages (Birr hr^{-1})	4.5	5.4	5.0
Minimum	2.2	4.4	2.2
Maximum	6.5	7.7	7.7

The further sub-division of total labor across the different cultivation components is shown in Table 3.32. Field management includes the maintenance of furrows, field inspection and guarding, while crop management mainly relates to the binding of the tomato crop to sticks. Since sticks are hardly used in Adami Tulu Jido Kombolcha labor input was very low compared to Dugda for this activity. In contrast, labor input for field maintenance was much higher in Adami Tulu Jido Kombolcha.

Table 3.32. Labor input (hour ha^{-1} and % of total labor input) in different tomato activities in Adami Tulu Jido Kombolcha and Dugda.

	Adami Tulu Jido Kombolcha		Dugda	
	Average	%	Average	%
Nursery activities	77	3	68	2
Transplanting	177	7	93	2
Land preparation/ploughing	141	5	177	4
Weeding/cultivation/fertilization	240	9	651	15
Crop protection	89	3	266	6
Irrigation	345	13	418	10
Crop maintenance	88	3	1445	34
Field maintenance	649	24	59	1
Harvest	892	33	1101	26
Total	2698	100	4278	100

Table 3.33 shows the gender division of labor across the different field activities in tomato in both districts. In Adami Tulu Jido Kombolcha, female labor was especially used during harvest and for field maintenance.

Table 3.33. Gender division of labor per activity in tomato cultivation in Dugda and Adami Tulu Jido Kombolcha (% of total labor).

	Adami Tulu Jido Kombolcha		Dugda	
	Male	Female	Male	Female
Weeding/cultivation/fertilization	9	0	12	3
Crop protection	3	0	6	0
Harvest	8	25	26	0
Irrigation	12	0	10	0
Land preparation/plowing	5	0	4	0
Crop maintenance	5	0	34	0
Field maintenance	12	12	1	0
Nursery activities	3	0	2	0
Transplanting	5	2	1	2
Total	61	39	96	4

3.4.4 Cost price and labor productivity

Onion

The average size of onion fields was larger in Dugda (0.41 ha) than in Adami Tulu Jido Kombolcha (0.28 ha). Average cost price was higher in Dugda than in Adami Tulu Jido Kombolcha mainly because of the lower marketable yield in Dugda (Table 3.34). Labor productivity was about one third higher in Adami Tulu Jido Kombolcha because of higher profits. Despite differences in marketable yield, profit per plot was similar in both districts because of the larger field size in Dugda. In general, cost-benefit ratios were more favorable in Adami Tulu Jido Kombolcha (0.28) than in Dugda (0.45); this means that each invested Birr in onion production gave a return of 3.6 Birr in Adami Tulu Jido Kombolcha and 2.2 Birr in Dugda.

Table 3.34. Average field size, cost price, profit, and labor productivity of onion in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Average field size (ha)	0.28	0.41	0.36
Average cost price (Birr kg^{-1})	2.4	3.2	2.8
Minimum	1.7	1.3	1.3
Maximum	4.2	4.6	4.6
Cost-benefit ratio	0.28	0.45	0.38
Actual profit (Birr ha^{-1})	153,298	79,197	109,709
Average labor productivity (Birr ha^{-1} day^{-1})	247	175	210
Actual profit per plot (Birr $plot^{-1}$)	34,910	34,287	34,544

Tomato

The average size of tomato fields was larger in Dugda (0.73 ha) than in Adami Tulu Jido Kombolcha (0.27 ha). The difference in average cost price between both districts was much smaller than with onion, only 10% (Table 3.35). The higher profits in Dugda more than compensated the higher labor input (3.32) in the labor productivity, which was about 30% lower in Adami Tulu Jido Kombolcha. The profit per plot in Adami Tulu Jido Kombolcha (9,299 Birr) was meager compared to Dugda (60,562 Birr). In general, cost-benefit ratios were less favorable in Adami Tulu Jido Kombolcha (0.56) than in Dugda (0.51); this means that each invested Birr in tomato production gave a return of 1.8 Birr in Adami Tulu Jido Kombolcha and 2.0 Birr in Dugda.

Table 3.35. Average field size, cost price, profit, and labor productivity of tomato in Dugda and Adami Tulu Jido Kombolcha.

	Adami Tulu Jido Kombolcha	Dugda	Mean
Average field size (ha)	0.27	0.73	0.43
Average cost price (Birr kg^{-1})	2.0	2.2	2.1
Minimum	1.2	1.4	1.2
Maximum	4.1	3.7	4.1
Cost-benefit ratio	0.56	0.51	0.53
Actual profit (Birr ha^{-1})	37,798	83,489	61,846
Average labor productivity (Birr ha^{-1} day^{-1})	112	158	142
Actual profit per plot (Birr $plot^{-1}$)	9,299	60,652	36,327

3.4.5 Price scenarios

This scoping study only provides a snapshot of small holder horticulture production in Meki-Ziway, which coincided with a period with extremely high output prices for tomato, but especially onion. Therefore, in this section we analyse some scenarios using different output prices and yield levels.

Tomato

Average production costs of tomato were about 50,000 Birr ha^{-1} but ranged from 10,000 to 150,000 Birr ha^{-1} (Table 3.27). In 2012, the average market price of tomatoes in Adami Tulu Jido Kombolcha was 3.7 Birr kg^{-1} and in Dugda it was 4.7 Birr kg^{-1}, while the long-term average market price is 2.7 Birr kg^{-1} (Stallen *et al.*, 2012). In 2012, tomato yields were on average 25 t ha^{-1}, while they varied between 10 and 50 t ha^{-1} (Table 3.25).

The break-even point, i.e. the market price above which farmers start to make profit, is about 5 Birr kg^{-1} with a yield of 10 t ha^{-1} and 1 Birr kg^{-1} with 50 t ha^{-1} assuming the same average costs of 50,000 Birr ha^{-1} (Figure 3.6). Break-even point at the observed yield level of 25 t ha^{-1} in our scoping study is approximately 2 Birr kg^{-1} implying that farmers also would have made profit based on the long-term average market price of 2.7 Birr kg^{-1} but considerable lower than observed in the scoping study.

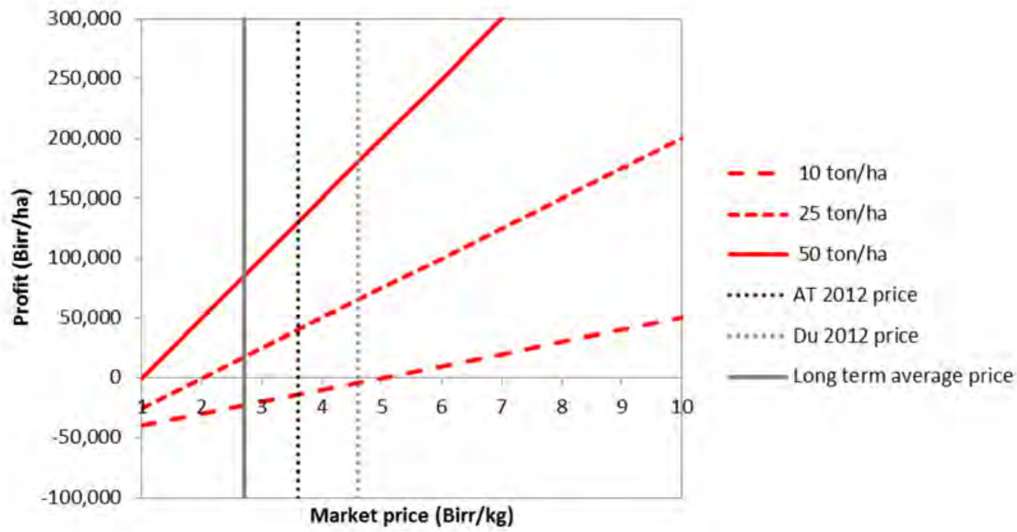


Figure 3.6. *Profit and market price relationships of tomatoes for three yield levels based on the same cost level of 50,000 Birr ha^{-1}. The vertical lines indicate the price levels observed in Adami Tulu Jido Kombolcha (AT 2012 price), Dugda (Du 2012 price) and the long-term average tomato price.*

Onion

Average production costs of onion were on average 50,000 Birr ha^{-1} (Table 3.26), while they ranged between 25,000 and 100,000 Birr ha^{-1}. Average onion prices in 2012 where very high with 7.4 Birr kg^{-1} in Dugda and even 8.2 Birr kg^{-1} in Adami Tulu Jido Kombolcha. The long-term average price was only 3.1 Birr kg^{-1} (Stallen *et al.*, 2012). In 2012, onion yields were on average 25 t ha^{-1}, while they varied approximately between 10 and 60 t ha^{-1} (Table 3.24).

The break-even point is about 5 Birr kg^{-1} with a yield of 10 t ha^{-1} and less than 1 Birr kg^{-1} with 60 t ha^{-1} assuming the same average costs of 50,000 Birr ha^{-1} (Figure 3.7). Break-even point at the observed yield level of 25 t ha^{-1} in our scoping study is approximately 2 Birr kg^{-1} implying that farmers also would have made profit based on the long-term average market price of 3.1 Birr kg^{-1} but considerable lower than observed in the scoping study. From this analysis it can also be concluded that farmers with the lowest yields (10 t ha^{-1}) would have lost money at the average price level of onion, while they have made profit in 2012 due to the high price level.

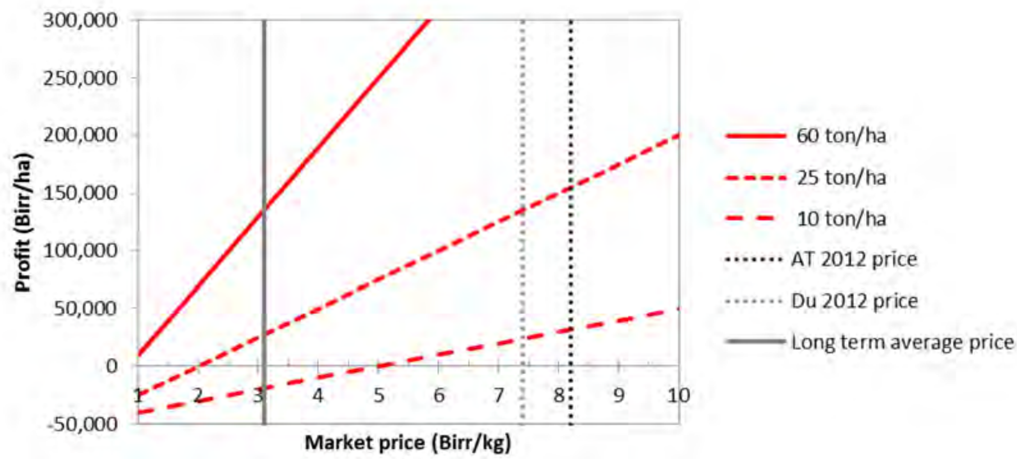


Figure 3.7 *Profit and market price relationships of onion for three yield levels based on the same cost level of 50,000 Birr ha^{-1}. The vertical lines indicate the price levels observed in Adami Tulu Jido Kombolcha (AT 2012 price), Dugda (Du 2012 price) and the long-term average onion price.*

4. Discussion and conclusions

4.1 General issues

Representativeness of sampled farmer plots
In this report we describe the horticultural management and associated agronomic and socio-economic performance of 37 onion and tomato smallholders in Dugda and Adami Tulu Jido Kombolcha. This relatively small sample raises the issue of how representative the monitored farmers are for the (horticultural) smallholder population in both districts, and for entire Ethiopia.

All monitored farmers were literate, which was an explicit selection criterion enabling to take written records. However, literacy is not a common characteristic of the rural population in the Central Rift Valley. In 2004, less than 50% of the population was literate in this part of the Central Rift Valley (MoWR, 2007), while in our study region about 20-30% of the population never attended school (Table 2.4). Mengistu Assefa (2008) showed illiteracy rates between 0 and 30% in two irrigation schemes in the Central Rift Valley.

The number of oxen, - which is an indicator of wealth, -was high, especially in Dugda (3.7 oxen per farmer) suggesting that our sample farmers were better-off than other households in the Rift Valley who typically own on average one oxen (MoWR, 2007). In general, horticulture smallholders may be better-off than the rest of the rural population because of their access to irrigation water, which is a valuable asset.

During the monitoring it became clear that 11 farmers out of the 37 monitored farmers had participated in a diversification programme sponsored by the Common Fund for Commodities (CFC) aiming at the production of green beans for the export. As part of that programme farmers have received ample technical backstopping and capacity building, which may explain the relatively high tomato and onion yields (twice as high) compared to those reported in other studies from the Central Rift Valley (Bedru Beshir, 2004; Beshir Keddi Lencha, 2008; Paas, 2010; Van Halsema *et al.*, 2011). The participation of farmers in the CFC programme indicates that our sample represented *commercial* smallholders, but also suggests they do not belong to the *emerging* commercial horticulture sector since they have already quite some experience.

Despite the fact that our sample farmers were probably above-average educated and trained, our results suggest that their agronomic and socio-economic performances are far from optimal and also large variation in performance among farmers indicates at possibilities for improvements in productivity, profitability and environmental footprint. Results of less educated and *emerging* horticulture smallholders most likely will be worse.

Sustainability
Farmers in Meki-Ziway appear to respond quickly to market incentives because three farmers changed the planned crop just before our monitoring campaign began. These farmers switched to crops with higher expected financial returns. Although this is an indication of the commercial attitude of farmers it also bears the risk of adopting unsustainable farming practices with little attention to proper crop rotation requirements. Similarly, the over reliance of farmers on onion and tomato also increases the risk of soil-borne diseases associated with the tight rotation of the same types of crops. In the mid or long-term such practices will have a negative impact on crop yields and profitability.

The use of obsolete pesticides (even the use of DDT) by some farmers needs further attention and control as it endangers the local environmental sustainability and consumer and occupational health. The use of DDT can indicate that farmers are unaware of allowed pesticides since DDT officially is banned for agricultural purposes and only allowed to be used for malaria control. DDT is sometimes sold openly by agro shops to be used against insect pests in crops (Amera and Abate, 2008).

The high salinity levels in various plots, especially in Dugda (data not shown) indicate unsustainable irrigation. The risk of unsustainable water management practices goes beyond the plot level as it also has regional dimensions. During the study, some farmers along the Meki River lost their seedlings as a consequence of water shortages preventing the timely irrigation of their seedbeds. Although the Meki River is mainly governed by rainfall and thus water shortages may be a natural phenomenon there are indications - based on discussions with farmers - that temporal water scarcity and competition for water among farmers along the Meki River has been aggravated in recent years associated with the increase in irrigated agriculture.

Horticulture, which is characterized by the high use of different types of inputs, needs continuous attention with respect to sustainability issues in policy regulation, education of farmers and research to develop less environmental harmful practices and techniques. Indicated unsustainable practices may endanger the socio-economic viability of horticulture production in the Meki-Ziway region in the medium and long-term, while some practices may be a direct threat to the health of field workers and consumers of horticulture produce.

Knowledge level of farmers

The scoping study did not assess the knowledge of farmers directly, but indirectly some observations can be made with respect to the knowledge level of farmers. First, soil and water quality sampling are not common practices in Ethiopia to understand the soil fertility status and to identify potential water quality problems. However, such insight is of utmost importance for an environmental sound and a cost-effective nutrient and water management. Farmers are hardly to blame for this as reliable and swift operating laboratory services are lacking. May be more remarkable is the lack of knowledge of farmers about their plot size. Farmers on average under- or overestimate their plot size with about 25% (Table 3.4), and this bias is not systematic, i.e. about half of the farmers over-estimated and the other half underestimated the size of their plots. This shortcoming hinders the adequate following up on advices with respect to good agricultural practices involving input amounts per unit of area such as fertilizer recommendations. Cadastral measurements of plots may provide farmers with better information on plot sizes and allow better uptake of cultivation recommendations.

Tesfaye *et al.* (2010) tested the knowledge of farmers through 14 open ended questions regarding potato, durum and onion. On a scale from 0-14, untrained farmers scored an average of 6.1 to 7.8, depending on the location, while farmers trained by research centres scored between 9.6 and 10.6 indicating still room for improvement. The relative high score of the untrained farmers was also ascribed to contacts with trained farmers (farmer-to- farmer knowledge transfer).

Gender

Commercial irrigated horticulture is a labor-intensive form of agriculture with the potential to significantly increase income of farm households as observed in our data set. From a gender point of view, smallholder irrigation can therefore have negative impacts on women if men capture an unfair share of farm profits, or if women's labor burden increases without adequate compensation, but it can also have positive impacts by enabling women to increase their cash incomes and diversify family nutrition. Field observations indicate that certain operations such as transplanting are consistently done by women while other operations such as pesticide spraying and fertilizer applications are performed by men. Hence, there seems a gender-distinct division of tasks and operations, but unknown is how earnings are divided according men and women. Though women are involved in specific field operations, few female-headed households are involved in the emerging commercial horticulture. Paas (2010) showed that in one irrigation scheme 20% of the plots were managed by females, but in most cases these were the wives of other farmers in the scheme. The absence of female-headed households in our data set and the low participation of these households in the emerging commercial horticulture in general has several possible causes (Gebreselassie, 2012): 1) the high labor requirements associated with horticulture while labor availability of these households is often limited; 2) little access to capital while horticulture is capital intensive related to expensive inputs; 3) poor (power) position with respect to male brokers; and 4) risk-aversive behavior related to price fluctuations of vegetables that often are more pronounced than in cereals.

4.2 Agronomic performance

Crop yields

Average higher onion yields in Adami Tulu Jido Kombolcha (24,843 kg ha^{-1}) compared to Dugda (17,340 kg ha^{-1}) were associated with higher N fertilizer use in Adami Tulu Kombolcha (162 kg N ha^{-1}) than in Dugda (242 kg N ha^{-1}). Average higher tomato yields in Dugda (31,563 kg ha^{-1}) compared to Adami Tulu Jido Kombolcha (16,335 kg ha^{-1}) are associated with higher N fertilizer use in Dugda (186 kg N ha^{-1}) than in Adami Tulu Jido Kombolcha (120 kg N ha^{-1}). As indicated before in this Chapter, these yield levels are on average more than twice as high as observed in other studies in the Central Rift Valley (Bedru Beshir, 2004; Beshir Keddi Lencha, 2008; Paas, 2010; Van Halsema *et al.*, 2011). Large yield differences and N inputs have been observed among farmers and within both districts, but based on the limited sample size it is difficult to derive statistical significant differences. This would require a larger sample size which was beyond the goal of the scoping study.

Applied fertilizer rates are in line with the formal, but very generic recommendations that have not been properly validated for prevailing soils in this region (and other regions). Especially, in onion the frequency and timing of fertilizer application need improvement to prevent nutrient losses to the environment, to reduce costs of farmers and to increase yield with the same or even less fertilizers. Fertilizers applied are mainly DAP and Urea because of their availability at low prices. In tomato cultivation, however, the use of ammonium and urea based fertilizers might enhance quality problems such as blossom end rot. The role of potassium as possible yield-limiting factor remains unclear. Potassium fertilizers are expensive and access is limited for smallholders. Evidence-based information on the potential impact of potassium fertilization on horticulture crop yields in Ethiopia is lacking.

In general, the age at which seedlings were transplanted from the seedbed to the field was too high. This increases the susceptibility to the so-called 'transplanting shock', which reduces final yield. The current method of raising transplants in a field bed nursery leads to high seed losses and uneven plant size. Especially with the use of more expensive (e.g. hybrid) seeds the raising of seedlings needs proper attention to reduce costs. The current method of raising seedlings, which goes hand in hand with high losses, may be one of the reasons for the low use of improved hybrid seeds. In practice this means that introduction of new high-yielding varieties needs to be complemented with better seedbed and seedling raising methods.

Pesticide use

Although a considerable number of pesticides are locally available only few are used frequently. In addition to the use of some obsolete pesticides by few farmers, there is remarkably little variation in the types of used fungicides and insecticides. However, modern more target-specific pesticides are not easily available. The 'old' and most frequently used pesticides such as the broad spectrum organophosphates and pyrethroids as well the mancozeb are relatively cheap. The efficacy of these pesticides is doubtful when compared with the newer more specific pesticides. Especially, the frequent and prolonged use of insecticides and the fungicide metalaxyl may result in the resistance of plagues and diseases. The high frequency of application of some pesticides suggests that plagues and diseases are already increasingly resistant against these pesticides, but further research is needed to confirm this.

Also with respect to timing and scheduling of pesticide applications improvements are possible. Fungicides are often applied after symptoms have become visible. However, in the case of mancozeb this stage is too late to control diseases. In addition, farmers tend to stop with spraying a long time before harvesting which could result in a fast deterioration of the crop and reducing yields. In most cases the period between last spraying and harvest is long enough to comply with the pre-harvest interval for the respective pesticide applied. Only in a few cases the period between spraying and harvesting seems too short resulting in possible pesticide residues on the marketable product.

Synergies of input use

As may be expected strong synergies have been observed between on the one hand the yields of onion and tomato and on the other hand seedling age, fertilization, crop protection, irrigation and labor. This does not mean that a limitation caused by one input, for example, the use of old seedlings can be compensated by the increased use of other inputs such as more crop protection or more fertilizer use. Substitution of inputs is only possible for a limited number of inputs while the majority of inputs have additive properties. The important theoretical implication is that all inputs need to be in optimal supply to achieve synergistic yield effects (De Wit, 1992). The practical implication is that if one input is in limited supply further investments in other inputs is of little value. For example, when yield is limited due to poor irrigation management (either a shortage or an excess of water) the supply of fertilizers is of little use and often a financial waste.

4.3 Socio-economic performance

Profit

Profit per hectare of tomato and onion is in Dugda almost the same (80,000 Birr ha^{-1}), but in Adami Tulu Jido Kombolcha profit of onion was four times as high as in tomato (150,000 Birr ha^{-1} *vs* 40,000 Birr ha^{-1}). Overall profits in onion were about one-third higher than in tomato: In onion average profit was 110,000 Birr ha^{-1} *vs* 60,000 Birr ha^{-1} in tomatoes. In general, cost-benefit ratios were more favorable in onion (0.38) than in tomatoes (0.53); this means that each invested Birr gave a return of 3.6 Birr in onion, while in tomato only 1.9 Birr.

Onion prices during the monitoring period (average 7.7 Birr kg^{-1}), however, were very favorable and more than twice as high as the long-term monthly average onion prices (3.1 Birr kg^{-1}; Stallen *et al.*, 2012). Average tomato prices were also higher during the monitoring period (4.1 Birr kg^{-1}) than the long-term monthly average tomato prices (2.7 Birr kg^{-1}), but relatively less increased than the onion prices. Analyses showed that especially farmers producing low yields (<10 t ha^{-1}) may face problems to reach an economic break-even point at average price levels. Obviously, also farmers with higher yields run into problems if prices drop below the long-term average price levels. As indicated before, other studies have observed much lower yields than in our study. This implies that our favourable profits provide a too optimistic view on the agronomic and economic performance of horticulture smallholders, the latter mainly caused by the extreme high product price level during our monitoring campaign.

Labor productivity and markets

Obviously, horticultural production is very labor intensive as also is shown in our study. The largest cost component is labor input and up to 40% of the costs are spent on hiring labor. However, returns to labor are high, i.e. average labor productivity in onion was 210 Birr labor day^{-1} *vs.* 140 Birr labor day^{-1} in tomato. This compares very favorable to daily wage rates such as common in greenhouses, i.e. about 25 Birr labor day^{-1}. However, also here the extreme high output prices provide a disturbing factor. The determined labor productivities can be considered as upper limits under observed management, yield levels and prices.

We found remarkable differences in the labor use and provision between Dugda and Adami Tulu Jido Kombolcha. Dugda farmers rely much more on externally hired labor than farmers in Adami Tulu Jido Kombolcha who use more family labor. Several reasons may explain this difference. First, the Meki area has a longer tradition in smallholder vegetable production than Adami Tulu Jido Kombolcha. Associated with this history is the more developed labor market and transport sector (horse carts) to transport daily wage earners to the fields. Second, the horticulture production area is more concentrated in Dugda and closer to a labor pool (Meki) facilitating the transport of daily laborers. Third, the Meki horticultural sector is more dominated by businessmen often from other areas who are forced to use hired labor, since they have no other choice. These differences result in higher costs for hired labor in Dugda than in Adami Tulu Jido Kombolcha.

4.4 Recommendations/follow up

- To secure the sustainable development of smallholder horticulture in the Central Rift Valley, there is an urgent need for expansion of the current crop portfolio of farmers. The over-reliance of farmers on onion and tomato results in increased market risks and in tight crop rotations, which enables the development of soil borne diseases and soil health problems. Business as usual will have negative effects on crop yields in the mid and long-term. Diversified crop rotations need to be designed that are economically viable and sound from an agronomic point of view.
- Hardly any improved varieties are currently used by farmers and most seed is locally multiplied and of uncertain quality. Since crop genetics are one of the most important yield determining factors testing and demonstration of new improved varieties in collaboration with the private seed sector is urgently needed to identify varieties adapted to the local conditions. This activity, however, cannot be considered in isolation and needs to be done in close collaboration with the next point:
- Improvements in nurseries and seedbeds are required for raising seedlings of improved (hybrid) seed, for example through the use of trays. Without improvements the loss of seedlings during the nursery stage and early crop establishment will be too high to economically use improved (and more expensive!) seed. Centralization and specialization, for example through development of nurseries within farmer cooperatives or managed by specialized nursery farmers may reduce costs.
- Better understanding is required on the relationship between nitrogen inputs and yields taken into account prevailing soil fertility. Current recommendations are generic, while soil differences are not accounted for, which may result in recommendations that are too low to attain targeted yield levels, or too high resulting in avoidable physical and economic losses. Also the role of potassium as possible yield limiting factor in horticultural production needs attention.
- More awareness and knowledge of DA and farmers is needed on the use of pesticides, i.e. types, frequency of applications, scheduling, proper pest and diseases identification, and diagnostics in relation to the type of pesticides, etc. This could prevent early resistance against pesticides, reduce environmental pollution, increase yields, reduce costs and avoid consumer and occupational health risks.
- Although no water use efficiencies of production could be estimated due to the lack of actual rainfall data, water use of the selected farmers seems rather high if we realize that a large part of the growing season was during the wet season July-August. Over supply of water may cause nutrient losses, create favorable environments for pests and diseases and is a direct cost factor (fuel for pumps). Earlier attempts to promote more water-efficient application methods (drip systems) all failed in the region for various reasons. However, a more efficient use of water needs to remain high on the R&D agenda also in relation to the increasing competition for irrigation water, salinity problems in some parts of the Central Rift Valley and energy costs, which most likely will increase in the future.
- This is one of the first studies in Ethiopia where the management of crops have been monitored and described in so much detail. Although only aggregate data have been shown in this report the available data of individual farmers provide excellent material to coach and advice farmers and to discuss in farmer groups as learning material and benchmarking. More systematic record keeping, in a reduced form but during multiple seasons, allows to monitor progress of farmers and to provide feedback to farmers during longer periods.

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Appendix I.

Summary of major soil characteristics (MoWR, 2007)

Soil group	Depth	Colour	Texture	Structure	Consistency	Drainage
Andosol (AN)	Deep to very deep	very dark grey to brown,	Loam, sandy loam	Weak to moderate, fine and medium, crumb and sub angular blocky structure	Very friable to friable; slightly sticky and none plastic	Well to excessively drained
Arenosols (AR)	Moderately deep to very deep	Very dark brown to dark brown	Sandy loam, loamy sand	Weak to moderate, fine; granular and sub angular blocky structure	Very friable to friable; none sticky and none plastic	somewhat excessively drained to excessively drained,
Cambisols (CM)	Shallow to very deep	Very dark Gray to dark reddish brown	Sandy loam, sandy clay ,loam, silty loam	Moderate to strong fine to coarse ,sub angular, granular and crumb structure	Very friable to firm, none sticky to very sticky, none plastic to very plastic	well to excessively drained
Fluvisols (FL)	Moderately deep to very deep	Black to dark yellowish brown	Clay, clay loam, loam, sandy clay loam ,sandy loam	Weak to moderate ,fine and medium, granular and sub angular blocky structure	Very Friable to firm, none sticky to sticky, none plastic to plastic	Imperfectly to well drained,
Leptosols (LP)	Very shallow	Very dark Gray to brown	Sandy clay, sandy clay loam	Weak to moderate ,fine and medium sub angular blocky structure	Friable, slightly and slightly plastic	Well to excessively drained
Luvisols (LV)	Moderately deep to very deep	Very dark Gray to dark red	Clay, clay loam , sandy clay loam silty loam	Moderate to strong, granular, crumb and sub angular blocky structure	Very friable to firm, slightly sticky to sticky; slightly sticky to very sticky	Moderately well to well drained
Nitisols (NT)	Moderately deep to very deep	Very dark brown to dusky red	Clay, clay loam	Moderate to strong, medium and coarse ,sub angular blocky structure	Very friable to slightly firm ,sticky and plastic	Well drained
Solonetz (SN)	Deep to very deep	Black to light olive brown	Sandy loam, silty loam	Moderate, medium and coarse sub angular blocky structure and massive in substrata	Very friable, slightly sticky and slightly plastic	Moderately well to well drained
Vertisol (VR)	Deep to very deep	Black to dark yellowish brown	Clay ,clay loam, loam	Moderate to strong, medium and coarse angular and sub angular blocky structure	Firm, sticky and plastic	Imperfectly to poorly drained