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Towards Productive Shallow-Well Supported Floodplain Area

Challenges and Solutions, Case of Koka Flood Plain, Ethiopia

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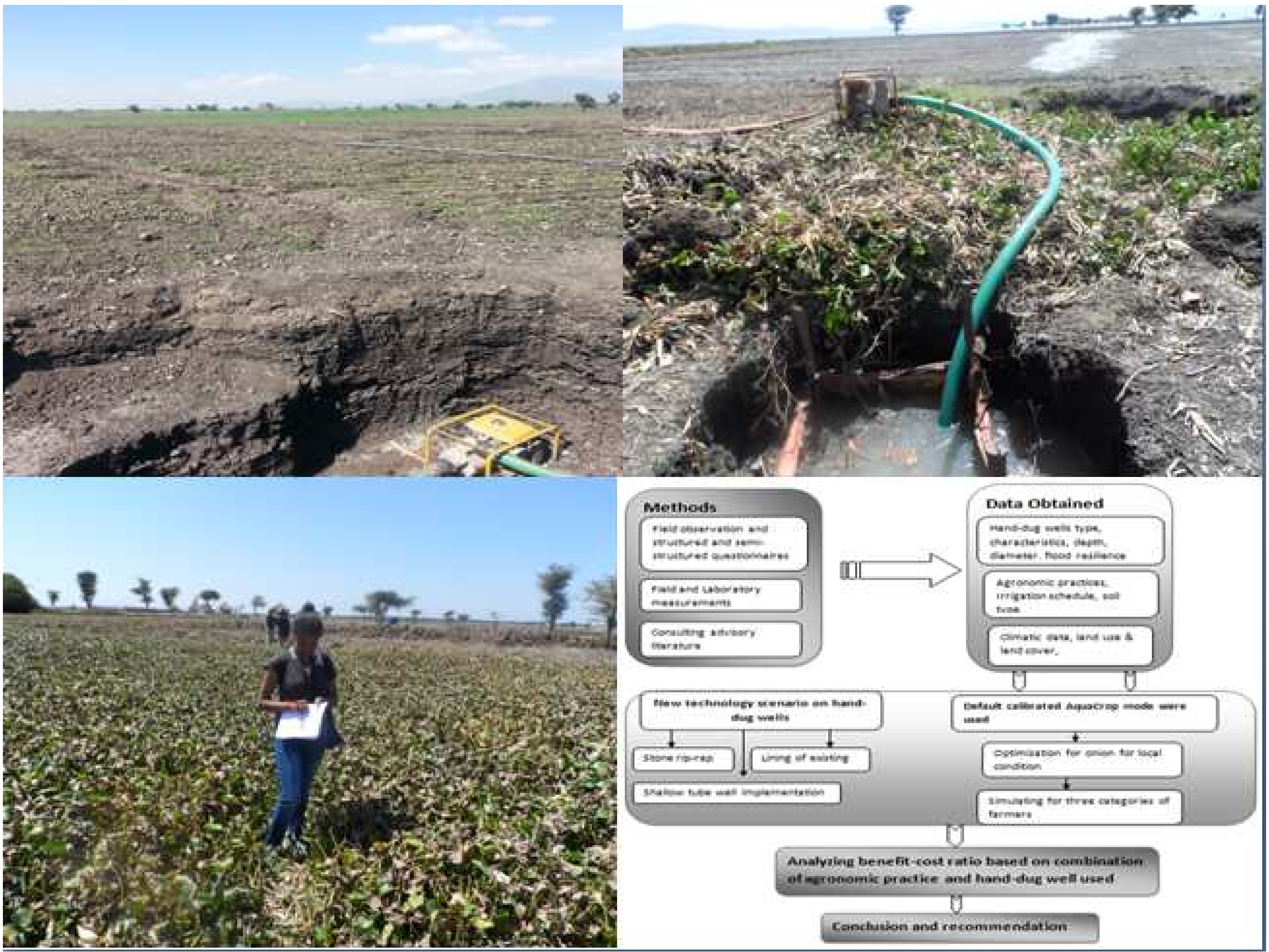

Towards Productive Shallow-Well Supported Floodplain Area

Challenges and Solutions, Case of Koka Flood Plain, Ethiopia

Master of Science Thesis
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Abstract

The floodplain in Koka area is mainly created through inundation of Mojo River and Koka Lake. Flooding from the river starts in beginning of July and lasts to beginning of September, while flooding from the lake lasts till February. These floodplains are potential source for crop production, due to the shallow ground water depth, alluvial soil and moisture which will be left after flood. Therefore farmers in Koka area produce chickpea and water melon using residual moisture. In addition crops like onion, tomato, pepper and maize are also cultivated by different farmers using surface irrigation. The area is classified as semi-arid region with high evapotranspiration rate; therefore hand-dug wells are implemented for supplemental irrigation. Nevertheless there are famers who don't construct hand-dug wells, farmers which are found near to the river and during irrigation they use river water.

The existing hand-dug wells mainly face problem of collapsing and sediment deposition due to the flood. Farmers every year either have to construct new hand-dug well or clean sediment from the wells. This is labour intensive, costly and may also result in a loss of a complete harvest if the reconstruction work is not done timely. Therefore, this research based on a careful technical and economic analyse identified alternative well technologies that can increase the household income. The research employed several quantitative and qualitative methodologies including field visit, observations, modelling using AquaCrop, structured and semi-structured questionnaires.

The hand-dug wells while technically they differ on the depth, diameter, installation of protection material and flood resilience, they all constructed from earthen material, are without any protection and they rely on diesel pumps for supplying irrigation. The major crop produced in the area was onion, ploughing was two to three times and irrigation interval varies from more frequent 3 to 5 days (initial and flowering stage) and 8 days (late to harvest crop growth stage); to a corresponding longer interval of 5 to 6 and 10 days. This difference in irrigation interval and the fact that some farmers use fertilizers and other not, has resulted in yield difference that ranges from 12 to 40 ton/ha.

As an alternative to the hand-dug wells, stone riprap, shallow-tube well and lining methods were assessed using the benefit-cost ratio. Stone riprap and lining of existing wells resulted in the highest (3.3) benefit-cost ratio. Lining of existing hand-dug wells together with frequent irrigation interval and fertilizer application will benefit farmers as it leads to a net income of 66,122 Euro. In addition, the variation between lining of existing wells and shallow-tube well application is significant; that is net income of shallow-tube well is 65,752 Euro. Therefore, farmers which located in ground water depth up to 8 meter and those farmers with 100 meter distance from Mojo River will be benefited.

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Abbreviations

CGC: Canopy growth coefficient

CDC: Canopy decline coefficient

Dr: Root depth

E-KL: Floodplain of Koka Lake of East side of Koka

E-MR: Floodplain of Mojo River of East side of Koka

ETo: Reference evapotranspiration

FAO: Food and Agricultural Organization

GPS: Global positioning system

HI_o: Reference harvest index

KL: Koka Lake

LWAO: Lume wereda agricultural office

MoWR: Ministry of Water Resources

MR: Mojo River

NMSA: National Metrological Service Agency

PW: Protected well

T_n: Minimum temperature

T_x: Maximum temperature

UPW: Unprotected wells

W-MR: Floodplain of Mojo River of West side of koka

CHAPTER 1

Introduction

Floodplain is low laying area which is mainly identified due to the inundation or lateral flow of rivers or lakes. Floodplain can be looked at from several different perspectives: To define a floodplain depends somewhat on the goals in mind. As a topographic category it is quite flat and lies adjacent to a stream; geomorphologically, it is a landform composed primarily of unconsolidated depositional material derived from sediments being transported by the related stream; hydrologically, it is best defined as a landform subject to periodic flooding by a parent stream. A combination of these characteristics perhaps comprises the essential criteria for defining the floodplain (Schmudde, 1968). In addition to classification of defining floodplain it is also potential area for agricultural production.

Agriculture has been practiced in flood plain areas for many years due to the high moisture retention capability of the floodplains; they are widely and increasingly used for recession farming. Furthermore, deposits of soil materials particular during flood periods enable them to provide fertile soils for agricultural production. Floodplains are also characterized by shallow groundwater levels that facilitate agricultural activities during dry periods. Many flood plains in the Africa support agricultural activities such as forestry, crop cultivation, fisheries, and livestock husbandry (GIAHS). The floodplains of northern Nigeria also support diverse dry-season cropping based on both residual soil moisture cultivation and more conventional forms of irrigation. (Kimmage K., Adams W.M, 1990)

Majority of production in Ethiopia is under small-scale and traditional way; resulting in low productivity and highly fragment, in addition most of farms are poorly oriented to market. Crop production is mainly under rain-fed agriculture with only 5% of irrigation. The rain fall pattern in Ethiopia varies yearly which sometimes leads to crop failure or failure to achieve the intended yield amount. Since Ethiopia is largely dependent of the agricultural sector, it provides 86% of the country's employment and 42% of its GDP (Growth and Transformation plan, 2010 and FAO, 2005). In general, heavy reliance on rain fed agriculture, especially when rainfall is highly variable, severely affects the performance of agriculture leading to recurrent droughts and adverse effects on the economy. The World Bank (2006 cited in Hagos et al. 2009), for example, estimated that hydrological variability costs the Ethiopian economy over one-third of its growth potential and has led to a 25% increase in poverty rates (Gebrehaweria G., 2012). There are different methods of crop production around the country from which flood recession agriculture is one type. The method is practised within few areas of lake: for instance Lake Tana, Baro-Akoba, Omo valley, Wabi Shebelle and upper Awash. In koka area, flood recession crop production is implemented with variability in flood recession frequency, planting date, crop type and source of irrigation.

Koka is located in the central part of Ethiopia; 93km away from the capital city with high variability in rainfall pattern and semi-arid weather condition. Agricultural activities like crop production, livestock and fisheries are practiced in the area being dominated by crop production. Crop production undergone in floodplain and non-flood area using under rain fed and surface irrigation methods. There are also companies of privately and governmentally owned farms and factories; like flower and fruit farms and leather factory located around Koka. Koka Lake, which is made by human, is found in East side of town with longitude $39^0 10^'$, latitude $08^0 28^'$, at elevation of 1,590 m.a.s.l, drainage area 11,250Km^2, surface area 236Km^2 and maximum depth of 13meter. The source of flood in floodplain area is from Koka Lake and Mojo River, Mojo River before it enters Lake Koka. The farmers in non-flood area depend on rain fed agriculture and produces teff starting from June. Farmers of floodplain area starts cultivating after the flood recede and fishing activities held during the flood from Koka Lake rather than flood of Mojo River due to its fast recession.

The type of crops produced in the floodplain area are onion, tomato, pepper, head cabbage, water-melon and chick pea using traditional agricultural activities. Since the floodplain is located in the semi-arid region of the country, evaporation rate is high and the soil moisture available after the flood event is only enough to support chickpea and water-melon crop production rather than other crops, hence to avoid crop failure local farms are opt to use shallow groundwater and river water as a supplemental source. The main crop item produced by most of the farmers due to its high value is onion. Onion in Ethiopia, is the most important crop produced by smallholder farmers mainly as source of cash income and for flavouring the local stew "wot" and it is believed to be intensively consumed than any other crops(Tekeste A., 2013).

1.1 Problem statement

Ground water is main resource for irrigation, especially in arid and semi-arid area, which can be accessed for different use through construction of wells. In areas where there occur shortages of surface water, ground water can be as source for irrigation, for instance in floodplain area where soil moisture fails to stay for the entire growing season. Water scarcity and high cost of surface irrigation have encouraged exploitation of groundwater for enhancing crop productivity, increasing cropping intensity and ultimately raising income of farming households to enable them a better quality of life (Ganesh R., 2011).

Shallow hand dug wells in Ethiopia generally, started in the early times with manual hand-digging wells. It has started in the southern and Northern part of Ethiopia called Gurage, Silti zones and Tigiray. Since then, it has been applicable in different parts of Ethiopia, one of which is in koka area. Hand-dug wells inside floodplain area have draw backs, which are, during inundation the wells either collapse or filled with sediment. Economically which means, farmers spent money every year for construction or maintenance of the wells. Whereas, those floodplain area which are within 100 meter distance from Mojo River, are not engaged with hand-dug wells due to frequent collapsing.

Production of crops, especially onion, is majorly applied by farmers through producing two times per season. Agronomic activities in the floodplain starts after flood recedes except few farmers apply ploughing before flood arrives for capturing fertile sediments. In the area, variation in yield obtained per farmers was observed due to varied agronomic application. Therefore, in this study model AquaCrop will be used for analyzing agronomic practices implemented by different farmers. And finally, for the yield obtained, benefit-cost ratio will be analyzed for comparing implemented irrigation scheduling with yield obtained. In addition scenarios will be created for improving the existing wells through stone rip rap, lining of existing wells and changing to shallow tube wells. Then later, new technology benefit-cost ratio will be compared.

1.2 Objective

1.2.1 Main objective

- ✓ To assess the current level of productivity of the shallow-well supported flood plains in Ethiopia taking Koka as case study and recommend as necessary, alternative technical and agronomic improvement measures.

1.2.2 Specific objectives

- ✓ Analyze the technical strengths and weaknesses of the existing traditional well and their distribution network with respect to withstanding flood damage and providing sufficient supplemental water for agricultural production.
- ✓ Recommend alternative shallow-well technologies also taking into account their affordability by the main beneficiaries.
- ✓ Assess the existing agronomic practices, benefit-cost ratio of irrigation scheduling and suggest improvement measures.

1.2.3 Research question

- ✓ What are the technical differences and commonalities among the various traditional shallow-wells and how does this translate into resilience to flood damage and timely delivery of supplemental irrigation?
- ✓ What alternative shallow-well technologies could be recommended that are technically feasible and affordable?
- ✓ How profitable is the irrigation system currently practiced in the flood plains? How these can further increased?

1.3 Thesis layout

Chapter 2: Literature review

This chapter clearly defines about floodplain and agricultural productions undergone. It also explains irrigation practices with application of hand-dug well in the floodplain area. Since hand-dug wells are manually made, this chapter also identifies new technologies that can alleviate the collapsing problem faced due to flood. Finally, it also clarifies about irrigation scheduling and model AquaCrop in determine yield for applied irrigation water.

Chapter 3: Study area description

This chapter describes the study area location and whether condition. It identifies the maximum, minimum temperature, precipitation, sunshine hours and soil type of the area. Agricultural production including land use and cover is also discussed in this chapter.

Chapter 4: Materials and methods

In this chapter, the methods followed to respond for the research question listed above are clearly described. Such as, field visit, measurement, structured and semi-structured were the methods to identify existing practices. Additionally, data's preparation is discussed for the model AqaCrop input. Scenarios developed in case of new technology of shallow wells are also discussed.

Chapter 5: Result and discussion

This chapter clearly states the results obtained by using methods expressed in chapter 4. Explains existing agronomic activities and compare the benefit-cost ratio of new technologies and followed method of irrigation scheduling.

Chapter 6: Conclusion and recommendation

This chapter is the ending of the thesis concluding about the general terms discussed above and stating conclusion based on the result obtained.

CHAPTER 2

Literature review

2.1. Floodplain

Floodplains are important wetland ecosystems providing a wide range of services. In their natural state, floodplains support diverse wildlife habitats, fisheries and forestry, whose productivity depend critically on the annual flood cycle (Mursaleena, 1998). According to GIAHS, floodplain is an area adjacent to rivers and streams that are subject to recurring inundation (FAO). The length of time that a floodplain is inundated depends on the size of the stream, the channel slope, and the climatic characteristics. On small streams, floods induced by rainfall usually last from only a few hours to few days, but on large rivers flood runoff may exceed channel capacity for a month or more. Water on the floodplain usually drains back to the channel as the channel flow recedes, infiltrate into the soil and evapotranspiration.

Agricultural productivity, the choice of crops grown and the cropping pattern in the floodplain are also largely determined by hydrologic conditions (MPO, 1987). Most important of these are flood depth, timing and duration of flooding, rainfall pattern, and the availability of dry season drainage and irrigation. For instance in Bangladesh, floodplain development has focused on structural changes in the form of flood control, Drainage and Irrigation projects. These projects are designed to enhance agriculture production, where flood control structures, such as levees, are built to reduce flooding. Floodplain management structures change the annual hydrologic regime, which are they changing flooding conditions, such as the intensity and timing and duration of flooding. The area flooded and depth of flooding are reduced so as to make more land available for agriculture and to increase agricultural productivity (Mursaleena Islam, 1998).

Floodplains of the Senegal River(Senegal, Mali, Mauritania), the Niger River(Niger), the Sokoto River(Nigeria) and of the Waza-Logone River(Cameroon) in the Sahelian region of West Africa, and of the Kafue River(Zambia), Phonlgolo River(South Africa) and Tana River(Kenya) in semi-arid zones of south and east Africa support very productive wetlands engage in promoting forestry, crop cultivation, fisheries, and livestock husbandry in synchrony with annual inundation patterns.(GIAHS, Globally Important Agricultural Heritage Systems, West African Sahelian floodplain recession agriculture, Mali). According to Junk 1989, floodplains are areas that are periodically inundated by the lateral overflow of rivers or lakes, and/or by direct precipitation or groundwater. The active floodplain of a river is defined by North American hydrologists as the area flooded by 100-year flood (Bhowmik and Stall 1979).

2.2. Irrigation in Floodplain areas

According to Regassa Namara, 2012, different versions of shallow groundwater irrigation system exists which are; seasonal shallow well irrigation, permanent shallow well irrigation system, shallow tube well irrigation system and borehole irrigation systems. Seasonal shallow well irrigation is one of the type that are usually used by farmers in areas in low-lying areas with high water tables, often along river banks, on riverbeds, in swampy areas or close to poorly functioning public or communal irrigation schemes such as reservoirs and dugouts. Permanent shallow well irrigation systems are developed closer to the homestead and they can be lined with cement or left unlined.

According to Daniel Davou Dabi, Floodplain agriculture is practiced throughout the dry season which may last from six to nine months. The floodplains support residual moisture agriculture at the end of the rainy season and small-scale irrigation during the dry season, thus providing opportunities for agricultural diversification not found in the uplands, and allowing for double, or even triple cropping during one year. During the past two decades, however, most floodplains in semi-arid northern Nigeria have come under severe pressure from several sources. This is due to the decline in rainfall (Anyadike, 1993; Hess etal, 1995) that increased the vulnerability of rain-fed agriculture, has caused many farmers to shift their attention to fadama agriculture (Adams, 1986; Kimmage, 1991; Dabi and Anderson, 1998). Declining rainfall has also led to water scarcity in the more arid regions, which were used by nomadic herdsmen for season in the semi-arid region, bringing added pressure and competition on fadama resources, principally, alluvial aquifers but also the surrounding land in the area.

Secondly, widespread acknowledgement that the green revolution Initiative of the 1970's failed to ensure food security in sub-Saharan Africa, compelled policy makers to shift attentions away from the large-scale government irrigation projects to fadama agriculture. For example, in Northern Nigeria, funding by the World Bank facilitated the drilling of thousands of tube wells in floodplains and the distribution of petrol-driven irrigation pumps at subsidized prices to farmers to stimulate adoption of irrigated agriculture (World Bank, 2001). Such large-scale investment in small-scale, floodplain irrigation sanctioned by the World Bank, illustrates the extent of the expectation that policy makers have come to place on alluvial aquifers. But these investments have increased pressure on the floodplains. This pressure coupled with the possibility of an increase in drought occurrences as projected by the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), could spell disaster for the sustainability of floodplain agriculture and food security in the region (IPCC, 2001).

2.3. Shallow Hand dug wells

Ground water extraction in Ghana is used or different purposes; for example for domestic purpose, livestock watering and for agricultural production. The use of groundwater for irrigation is mainly via shallow well, which are dug along river banks and in low-lying areas mainly in Volta, upper East, Upper West, and the Greater Accra regions. The shallow wells are commonly dug near dugouts and reservoirs of the 381 shallow wells reported from UER, 64 were near dugouts and 128 near small reservoirs. Those wells which are seasonal shallow well are unlined and irregularly shaped, but are usually cylindrical. The depth of seasonal shallow wells ranges from one to five meters depending on the level of the water table and the technology used for lifting water. The diameter ranges between 70 cm to 100cm but most are one meter in diameter. Simple tools (bar, axe and hoe) are used for digging. A rope is tied to a bucket and the soil collected and pulled out of the well. This is continued until the water table is reached. Slopes are trimmed to specification when the water table is reached to enable the well to collect enough water. The number of wells constructed per unit cultivated area depends on depth and availability of water, planned size of irrigated area, the type of technology involved in lifting and distributing water, and the seepage rates from

the surrounding ground into the well. Water is collected from the wells using different pumping technologies such as motorized pumps, hand pumps, treadle pumps, and rope and bucket systems.
There are several potentially suitable low-cost and sustainable drilling solutions for smallholder private irrigation; the choice of the technique depends on the intended application and on environmental and hydrological conditions. In West Africa, manual drilling has been practiced for many decades then after 1990 manual drilling of tube wells experienced a huge boom. Manual drilling can be classified in to different methods in consideration of density of the soil layers to be dug. The methods are inclusive in maintaining the sides of the borehole to avoid collapse and removal of materials from the bore hole.
There are four types of manual drilling; which are

- ✓ Manual Auger; - These method works by helicoids auger rotating into the ground until it is full and then lifted out of the borehole to be emptied. Cylindrical auger equipped with a bailer is used below the water table to empty water and soil. The sides of the borehole are maintained with a temporary casing.
- ✓ Percussion; - A heavy cutting or hammering bit attached to a cable is lowered into the open hole. By moving the cable up and down, the cutting or hammering bit loosens the soil or consolidated rock in the borehole, which is later extracted by using a bailer.
- ✓ Sludging; - A drill bit penetrates the hard layers of soil with a vertical, rotating movement. Thickeners (clay or cow dung) are added to the water in order to prevent the borehole from collapsing and to reduce water loss. Water pressure keeps the borehole open. The excavated materials are brought to the surface with the ascending movement of the fluid.
- ✓ Wash bore; - The injection with a motorized pump of pressurized water into a tube penetrates the soil and lifts the soil to the surface of the borehole.

Manual auger and wash bore drilling are commonly used in areas where the soil is soft (sand) and the aquifers shallow. Both methods are well adapted to condition in Northern Nigeria and Niger. The water can be pumped out using motorized or treadle pumps. In areas where the soil is consolidated the manual auger technique needs to be combined with hammering and sledging techniques in order to dig through the harder layers of soil. In Nigeria because it was easy to use and was inexpensive, wash bore technique quickly adopted by farmers. A manually drilled tube well can be more profitable than a concrete well because it is both less expensive to build and more productive. In addition, tube well (with slots) has a larger surface hydraulically in contact with the aquifer than a concrete well. However, the financial profitability of low cost drilling depends on the pumping mechanism used as a motorized pump can irrigate a larger area than a treadle pump. (Regassa N., 2012).

The pounder Rig is an adaptation of the Asian sludging method which uses galvanized water pipe, a pipe coupling, a bamboo lever and pivot, and the skill of the operators to rapidly drill through soft alluvial material. The drilling method involves reciprocating a water filled pipe in a water filled hole using the lever. The palm of the operator's hand acts as a flap valves across the top of the pipe. The hand is held tightly across the pipe on the upstroke and thus holds water in suction. On the down stroke, the operator lifts his hand and releases the water from the top of the pipe. The water thus discharged contains drill cuttings, which have been sucked up from the bottom of the pipe. By thus removing material, the pipe progresses down and drills a hole. The diameter of the hole is slightly larger than the diameter of a pipe coupling, which is attached to the bottom of the drill pipe. (Danert K., 2003)

Motorized drilling techniques, including motorized augers and percussion drills, can be used to drill tube wells in regions with hard soil layer and the cost of digging is 10 times higher than the cost of a manual drill. Motorized auger is most suitable for drilling in geological strata that cannot be penetrated by manual drills or where aquifers are more than 25 meters deep. Water from bore hole can be accessed by using treadle pumps and low-cost motorized pumps which are more easy solutions for smallholder private irrigation. Treadle suction pump was developed by Gunnar Barnes in Bangladesh in the 1970s. There are many models of pumps, but they can be divided into two main categories;

- ✓ Suction pumps bring water to surface from aquifers of less than about 7-8 meter deep. They are operated with hand or foot powered treadles. Water flows directly to irrigation canals or plot furrow.
- ✓ Pressure pumps deliver pressurized water to a pipe or hose to fill a tank or to irrigate a plot located above the pumping point. They are also used for aquifers of less than 8 meter deep.

Shallow-tube well implementation follow method of sludging as described above, the difference is during digging circular tube wells are used. It is a manual drilling technique in which water is circulated to bring the cuttings to the surface. The drill pipes are moved up and down. On the down stroke, the impact of the drill bit loosens the soil and on the up stroke, the top of the pipe is closed by hand (or a valve), drawing up the water through the pipe and transporting the cuttings to the surface. On the next down stroke, the hand (or valve) opens the top of the pipe and the water squirts into a pit, in front of the well. In this pit, the cuttings separate from the water and settle out, while the water overflows from the pit back into the well. (http://akvopedia.org/wiki/Sludging_-_Asian_sludge)

2.4. Lining of wells

Well lining is very important part of proper functioning well but is also the most expensive part. Lining of well is necessary if the wall collapse during digging or if there is expectation that the wall to collapse during rainy season or during flooding. There are different types of lining such as, lining with bricks and lining with concrete rings. Lining with bricks is very strong material especially when the bricks are well burned since they stay below water level for long time. While implementing, the first two bourses of bricks at the bottom of the well should be laid radials for a stable foundation. Using well rings for lining is more expensive than the bricks and it is the best way of construction a well lining. Sometimes well rings are only used for the wall that is expected to be below the water level. The lining above the water level is done with bricks, other times the whole lining is done with well rings. The purpose of the lining is to ensure that the well retains its excavated shape, allowing access to the water in the aquifer, while at the same time helping to prevent contamination of the aquifer. Lining can be used as over the full depth of the well or only partially. There are six types of lining ;(Water Aid, SKAT)

- ✓ Unreinforced precast concrete: - Using specially-made formwork, concrete is cast in rings with an internal diameter of 1.2-1.3m and a thickness of 7.5-10cm. The height of the rings can vary from 50cm to 1m.
- ✓ Reinforced Precast Concrete: - Concrete is cast in special formwork, but using steel reinforcement and with a reduced thickness (5-7.5cm), depending on whether the rings are to be transported over long distances or rough terrain.
- ✓ Reinforced Cast In-situ Concrete: - Using one leaf of formwork, concrete is placed directly against the walls of the excavated well.
- ✓ Cast In-situ Mass Concrete: - As above, but with thicker walls to compensate for the lack of reinforcement.
- ✓ Brick or Masonry Lining: - Brick and masonry linings are also used, but the porosity of the materials in question impairs their suitability for this particular application. Any gaps between the pit wall and the lining should be filled with a plaster mix to develop some small degree of impermeability in the important top section of the well. The inside of the lining should also be plastered for at least the top 3 meters.

- ✓ Other Lining types: - This manual concentrates on the construction of wells for the provision of drinking water, and as a result deals with lining methods which are long-lasting and easy to keep clean.

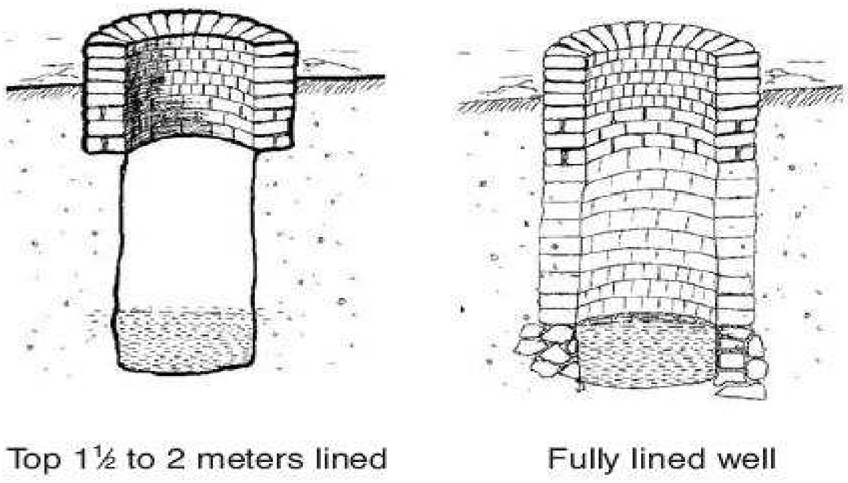


Figure 2.1 Types of lining methods

2.5. Stone riprap

Stone riprap is the most commonly used bank protection material in British Columbia. In some cases and also in some other jurisdictions, revetments are constructed of concrete blocks, gabions, concrete bags or mattresses, jacks or similar structures, articulated concrete slabs, rigid pavements, timber piles or fences, bio-engineering, or woody debris, such as trees, root boles, or brush. The advantages of riprap are that it is highly durable. (Riprap design, 2000).

2.6. Crop water requirement and cropping pattern

According to Peter Fraenkel (Water-pumping Devices, 1997) the quantity of water needed to irrigate a given land area depends on numerous factors nature of crops, crop growth cycle, climatic condition, type and condition of soil, topography, conveyance efficiency, field application efficiency, water quality and effectiveness of water management. Crop takes its water from moisture held in the soil in the root zone. The soil therefore effectively acts as a water store for the plants. The soil moisture needs replenishing before the moisture level falls to what is known as the permanent wilting point where irreversible damage to the crop can occur. The maximum capacity of the soil for water is when the soil is saturated, although certain crops do not tolerate waterlogged soil and in any case this can be a wasteful use of water. In all cases there is an optimum soil moisture level at which plant growth is maximized. The art of efficient irrigation is to try to keep the moisture level in the soil as close to the optimum as possible.

The output from the water-lifting device has to be increased to allow for conveyance and field losses; this amount is the growth irrigation requirement. For example, conveyance efficiencies fall into the range 65-90% (depending on the type of system), while farm ditch efficiency or field application efficiency will typical be 55-90%. Therefore, the overall irrigation system efficiency, after the discharge from the water-

lifting device, will be the product of these two, typically 30-80%. This implies a gross irrigation water requirement at best about 25% greater than the net requirement for the crop, and at worst 300% or more.
Cropping patter varies under different conditions of a region. As a characteristic of variation availability of water soil type and climatic condition have effect for the implemented crop pattern. Agricultural production can be increased by expanding agricultural land and by increasing the intensification of crop production through higher crop yields and higher cropping intensities. The cropping intensity in less-developed countries can be increased by about 5 - 10% during the next 35 years if adequate amounts of input are available (Doos and Shaw, 1999). Multiple cropping systems allow for this intensification by growing two or more crops on the same field either at the same time or after each other in a sequence (Francis, 1986b; Norman et al., 1995). They already are common farming systems in tropical agriculture today. In multiple cropping systems the risk of complete crop failure is lower compared to single cropping systems and monocultures providing a high level of production stability (Francis, 1986a). Furthermore the second crop in sequence may benefits from an increased amount of nitrogen derived from fixation (Bationo and Ntare, 2000; Sisworo et al., 1999) or phosphorous from deep-rooted species (Francis, 1986a) as well as from decreased disease pressure (Bennet et al., 2012) which helps to reduce the use of mineral fertilizer and pesticides. Cropping intensity is not only important in terms of agricultural production; the duration crops cover the soil will also influence albedo, ground cover, carbon sequestration potential and soil erosion (Keys and McConnel, 2005).

2.7. Irrigation Scheduling

Irrigation scheduling is system to determine frequency and duration of watering. It has been practiced with different models in different country. It means a viable practice that can enhance crop production and greater profit for farmers. It can lead to significant water saving, reduced environmental impact of irrigation and improved sustainability of irrigated agriculture. In order to define appropriate irrigation scheduling protocols for optimal water management and crop response and make recommendation to farmers, there is a need for proper evaluation of feasible irrigation scheduling option (Henry E, et al., 2006).

According to Colorado State University, the purpose of irrigation scheduling is to determine the exact amount of water to apply to the field and the exact timing for application. Irrigation criteria are the indicators used to determine the need for irrigation. The most common irrigation criteria are soil moisture content and soil moisture tension. Less common types are irrigation scheduling to maximize yield and irrigation scheduling to maximize net return.

2.8. AquaCrop

AquaCrop is model developed to determine the yield response to water (FAO, Irr & Ddra. 66). A direct relation exists between biomass production and water consumed through transpiration. Therefore water stress and reduced transpiration leads to biomass reduction in production. The model is developed by using the following concept and by separating the evapotranspiration into transpiration that is non-productive and evaporation which is productive.

$$\left(1 - \frac{Y_a}{Y_x}\right) = K_y(1 - \frac{ET_a}{ET_x}) \tag{2.1}$$

Where
Y_x and Y_a are the maximum and actual yield,
ET_x and ET_a are the maximum and actual evapotranspiration, and

K_y is a yield response factor representing the effect of a reduction in evapotranspiration on yield losses.

K_y values are crop specific and vary over the growing season according to growth stages with:
$K_y > 1$: Crop response is very sensitive to water deficit with proportional larger yield reduction when water use is reduced because of stress.
$K_y < 1$: Crop is more tolerant to water deficit, and recovers partially from stress, exhibiting less than proportional reductions in yield with reduced water use.
$K_y = 1$: Yield reduction is directly proportional to reduced water use.

The separation of transpiration lead to Equation 2.2 and also from the biomass produced part of it goes to harvest then it is formulates as it shown in Equation 2.3.

$$B = WP \sum T_r \quad (2.2)$$

$$Y = HI.B \quad (2.3)$$

Where
WP stands for water productivity
T_r = Crop transpiration
Y = Crop yield
HI = Harvestable index and
B = Biomass

Schematically it is represented as shown in Figure 2.2

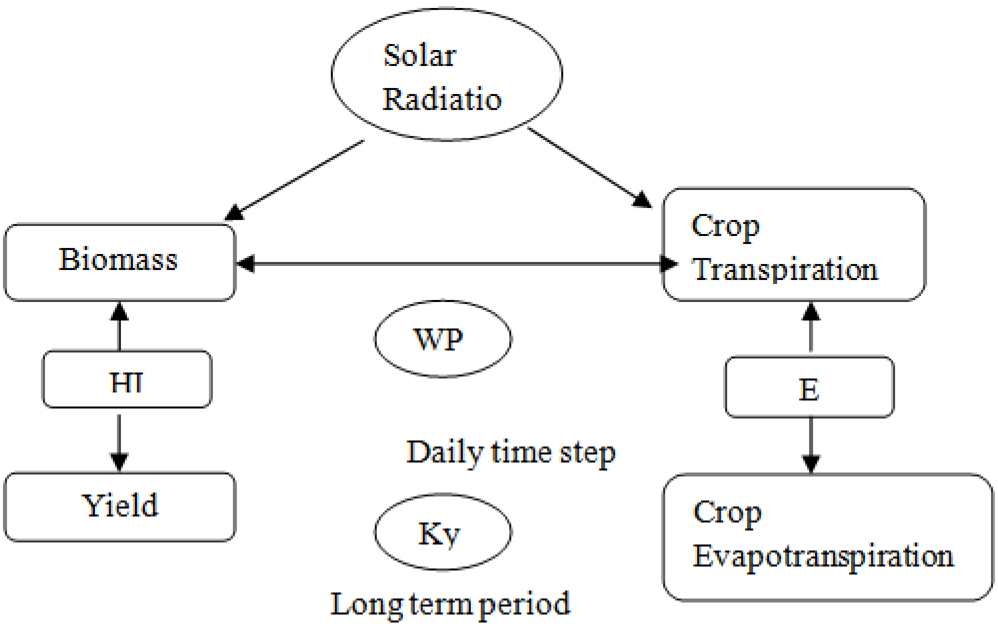


Figure 2.2 Schematically representation of biomass and yield

In addition the model uses as input the following data's:-

- **Climate** with its thermal regime, rainfall, evaporative demand and carbon dioxide concentration;
- **Crop** with its development, growth and yield processes;
- **Soil** with its water (and salt) balance;
- **Management** with practices including irrigation, fertilization and mulching.

Climate

Temperature influence crop development, like maximum and minimum air temperature, rainfall and evaporative demand of the atmosphere to be calculated using Penman-Monteith equation (Allen et al., 1998), including annual mean carbon dioxide concentration of the atmosphere. In order to run AquaCrop, the climatic variables from NewLoc Climwat were used.

Crop

In the crop component the included parameters are: phenology, canopy cover, rooting depth, crop transpiration, soil evaporation, biomass production and harvestable yield. After emergence, crop grows and develops over its growth cycle by expanding its canopy and deepening its root system, transpiring water and cumulating biomass, while progressing through its phenological stages. The harvest index (HI) alters the portion of biomass that will be harvestable.

$$CC = CC_o . e^{CGC.t} \tag{2.4}$$

Where
CC is the fractional coverage of the soil by the canopy at time t,
CC_o is initial CC (at t=0) and
CGC is canopy growth coefficient in fraction of percentage of existing CC at time t

The above formula works till the simulation reach to the point when CC = 0.5 CC_x then it continues with Equation 2.5.

$$CC = CC_x - (CC_x - CC_o). e^{-CGC.t} \tag{2.5}$$

Where: CC_x is the maximum canopy cover for optimal conditions.

Soil

The soil profile can be divided in two different layers of dept, each layer accommodating different soil physical characteristics: the water content at saturation; the upper limit of water content under gravity (FC, field capacity), the lower limit of water content where crop reach permanent wilting point (PWP) and hydraulic conductivity at saturation (K_{sat}).

Management

Management includes irrigation and field management. In case of irrigation management crop production can be under either rain fed or irrigation. While field management considers: fertility of the soil for growing the crop, use of soil bund (small dykes) to pond water or control surface runoff and enhance infiltration.

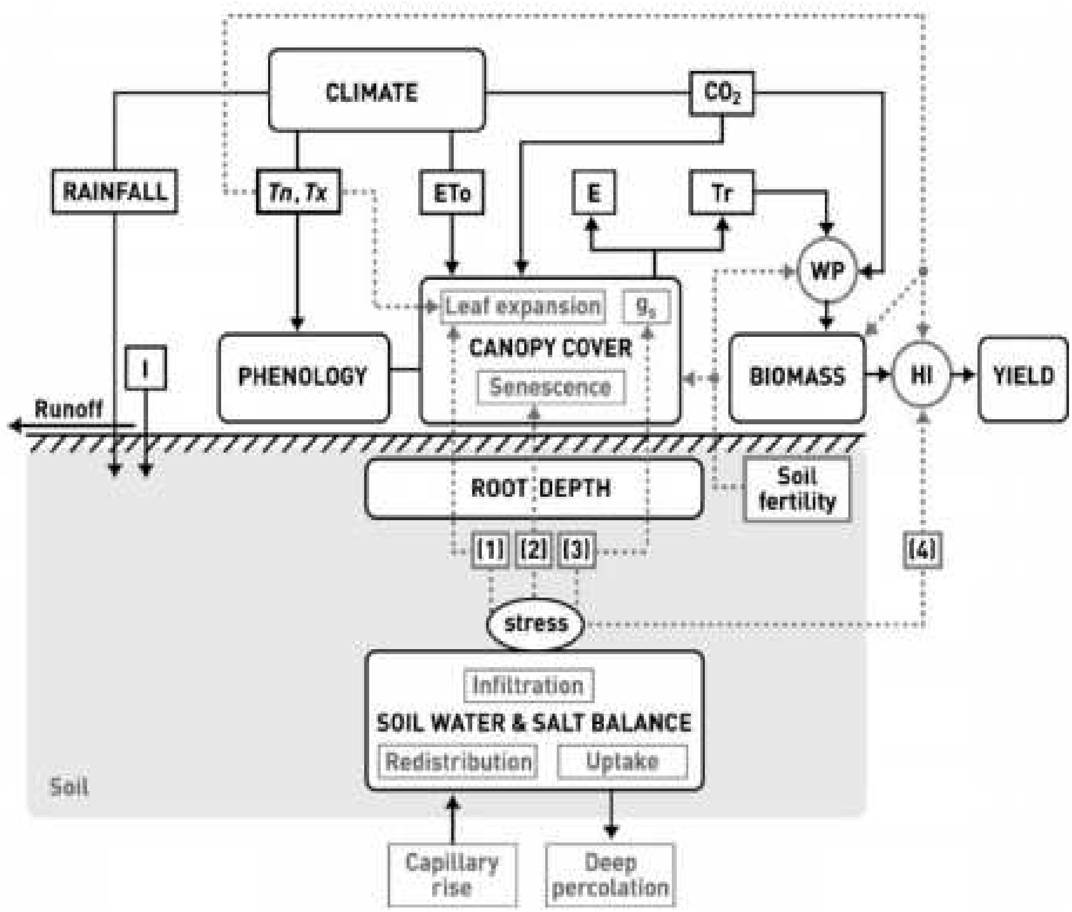


Figure 2.3 Main components of soil-plant-atmosphere

Stress

Stress can be classified as: Water stress, Temperature stress, Aeration stress, Mineral (nutrient) stress and soil salinity. The following factors affect the biomass production and harvestable index. The effects of stresses on crop growth are described by stress coefficient K_s have different formula for different shape of stress. Soil water stress affects the development of the canopy cover, expansion of root zone resulting in stomata closure and reduction of crop transpiration rate and alters the harvest index (AquaCrop manual 66). Air temperatures stress affects production of biomass and pollination of flowers. Soil fertility stress affects canopy development and biomass production. Whereas soil salinity stress affects crop production, it affects biomass production.

Green canopy cover

Green canopy cover is affected by soil water, soil fertility and soil salinity stress by decreasing its expansion. During crop growth maximum canopy might fail to be achieved and also the decline in canopy will be very fast due to the stress.

Effective rooting depth

The effective rooting depth is defined as the soil depth where root proliferation is sufficient to extract most of the crop water demand. It is affected when soil water stress starts to affect crop transpiration.

CHAPTER 3

Study area description

3.1. Location

The study area, which is called Koka, is located in the upper part of Awash River; which is one of the main rivers from the existing 11 main rivers in Ethiopia. It is located in the North latitude of $8^0 26^{'} 27.56^{"}$ and altitude of $39^0 01^{'} 54.45^{"}$ East and with average elevation of 1,613 m a.m.s.l. In related to the capital city; Addis Ababa, it is 93 Km far and the floodplain is accessed through walking, using motor bike or small car (Baggage). In Koka, totally there occur 35 kebeles.

Being in the area, Koka Lake can be observed and also while Mojo River joins the lake in East side of town. Koka Lake is manmade lake, which is created through diverting Awash River. There is 458 m long dam constructed in the northern part of the lake for production of hydro power generation. Around koka area, different companies are available which are; flower producing companies and leather factory. Other than these, farmers traditionally produce different crops on both flooded and non-flooded area.

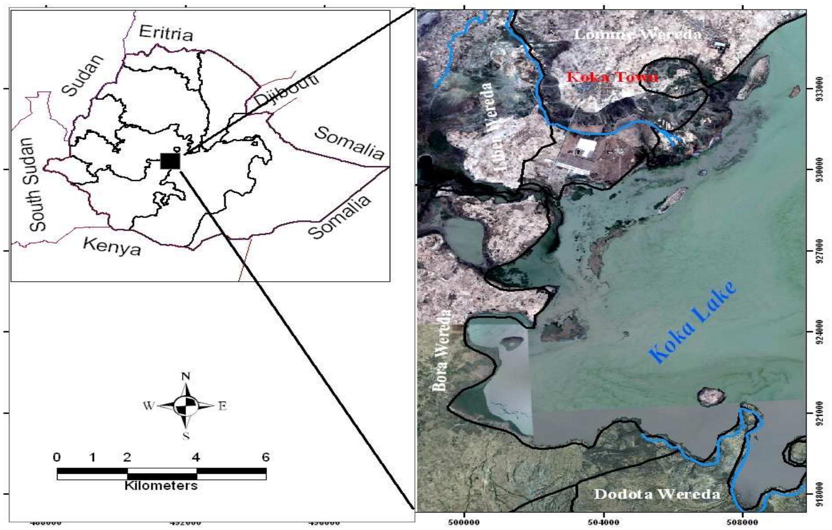


Figure 3.1 Location of study area

3.2. Climate and Hydrology

Precipitation and Temperature

Climatically the area is classified as arid and semi-arid region with quite huge variability in climate condition. As it seen from Figure 3.2, rainfall mainly occurs in July and August which is very short duration. This short duration of rainfall leads to long period of dry season, with minimum temperature of 11^0c and maximum temperature 33^0c. 15 years records of rainfall, temperature and four years of sunshine data were collected from National Meteorological Service Agency (NMSA) of Ethiopia. The mean monthly maximum and minimum records of temperature data are shown in Table 3.1 and 3.2 respectively. For the mean monthly rainfall and sunshine hours Table 3.3 and 3.4 can be referred respectively.

Table 3.1 Maximum mean monthly temperature of koka area

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max. Temp.	29.4	30.5	32.18	32.21	33.07	31.88	29.21	29.55	30.50	29.12	28.42	28.43

Table 3.2 Minimum mean monthly temperature of koka area

Month	Jan.	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Min. Temp.	12.12	13.63	14.61	15.21	15.52	14.97	14.50	14.71	14.8	12.89	12.58	11.3

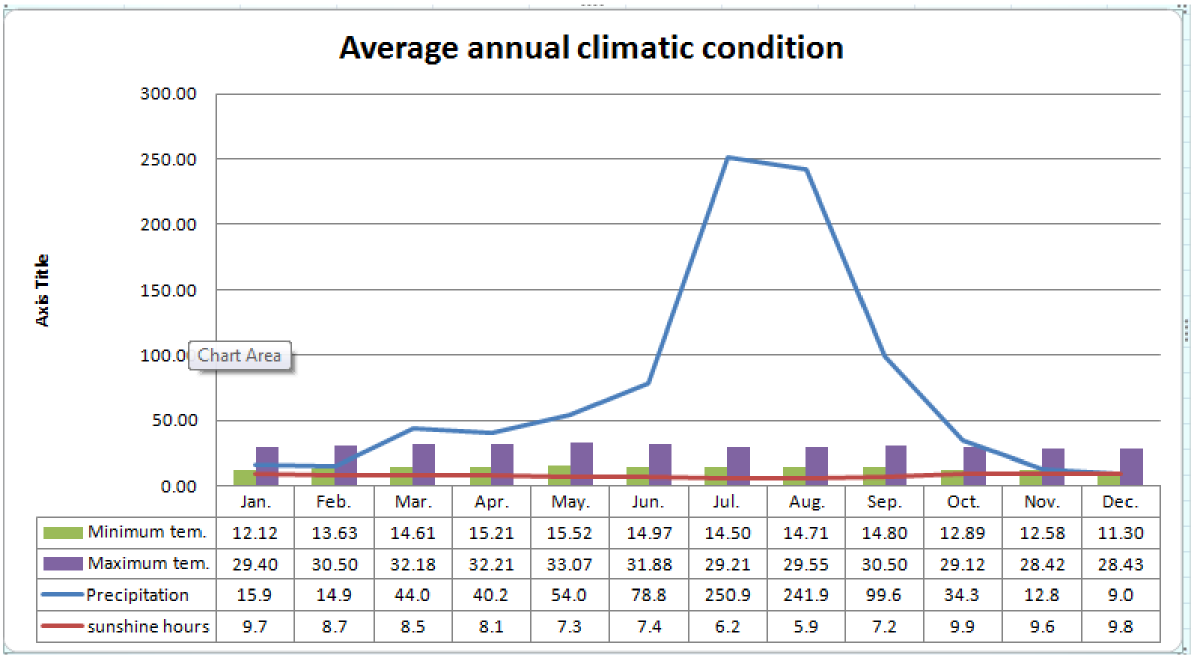
The area is characterized by unimodal distribution of rainfall patter ranging from 9 - 250.9 mm from monthly mean rainfall.

Table 3.3 Mean monthly rainfall of koka area

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Precipitation	15.9	14.9	44.0	40.2	54.0	78.8	250.9	241.9	99.6	34.3	12.8	9.0

Table 3.4 Mean monthly sunshine hours of koka area

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Sunshine hours	9.7	8.7	8.5	8.1	7.3	7.4	6.2	5.9	7.2	9.9	9.6	9.8



	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Minimum tem.	12.12	13.63	14.61	15.21	15.52	14.97	14.50	14.71	14.80	12.89	12.58	11.30
Maximum tem.	29.40	30.50	32.18	32.21	33.07	31.88	29.21	29.55	30.50	29.12	28.42	28.43
Precipitation	15.9	14.9	44.0	40.2	54.0	78.8	250.9	241.9	99.6	34.3	12.8	9.0
sunshine hours	9.7	8.7	8.5	8.1	7.3	7.4	6.2	5.9	7.2	9.9	9.6	9.8

Figure 3.2 Summary of mean monthly climatic condition of koka area

3.3. Land use and Land Cover

Data from MoWR was obtain showing in Figure 3.3; in which 44% of study area is cultivated under agriculture where as the remain 56% is occupied by urban and rural settlement, open bush lands etc.

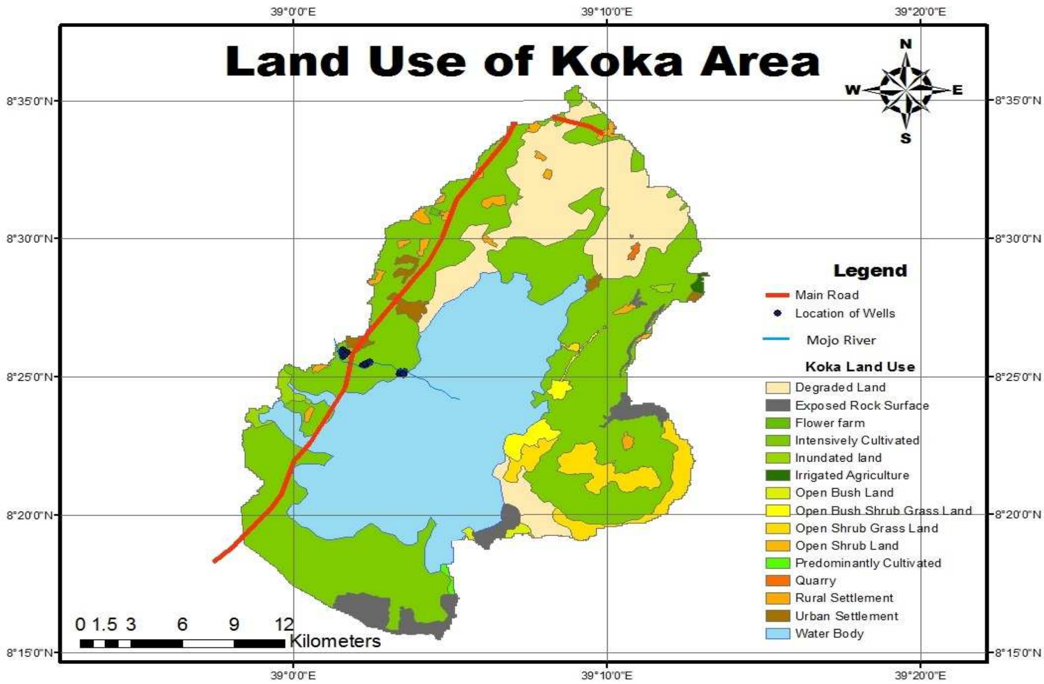


Figure 3.3 Land use of Koka area

3.4. Soil Type

According to the shape file obtained from MoWR of Ethiopia, soil type can be observed in Figure 3.4 which is Leptosoil is the dominant soil type in the area.

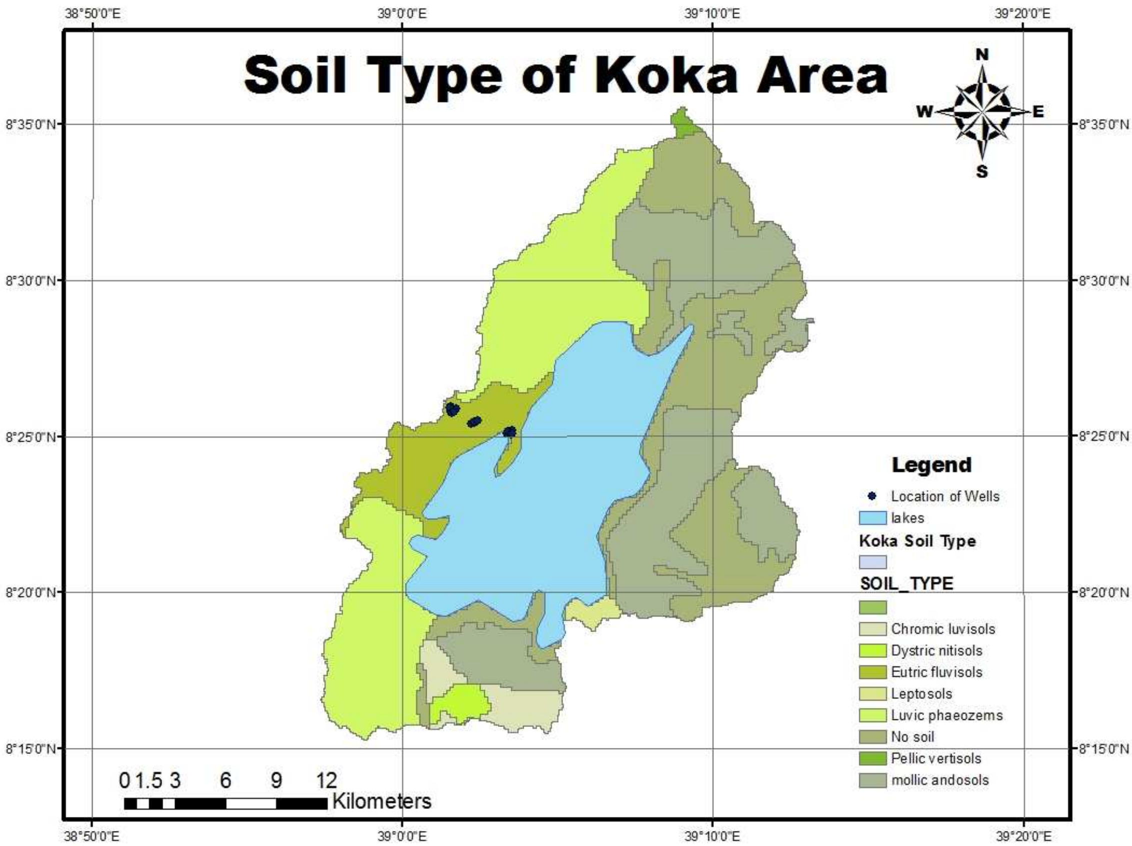


Figure 3.4 Soil type of Koka area

3.5. Agricultural Production

The livelihood of koka area depends on mixed agriculture; which is crop and livestock production. Fishing is also one of agricultural production which is done in Koka Lake side. During recession of flood water, as it happens slowly, few farmers do fishing following on the edge of the flood. Crop production is practised under rain fed and irrigated. Crop production is main agricultural activity implemented widely on the area.

Figure 3.5 Fishing following flood recede

Both non-flooded and flooded areas are engaged in crop production. In case of the non-flooded area, crop type produced is Teff in which it is produced under rain fed. Farmers which are in non-flooded area but on the edge, which is near to flooded area, cultivate their land other crops in addition to teff. Whereas in flooded area, crop type produced are; onion, maize, chickpea, water melon and tomato.

As teff is the main consumable crop type, most farmers engage themselves in production before rain starts. The yield generally varies farmers to farmer due to the existence of soil type. This is, in clay soil type area it can be produced up to 20 quintal/ha, though in sandy soil area 12 quintal/ha is gained. In the floodplain area cropping patter varies due to flood recession timing and farmer preference. The main resources for irrigation are hand-dug wells and river water. Farmers implement pumps for abstraction of water either from the hand-dug wells or river. The major crop produced in the area is onion, because it is cash crop.

CHAPTER 4

Materials and methods

4.1. Methods

During field visit, materials were collected through structured and semi-structured questionnaires, field measurement, field observation, laboratory analysis and consulting advisory literature review. Consulting available materials were done in the agricultural office (Lume Wereda Agricultural Office), metrological station (NMSA) and ministry of water resource (MoWR). The questionnaires forwarded to stakeholders are listed in Appendix A. Generally, the agricultural office can be said, doesn't have good structure in organizing information available on field and it was also difficult to get the papers all together or compiled properly. Setup of the methods summarized in Figure 4.1

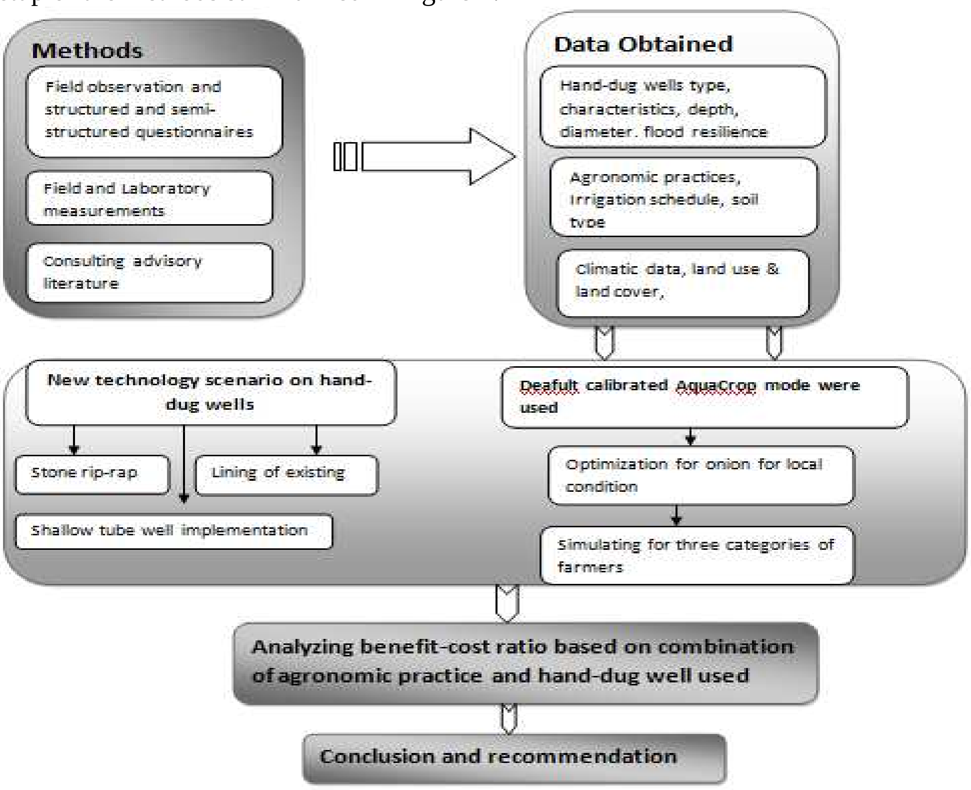


Figure 4.1 General flow of methods and methodology

Totally 50 farmers were interviewed, from which 34 had hand-dug wells, whereas 16 didn't had well because of their field exists near to Mojo River. During the visit, farmer were doing different activity; like ploughing, irrigating, cleaning and planting. There were also farmers who were waiting for flood, from Koka Lake side, to recede back. Therefore, the interview was both on field and outside field.

Metrological and hydrological data were also obtained through consultation of MoWR and NMSA which were used to express the study area and as an input to AquaCrop model. Areal delineation based on digital elevation models (DEMs) was done using data obtained from MoWR.

Field measurement was also one of the method implemented to obtain; depth of ground water from hand-dug wells, diameter of the wells and GPS reading of hand-dug wells. GPS reading helped to locate the wells in a map as shown in Table 4.1. Ground water depth measurement inside hand-dug wells helped to respond for both first and second research question.

Soil textural class were identified by taking soil sample from the area. Disturbed sample were taken from field and it was processed in laboratory (Ministry of water resource) to identify field capacity, permanent wilting point and textural class.

Table 4.1 GPS reading of existing hand-dug wells

Well number	Latitude	Longitude	Depth of well (meters)	Static water level (meters)
1	506188	930532	12	6
2	506487	930725	12	8
3	506257	930692	8	4
4	506433	930479	10	7
5	506465	930545	8	6
6	503159	932003	12	7
7	503145	932020	8	6
8	503142	932013	12	9
9	506243	930688	10	7

Site observation was also one of the methods that have helped in identifying agricultural activities being implemented. In addition, structured and semi-structured interviews were conducted with stakeholders on field and outside field. Floodplain were able to be observed without flood and with flood, because of flood on Koka Lake side were not completely receded and from Mojo River side flood were already recede in September. Agronomic activities like preparation of land, planting, irrigating and weeding were also being practiced. Hand-dug wells in floodplain area and outside floodplain area were observed including problems faced that was caused due to flooding. Few of questionnaires which were addressed to farmers during field visit are listed below and the full is listed in Appendix A.

- Does your hand-dug well affected during flooding?
- When does flood come and recedes back?
- What happens to the hand-dug well after the flood recedes back?
- What are the crops produced, when do you plant, harvest, how do you irrigate and how much hectare do you have?

4.2. Data Preparation

Data which were used in AquaCrop model and for analyzing benefit-cost ratio are obtained from NMSA and farmer's response. For interpretation of results in AquaCrop, the following data were used; climate, crop, soil and management data. Climatic data were obtained from NMSA in terms of daily rainfall, sunshine hours, maximum and minimum temperature. Daily sunshine hours, maximum and minimum temperature were used to get evapotranspiration in software called ET_o calculator and the result data were used as input for AquaCrop together with daily rainfall and temperature.

Crop characteristics were obtained from stakeholders and literature, which identify existing condition as optimum situation. Parameters which were required to be filled in AquaCrop were; development of crop, evapotranspiration under no fertility, salinity and water stress, and response of crop to different stress. Soil horizon is one of the parameters to be identified for result analysis. In the management part, irrigation schedule applied by different farmers and field handling are included. The data's were obtained from measured, observed and questionnaires. The last part was cost encored for production of onion which also differs between farmers due to income and availability of resource.

Precipitation, Temperature and Sunshine hours

The data from year 2010 till 2012, of minimum, maximum temperature and sunshine hours were used in ET_o calculator to determine daily ET_o. As specified in AquaCrop manual 66, ET_o calculator determined either with few years' data or more can't be vary too much. Therefore the input data's' can be observed from below figures.

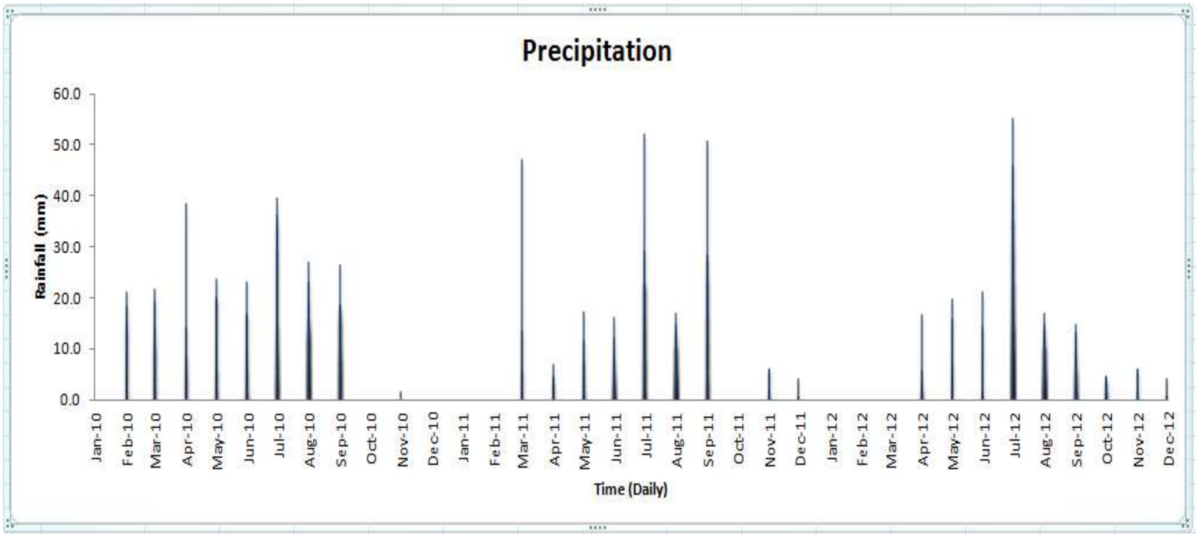


Figure 4.2 Daily Precipitation of Koka area

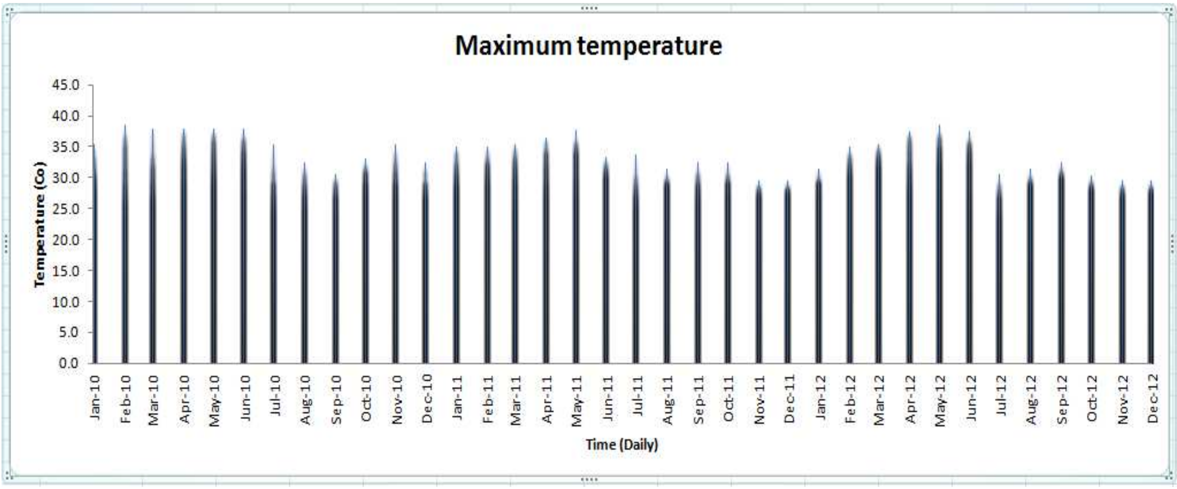


Figure 4.3 Maximum temperature of Koka area

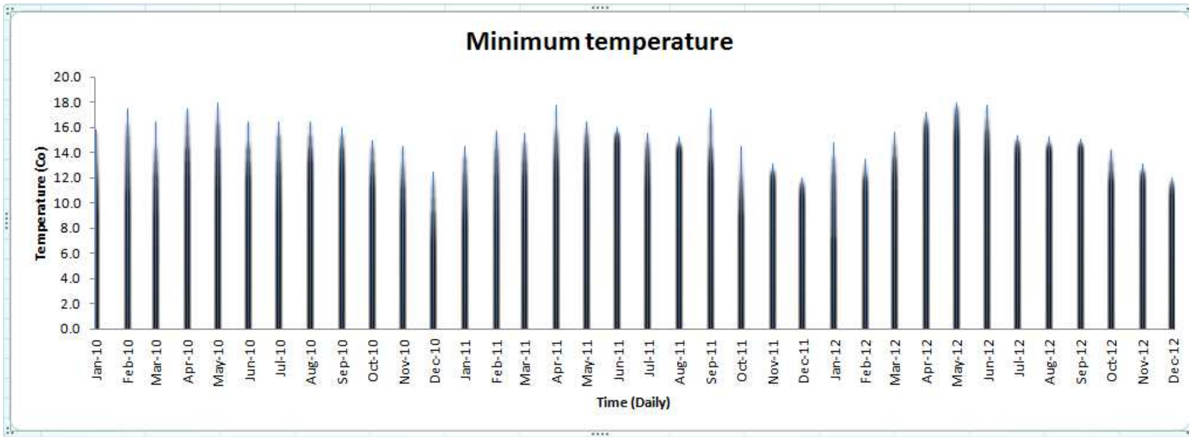


Figure 4.4 Minimum temperature of Koak area

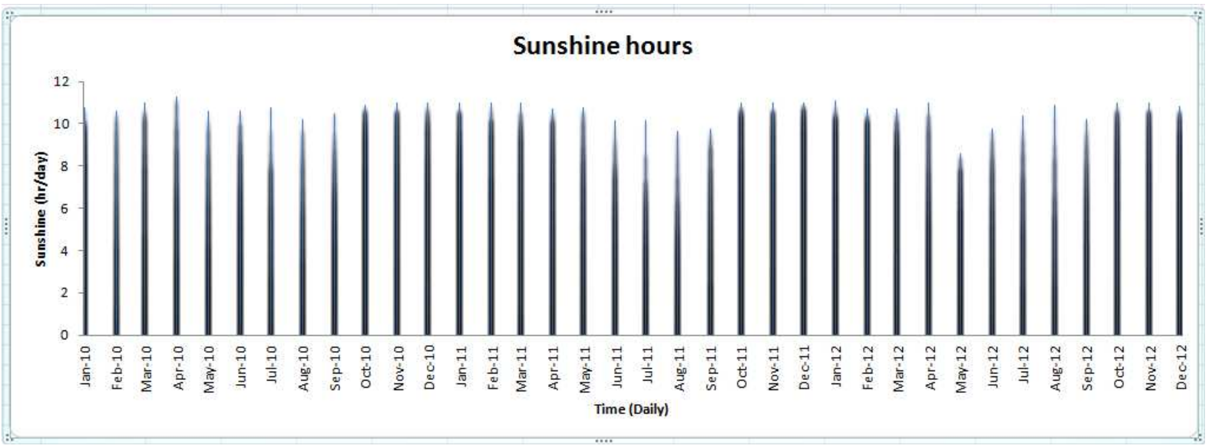


Figure 4.5 Sunshine hours of Koka area

4.3. Model Setup

AquaCrop calculates a daily water balance and separates its evapotranspiration into evaporation and transpiration. Transpiration is related to canopy cover which is proportional to the extent of soil cover whereas evaporation is proportional to the area of soil uncovered. The crop responds to water stress through four stress coefficients (leaf expansion, stomata closure, canopy senescence, and change in harvest index). The model reproduces the canopy cover from daily transpiration taking into account leaf area expansion and canopy development, senescence and harvest index. (Steduto et al 2009). The model generally has input parameters of weather data, crop and soil characteristics, and management practices that define the environment in which the crop will develop (Dirk R., Pasquale S., Theodore C., and Elias F., 2011). It relates its soil-crop-atmosphere components through its soil and its water balance, the atmosphere (rainfall, temperature, evapotranspiration and carbon dioxide concentration) and crop conditions (phenology, crop cover, root depth, biomass production and harvestable yield) and field management (irrigation, fertility and field agronomic practices) components (A. Araya, Solomon H., Kiros M., Afewerk K. & Taddese D. 2010). The model has interface as shown in Figure 4.6 with specification of input data requirement.

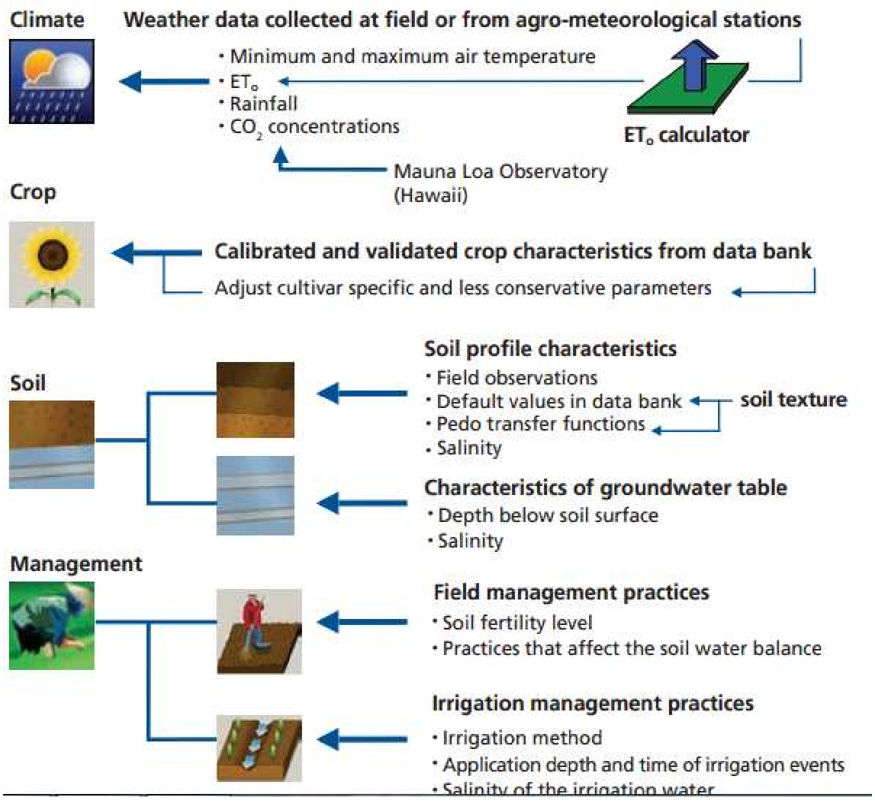


Figure 4.6 AquaCrop model over view

4.3.1. Climate Data

Weather data includes; Tn, Tx, precipitation, ETo and CO2 concentration are required as input in AquaCrop model. The data's were obtained from NMSA while the evaporative demands of the atmosphere were calculated using software called ETo calculator. It is software developed by Land and Water division of FAO. The ETo calculator assesses ETo from meteorological data by means of the FAO Penman-Monteith equation. This method has been selected by FAO as the reference because it closely approximates grass ETo at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters.(FAO manual, ETo calculator). The software looks as shown in Figure 4.7, which uses climatic data as input to generate the ETo. Required data's are maximum, minimum temperature, sunshine hours, relative humidity and wind speed. In case of this thesis, due to failure of existence of few parameters data, input data like daily air temperature and sunshine hours starting from 2010 up to 2012 were used to obtain evaporative demand of the atmosphere. Even where the dataset contains only maximum and minimum air temperature, it is still possible to obtain reasonable estimates for ten-day or monthly ETo. (FAO manual, ETo calculator).

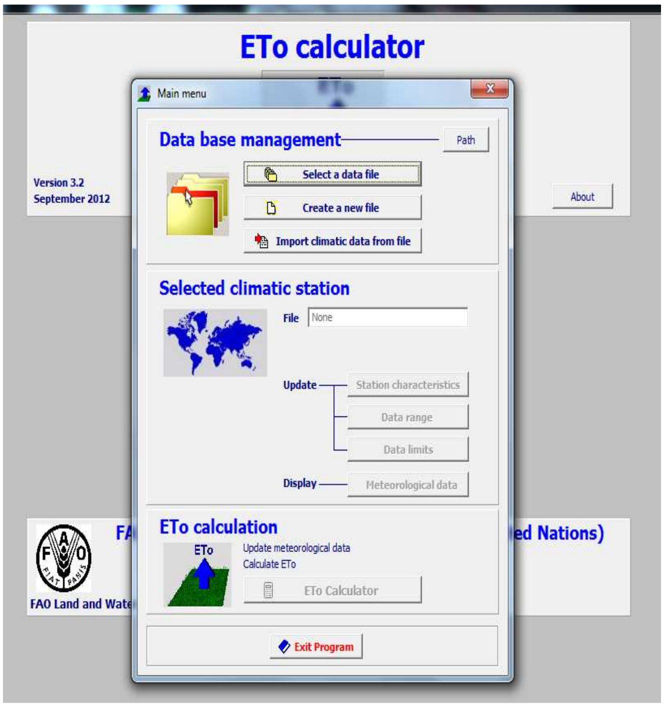


Figure 4.7 ETo calculator

The result obtained from the software for three years of ETo is shown in Figure 4.8.

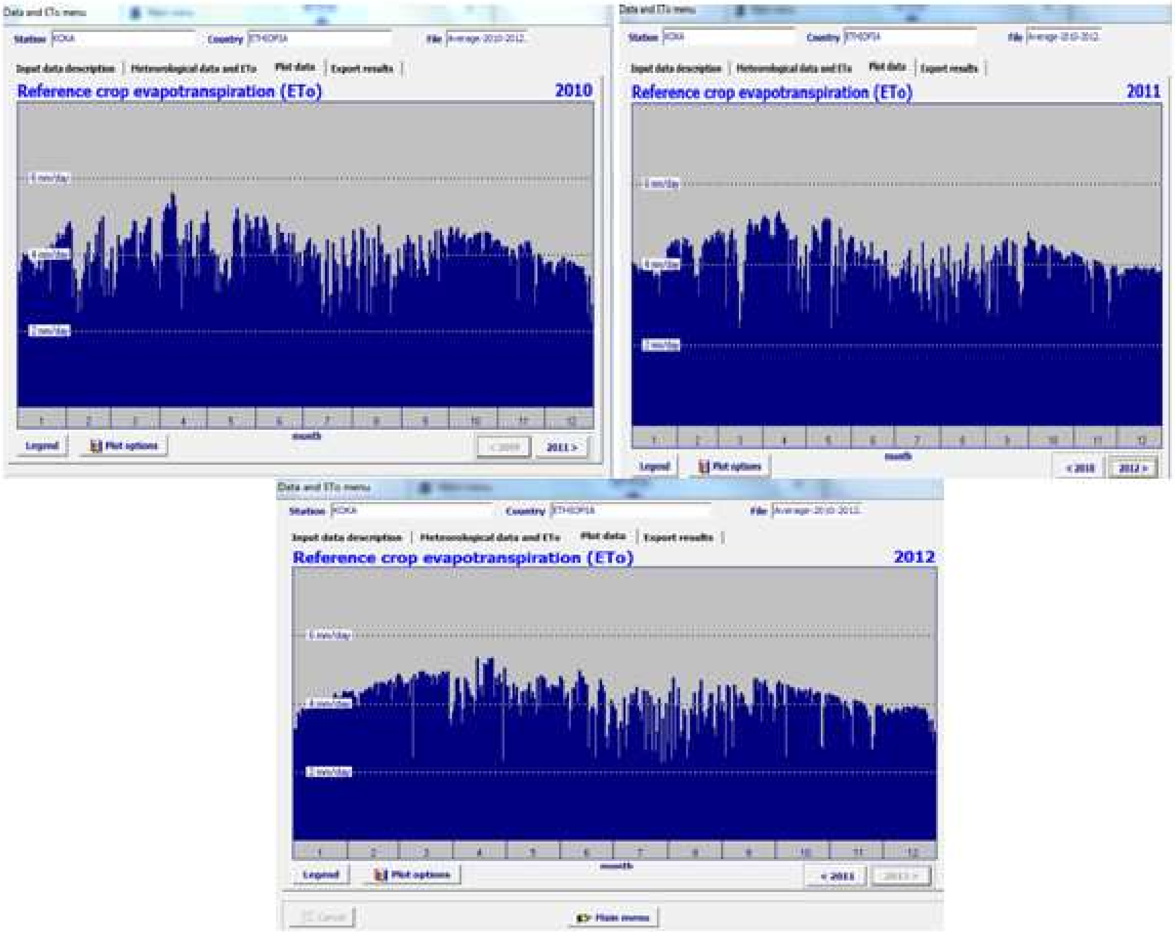


Figure 4.8 ETo result from ETo calculator for the period of 2010 to 2012

Monthly evaptranspiration observed for three years with range between 104.7 and 141.9 mm that has resulted from daily variation of 2.2 and 5.6 mm of Koka area.

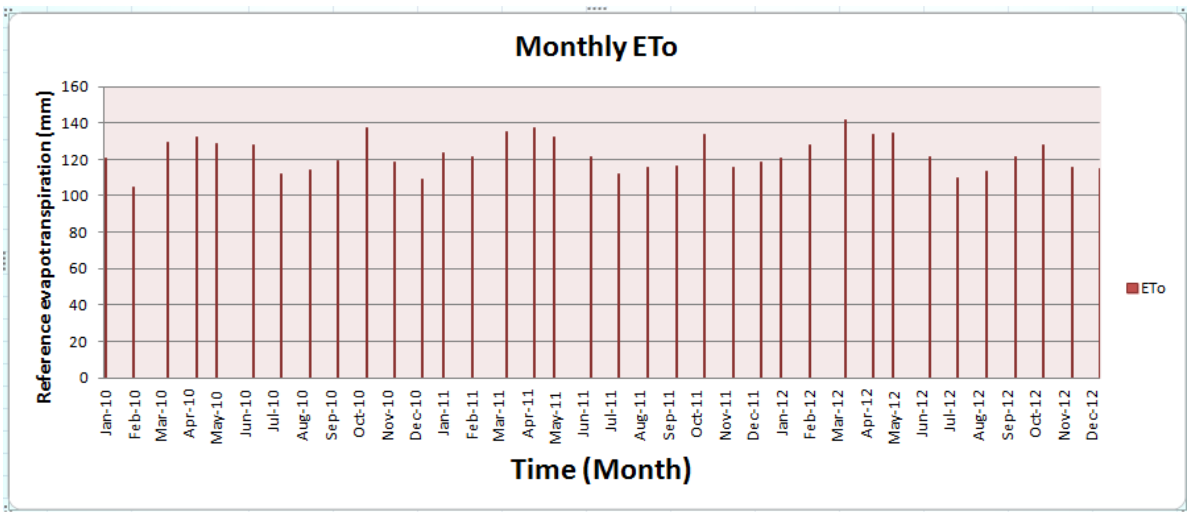


Figure 4.9 Monthly reference evapotranspiration of Koka area

The output from the software; that is reference evapotranspiration, together with CO2 concentration, daily rainfall and temperature was used as input in AquaCrop for generating growing condition of the crop.

4.3.2. Crop characteristics

Characteristics of onion crop were obtained from interviewing farmers and reviewing of literature; which are crop development, crop production and response to stress. Since the model need experimental results for the entire growth of onion, calibrated potato was chosen and made changes on few parameters with local condition; that is to validate for onion crop. Conservative parameter which were not changed and parameters which were updated for validating the model are shown in Table 4.2 & 4.3.

Table 4.2 Conservative and non-conservative parameter for onion crop

Parameters	Methods	Values
Plant density	Calculated from estimation with planting spacing of 30 cm between rows and 8 cm between plants	416,667 plants / ha
From day 1 after transplanting to recovered	Non-conservative	7 days
From day 1 after transplanting to maximum canopy	Non-conservative	47 days
From day 1 after transplanting to senesces	Non-conservative	90 days
From day 1 after transplanting to maturity	Non-conservative	120 days
From day 1 after transplanting to maximum rooting depth	Non-conservative	91 days
Maximum rooting depth	Non-conservative	70 cm
Canopy expansion	Conservative	13 % /day
Canopy decline	Conservative	1.9 % /day

Onion generally classified as shallow root depth crops but according to Drinkwater and Janes (1995) found that although the maximum root penetration was 0.76 m, most of the roots were in the top 0.18 m of soil, whereas only few roots were found below 0.31 m. Irrigation water that moves below 0.76 m is most likely not available to the onion crop. According to Greenwood et al. 1982 showed that 90% of the root system of the onion plant was concentrated at the top 0.4 m of soil and only 2 -3 % of the total root length was recorded below 0.6 m depth, which indicates that very little water could be extracted from soil depths below 0.6 m. (Peji et al., 2011).

The parameters which were updated to validate the model for onion is listed in Table 4.3

Table 4.3 Validation parameters of AquaCrop

Parameters	Based on	Inserted as
Root depth	Maximum achievable growth	70 meter
Reference harvest index	Crop type and less biomass needed (under no	200 %
Soil salinity	Biomass production affected by soil salinity	Not considered
Soil fertility	Biomass production affected by soil fertility	Not considered

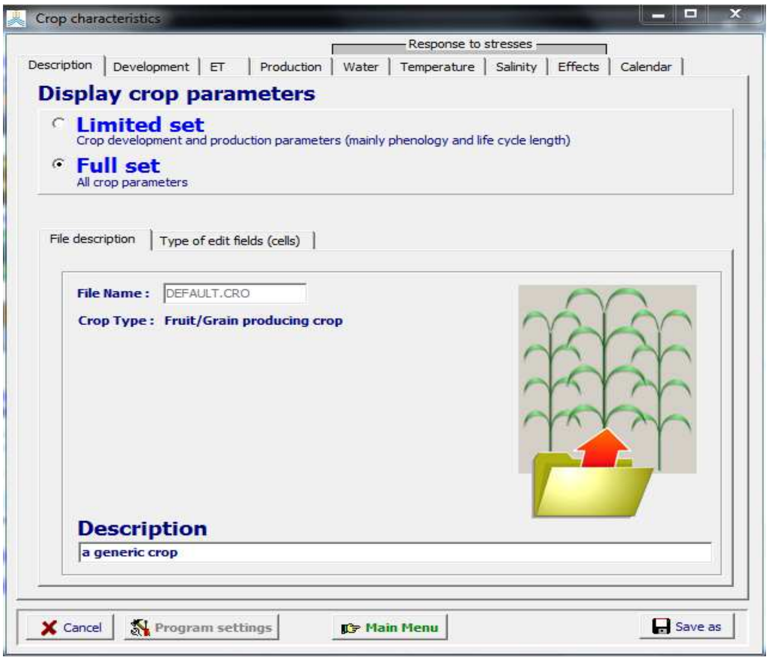


Figure 4.10 Crop characteristics input in AquaCrop

4.3.3. Management practices

The following part includes irrigation and field management parameters, in which irrigation either can be generation, net or practiced irrigation schedule. In case of field parameter, available field surface practices like soil bund height and soil fertility practices like mulching are parts to be filled thus soil bud height in the study area is 20 cm. In case of irrigation, base line for the optimum available production was created while validating the model.

Scenarios were also created to assess profitability of the existing irrigation methods; which are those farmers who has financial capacity and good follow up. Secondly, farmers that don't apply fertilizer but that follow proper irrigation schedule and the last one, farmer's application without fertilizer and follow different irrigation scheduling.

4.3.4. Soil characteristics

Soil profile and ground water depth are parameters to be inserted in this part. The existing textural soil classifications in horizon were obtained from Debrezeit research center. As shown in Table 4.4, soil sample were taken from the area for textural identification in ministry of water resource and resulted major clay loam.

Table 4.4 Textural analysis from laboratory result

% of particle	Sample 1	Sample 2	Sample 3	Sample 4
Sand (%)	8.15	24.78	50.51	27.03
Silt (%)	32.48	38.13	32.64	35.44
Clay (%)	59.37	37.07	16.85	37.53
Textural class	Clay	Clay loam	Loam	Clay loam

4.4. Optimization

Model optimization was done by first changing the non-conservative parameters based on local condition and keeping CGC and CDC as it is calibrated before. Hence production of onion in the area were obtained up to 40 ton /ha, therefore to get the value harvest index were put at 200 % since onion is kind crop in which bulb building up needed instead of the biomass produced. For fertility stress, it (we) was considered none because of farmers apply fertilizer. The irrigation was under generation of irrigation schedule based on 50% RAW, in which irrigation starts while 50 % of the readily available water is decreased in root zone to be abstracted by the crops. The existing farmers' were looked under three categories in assessing their yield obtained.

First category (Farmer type A)

Keeping the entire parameters input constant, which were obtained during optimization, application of fertilizer and irrigation schedule were update base on existing condition. For these farmers type, as they apply fertilizer, soil salinity and fertility stress were not considered. In case of irrigation, the schedule they were using; for initial growth irrigating per 3 and 5 days interval. In case of mid and late season growth 8 day interval were applied.

Second category (Farmer type B)

In the second category, farmer type B was considered. These farmers doesn't apply fertilizer therefore, soil salinity and fertility were considered. The irrigation schedule that was followed by these farmers was also updated by 5 and 10 days interval.

Third category (Farmer type C)

These farmers' were almost like farmer type B, but their main difference was in application of irrigation scheduling; that is type C farmers adopt 10 days interval earlier than type B farmers.

4.5. Scenario development for Hand-dug well

To alleviate existing hand-dug well problems, three technologies were selected to be assessed: stone riprap, lining with cement and shallow-tube well implementation.

4.5.1. Shallow tube well

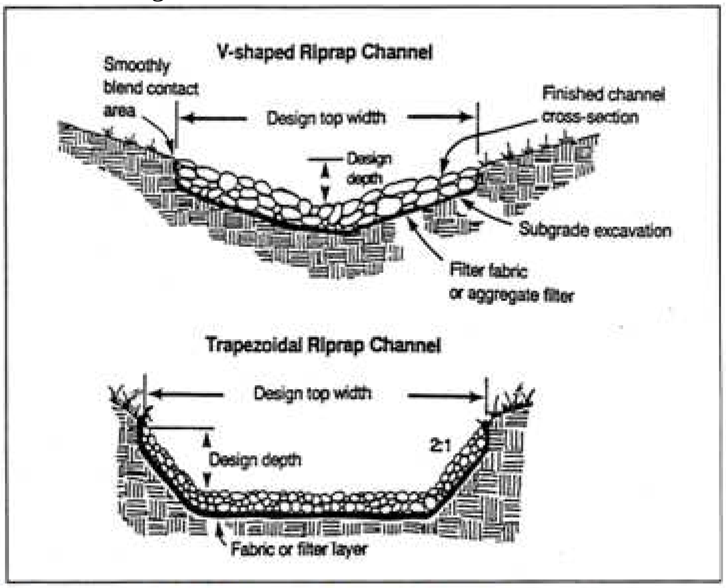
Ground water irrigation is one of method which is applicable in areas where there is less surface water available. To access ground water, wells can be implemented; which are manual drilled wells or machine drilled wells. The difference in between the wells drilled in both methods are; machine drilled wells are very deep and expensive but in case of manual drilled wells, they are cheap and can be applicable by small holder farmers. There are four types of manual drilling techniques; Jetting, Percussion, Hand Auger and sludging.

Table 4.5 Drilling type of wells

Type of drilling	Applicability of soil type
Jetting	Loose and soft
Percussion	Consolidated rock layer
Hand Auger	Soft soils
Sludging	Applicable for a range of soil formation

4.5.2. Stone riprap

Stone riprap is one of technology which helps in protecting surface from scouring. It is constructed by using different size stone lined in slant shape. Its limitation is it cannot be installed for steep a slope which is difficult to re-grad to a lower angle.



https://www.google.nl/search?q=images+of+stone+riprap

Figure 4.11 Stone riprap

4.5.3. Lining of Hand-dug well

Lining of hand-dug well is concrete made form. Hand-dug wells in the top up to two meter can be constructed by lining to alleviate continues collapsing of side walls. After lining the side wall, in order to protect the well from sediment deposition top part can be covered.

https://www.google.nl/search?q=images+lining+of+hand-dug+wells

Figure 4.12 Lined well

4.6. Benefit-cost Analysis

Benefit-cost analysis is process of calculating and comparing cost and benefit of engaging new technology or existing practice. During interviewing of farmers, costs spent for both agronomic and hand-dug well implementation were obtained. Therefore in this study, benefit-cost ration studied both for existing practice and improved method of production.

General cost spent for all activities implemented starting from cleaning of lilies, which are grown during flooding, up to harvest and either construction or maintenance cost will be total cost. And revenue obtained by selling onion crop will be calculated to deduct the cost spent for production. Finally, to get BCR, benefit obtained will be divided by the total cost.

CHAPTER 5

Result and discussion

5.1. Agronomic practices in floodplain

Floodplain agronomic practices are implemented after flood recedes back, except few farmers start ploughing before flood comes in order to capture fertile soil. Generally, floodplain crop production is off-season production in which agronomic practices starts from cleaning of debris, which are left behind flooding. At the time of visit, flood from Mojo River has already recedes back, which usually starts flooding around July and end in the beginning of September. While on Koka Lake side (KL), flooding starts in September and continues to recede back till end of February therefore, during field visit the floodplain observed from KL side can be observed as in the Figure 5.1.

Flooding from Koka Lake takes around five month to completely recede back. Therefore farmers implement fishing while it recedes back.

Figure 5.1 During flooding from Koka Lake

During flooding material like alluvial sediment, plants (which are called lilies) and debris are deposited and grown. The plants which have grown can be observed in Figure 5.4. Later than flooding and when the field is suitable to work, farmers start to hire employees for uprooting, collecting and burning of debris. During visit, it was observed that 20 employees were working in one hectare to finish the cleaning work for two days.

Figure 5.2 Flood receded from Mojo River floodplain

Figure 5.3 Farmers fishing and field without lilies

Ploughing

Ploughing is different per farmer's preference, crop type and season of cropping. It is done using tractor and oxen as shown in Figure 5.5 after cleaning of the debris left behind from flooding. It is also differ in when to start the activity, which are some farmers start to plough before flooding and other after flooding. Generally, for onion three times and for chickpea one time ploughing is implemented. Nevertheless some farmers only plough two times for onion. In case cropping season, for second cropping period two times of ploughing is done. The farmers use tractor especially for first round then oxen for the two rounds.

Figure 5.4 Lilies grown, uprooted & burned

Figure 5.5 Ploughing using tractor and oxen

Planting and irrigation

The next agronomic practice implemented after preparation of land is planting and irrigation. As shown in the next figure, planting was done following irrigation. One person assigned for irrigating the field and two other persons follow by planting on the irrigated part. Planting space varies per crop type; for instance for onion, planting space between plants is 5 - 8 cm and between rows 25 - 30 cm. However for chickpea, spacing between plants is 1.40 meter. Another variation in case of planting is due to flood recedes in different time, farmers have different planting date.

Figure 5.6 Planting & Irrigation

Irrigation varies per crop type, season of planting, farmers understanding and income of farmers. However, chickpea and water melon doesn't use irrigation as they are planted immediately after flood recedes, therefore growing condition will be with moisture retained from the flood. While for onion, tomato and maize will be grown under irrigation but under different irrigation scheduling

Table 5.1 Irrigation interval per crop type

Type of crop	Irrigation schedule for first cropping season	Second Cropping season
Onion	3 days up to 10 days interval irrigation, depending on plant status, climatic condition and affordability. First growing season, from October to January.	3 days up to 10 days interval irrigation, depending on climatic condition, crop development and affordability. Second growing season, from March to June.
Tomato	One day per each week	
Chickpea	No irrigation during crop growth period, use residual moisture	
Maize	Every week	
Water Melon	No irrigation during crop growth period, use residual moisture	

Water source for irrigation in the floodplain are hand-dug wells and Mojo River. Farm fields which are found near to Mojo River; that is within 100 meter distance uses the river as source for irrigation. And those field which are within floodplain area but away from the river, uses hand-dug wells. To convey water, pipes were used till 100 meter length.

Figure 5.7 Irrigation from river and hand-dug well

Table 5.2 General farming practices followed

Different farmers	Ploughing	After flood	1st cropping	2nd cropping	Irrigation	Farmers near to river
Farmer 1	Ploughing Before flooding	Cleaning then two times ploughing with oxen	Plants chickpea	Continues with chickpea	Source for irrigation are hand-dug wells and Mojo River, using pumps	Because of flow inside river decrease or even sometimes no flow occur, few of farmers leave the area for grazing and some of them continue producing maize production.
Farmer 2			Continue with preparation of land	Plants onion		
Farmer 3			Plants Onion	Plants Onion or Maize		
Farmer 4	Ploughing later than flooding	Weeding then ploughing three times	Plants chickpea	Continues with chickpea		
Farmer 5			Continue with preparation of land	Plants onion		
Farmer 6			Plants onion	Plants Onion or Maize or grazing		

5.2. Cropping pattern & irrigation

Cropping patter is yearly sequence and spatial arrangement of crops on an area. In koka floodplain, cropping patter in a season especially after flood receded, were observed to be planted by chickpea and onion. Generally crop preference to be planted in a season is mainly chosen by farmers. Since it depends on their income and properly follows up, it varies within each farmer. Farmers may start planting the first season by chickpea, onion or tomato. Farmer plant chickpea immediately after flood recede; as it grows without irrigation, only using moisture left behind flooding. Later the farmer will continue planting either onion or tomato. Another type of farmers is, they wait few more days after flood recede till the moisture decrease by cleaning of debris and ploughing then planting continues.

Second season choice of crop was also dependent on farmer preference, income and for those farmer who use Mojo River as source of irrigation, availability of river flow determines what and when to irrigate. Most of crops followed are onion, tomato and maize. Third cropping season is applicable for those farmers relatively on the edge of floodplain or for farmers which plant and harvest chickpea earlier. Otherwise farmers leave the area for grazing before flood comes. Types of crops planted can be shown in Table 5.3. Cropping season followed by few farmers and planting date by farmer is shown in Table 5.4 and 5.5.

Table 5.3 Applicability of cropping area

Crop Type	Planting area and cropping period
Onion Tomato	➢ In flooded area and farmers on edge of floodplain apply the practice. ➢ Takes 4 month to be harvested
Pepper	➢ Applied by few farmers, who understand the benefit of crop rotation.
Head Cabbage	➢ Applied by few farmers, who understand the benefit of crop rotation.
Water Melon	➢ Farmers on floodplain area from Koka Lake produce water melon, in which the growing period is for one season cropping.
Chick pea	➢ Applied immediately after flood recede and takes 3 up to 4 months
Teff	➢ Production in non-flooded area and takes up to 4 month
Maize	➢ In flooded area and farmers on edge of floodplain apply the practice. ➢ Takes 3 up to 4 months

Table 5.4 Cropping pattern followed by most farmers

Farmer type	First Cropping	Second Cropping	Third cropping
Type 1	Chickpea	Onion	It depends on farmer wish; that is either farmers will plant maize or leave the area for grazing.
Type 2	Onion (Late planting)	Onion	
Type 3	Onion (Late planting)	Either farmers continue planting maize or field will be grazing area	
Type 4	Onion (Late planting)	Flood appears or area will be for grazing	
Type 5	Onion	Tomato	Flood appears

For few farmers one cropping season is applicable due to the flood recedes very later and comes early. Another reason told by farmers is, which are from Koka Lake side, they had an agreement to plant only for one season and later to use it for grazing. These farmers have huge (4 - 8 ha) hectare of land as compared to the other farmers who own only half hectare of land.

Table 5.5 Cropping season and irrigation source

Crop Type	Season of Production	Means of irrigation	Area of Production
Onion	Summer (120 days), can be planted two times per year.	Ground Water	Floodplain and partially flood area
Tomato	Summer (120 days), planted one time per year	Ground Water	Floodplain area
Pepper	Summer, planted by very few farmers	Ground Water	Floodplain area
Teff	Winter (3 up to 4 month), planted one time per year.	Rain Water	Outside floodplain area
Water melon	Summer (3 up to 4 month), Planted one time per year but there are farmer who do two times.	Moisture of soil / Ground water	Floodplain area
Chickpea	Winter (3 up to 4 month), planted one time per year.	Rain Water/Using soil moisture	Floodplain area
Maize	Summer (3 up to 4 month), planted one time per year.	Mojo River/Ground water	Floodplain and partially flood area

Farmers which are found near to Mojo River cultivate maize using water from river to irrigate the area before they plant. The planting season is in April, in which the flow gets very low and temperature is high. Therefore farmers struggle to get irrigation by doing at night two times before and during planting in April, as in this month evaporation is very high. The farmers will harvest maize before flood starts to inundate the area; which is starting beginning of July. Water flow inside Mojo River at the time of data collection looks as shown in Figure 5.8.

Figure 5.8 Irrigation from river water

Farmers or other investors in these times; that is when flow gets lesser, will collect sand that was deposited at the time of flooding. Farms which are relatively far from Mojo River uses ground water for irrigation; that is using hand-dug well as shown in Figure 5.9.

Figure 5.9 Irrigation from hand-dug well

Irrigation scheduling applied per each farmer varies. The variation comes due to number of reasons such as; farmers are in lack of money for pumping water either from river or hand-dug wells, failure to implement continuous follow up and less flow in case of irrigation from Mojo River. In addition, variation in application of fertilizer was observed which leads to decrease of yield obtained per farmers. Generally variation between farmers can be observed starting from when to plough, as shown in Table 5.6.

During cropping period, before they harvest rainfall might occur after they already stop irrigating, therefore few farmer continue to irrigate it again one time or two times. Irrigation then means, increasing bulb forming time and it will affect harvesting day by extending. Generally agronomic activity being applied in the area can be observed in Figure 5.10. After preparation of land, planting continues being applied in different days for different plot of land, since the flood recede in different time step.

Table 5.6 General agronomic activity

Farmer	Ploughing	After flood	1st cropping	2nd cropping	Irrigation	Planting date
1	Ploughing Before flooding	Removing lilies then ploughing either 2 or 3 times	Plant Onion	Plants Maize	Source;-hand-dug wells & river water Schedule;-3,5,8 and 10 days interval	Onion Planting is in between November and March Maize planting is April
2			Plants Water Melon	Grazing		
3	Ploughing later than flooding		Plant Onion	Plants Maize		
4			Plants Water Melon	Grazing		

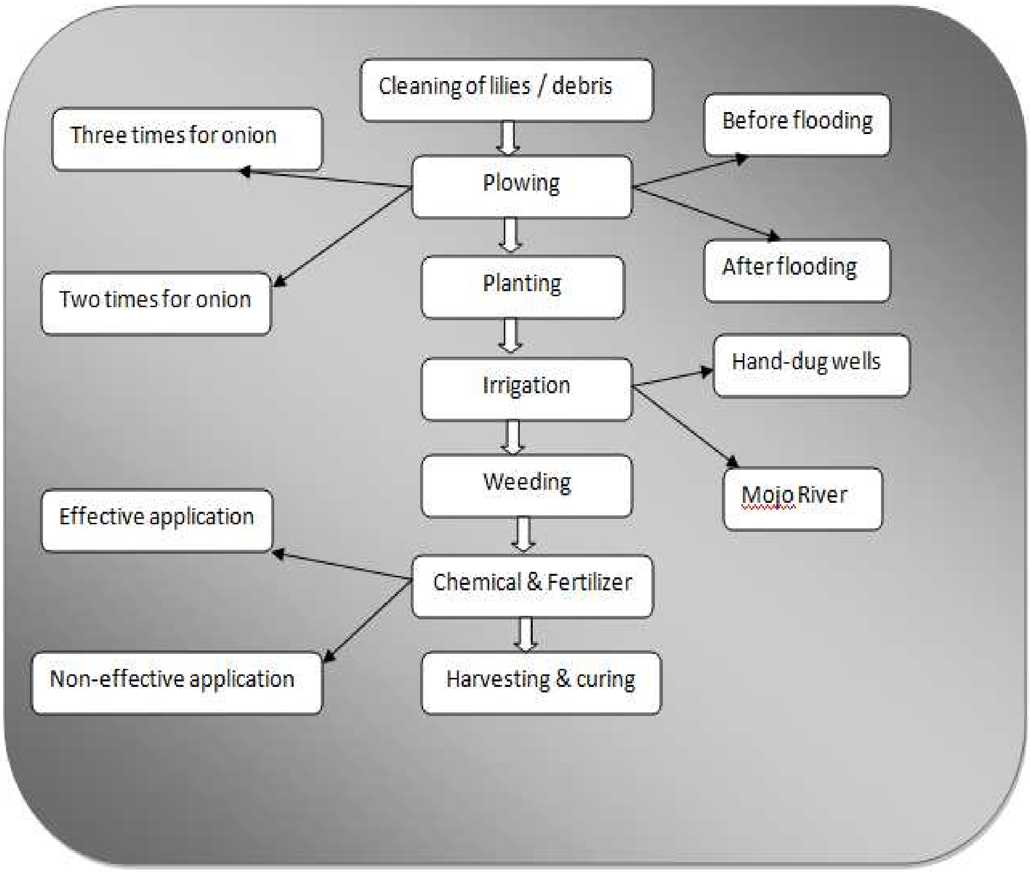


Figure 5.10 Agronomic activities

Cultivars produced in floodplain area are Adama red and Bomby red. Agricultural practices in the non-flooded area starts before the beginning of rain; ploughing, then later activities will continue for harvesting end of September, when the rain stops. In the case of flooded area; that is in offseason varieties of crops produced are Onion, tomato, head cabbage, pepper, watermelon, chick pea and maize. From all crops, the mainly produced crop type in the area is onion.

Onion and tomato are majorly cultivated crops followed by vegetable, water melon and maize. Furthermore, there are two irrigation seasons with in a year, the first season being from October to January and the second one between February and May. From the number of existing lakes, Koka Lake is one which is found here; that is explored on the figure. During rainy season, there occur flood around the lake which forces the farmers to stop using the land for cultivation. There is also floodplain along the river due to low capacity for accommodation of flood coming from the upper catchment.

5.3. Existing hand-dug wells

Existing hand-dug wells visited in floodplain areas were observed in three side; Hand-dug wells in floodplain which is inundated by Koka Lake as E-KL (floodplain in east side of koka inundated by koka lake), inundated by Mojo River in East and West side of koka as E-MR (floodplain in east side of koka inundated by Mojo River) and W-MR (floodplain in west side of koka inundated by Mojo River). Generally, methods of constructing the wells for the three sides are the same. Even though they have similarity, there also exist difference among them; which is depth of well, diameter of wells and resistance to flood damage. According to R.E. Mace, hand-dug wells have large diameters to facilitate construction and to store water. At a minimum, a hand-dug well needs to have a diameter large enough to provide working room in which a person can dig the well. In low-permeability environments, the size of wells may be large to maximize inflow and provide a large capacity for water storage. Location of wells is presented in Figure 5.11.

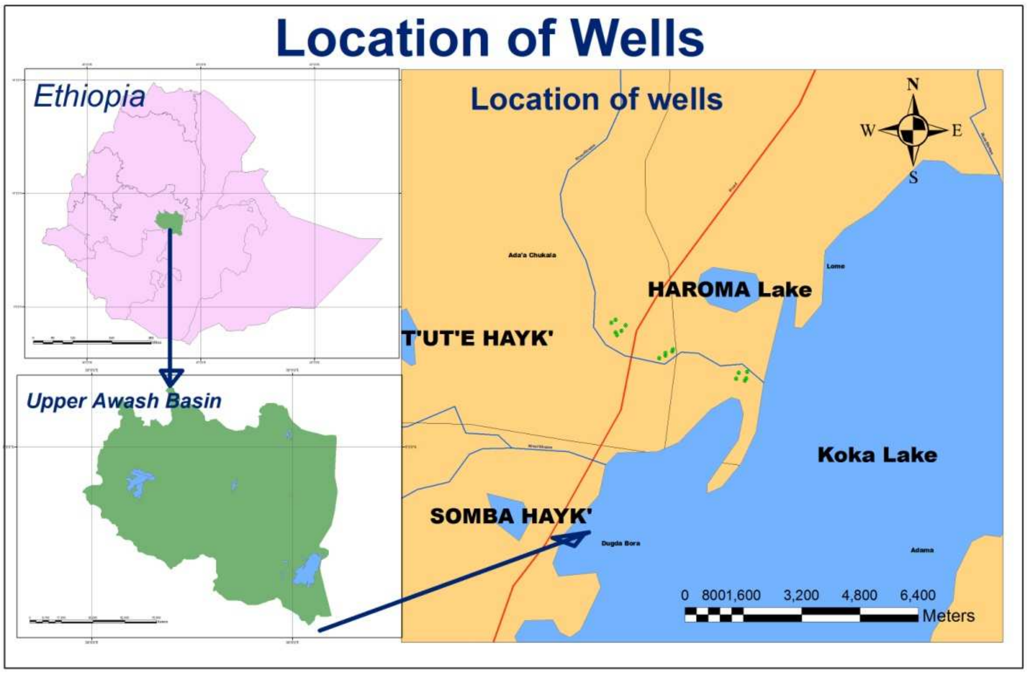


Figure 5.11 Location of wells

Traditional tools like bucket, shovel and rope were used during construction of wells. The rope will be tied up on the bucket for removing soil inside the well, which was loosening by using shovel. It is done with two peoples as shown in Figure 5.12 and construction takes two and more days for depth of 8 meter depending on agreement of payment for the employee. Procedure they follow while digging was, till they observe continuous supply of water, digging will continue; for example if they found water at depth of 4 meter they will continue until they reach to 8 meter to be sure for continues water supply.

Figure 5.12 During construction of hand-dug well

Due to inundation of either MR or KL, existing hand-dug wells either collapse or sediment will be deposited. Farmers which are located in MR side, and which are within 100 meter from the river doesn't implement hand-dug well. Whereas farmers beyond 100 meter distance away from the river implement wells; in which hand-dug wells beyond 100 meter but inside floodplain face either collapsing or sediment deposition. General characteristics' of hand-dug wells is listed in Table 5.7.

Table 5.7 Communality and difference between existing hand-dug wells

Characteristics of Existing hand dug wells	**Similarity between existing hand-dug wells**	**Difference between existing hand-dug wells**
Hand-dug wells from the three visited side.	➢ Way or method of construction (traditional method) ➢ Materials used for construction (shovel, rope and bucket) ➢ Abstraction of water using motor pump.	➢ Depth and diameter of hand-dug wells (depth of hand-dug wells vary from 7 - 16 meter and diameter varies between 1 - 3.5 meter)) ➢ Placing of the pumps (on the ground, 1-4 meter below the ground) ➢ Shape of hand-dug wells (circular and distorted circle) ➢ Flood protection materials (wooden and plastic membrane) ➢ Resilience to flood (collapsing of every year and sediment deposition)

5.3.1. Hand-dug wells from Mojo River floodplain

In Mojo River floodplain side, problems faced related to collapsing and sediment deposition. After flood recede most of well either face collapsing or sediment deposition as shown in below figure. Therefore farmers will be forced to re-construct or maintain the wells before they start irrigation. The collapsed well then affects early supplemental irrigation.

Figure 5.13 Collapsing and sediment deposition of hand-dug wells

During irrigating the field, pump was used to abstract from the wells and pipe for conveying water to the field. Depending on size of their farms, pipe will be installed but in case of those field which is near to the well, doesn't apply pipes.

Figure 5.14 Pump position relative to ground surface

In Figure 5.15 after irrigation water is brought to surface using pipe, it will be conveyed by creating passage (unlined canal form) to direct to the field.

Figure 5.15 Conveyance of irrigation water

On Figure 5.16 it can be observed that when the field is far from water source, pipe will be used for conveying to the area.

Figure 5.16 Irrigation water conveyance with pipe

During the visit from MR floodplain, there were observed installation of protected material. The materials used are wood and plastic as shown in Figure 5.17. The material doesn't have sustainability as the plastic membrane was affected by flood force.

Figure 5.17 Hand-dug wells with protection material

5.3.2. Hand-dug wells from east side of Koka Lake

During visiting of floodplain which was inundated from Koka Lake, floods were on the field and only on few parts were able to be visited. In Figure 5.18 the flood were did not completely receded back and the hand-dug wells were full of flood water.

Figure 5.18 Ongoing flood recession

In some part of the area on KL side floodplain, due to the flood staying for longer period, there were plants grown called lilies. On the Figure 5.19 shown, even if flood inundates the area, places can be observed without plants grown.

The plants has also grown inside the hand-dug wells, which literally means removing must be implemented before plowing and irrigation started. Hand-dug wells with lilies is shown on Figure 5.20.

Therefore farmers starts to collect the plants after the flood receds back. And by collecting the plants, they burned it being in the field as shown in Figure 5.21.

Figure 5.19 Areas with and without lilies grown

Abstraction of irrigation water was using pumps and due to the depth of ground water is at 4 - 6 meter, the pumps were placed on the ground as shown in Figure 5.22. The result of inundation on the hand-dug wells was sediment deposition. And as per farmers response on those wells which were near to the lake, collapse every year. Because of that few farmers also didn't implement hand-dug wells; they only produce water melon one time using moisture of soil.

Figure 5.20 Plants grown inside hand-dug well

Figure 5.21 Collecting and burning of lilies

Figure 5.22 Abstracting of irrigation water and protection material

From Figure 5.22, it can be observed that protection materials were being applied. But due to less sustainability it collapses per three years of time.

5.3.3. Improved technology of wells

Improving traditional hand-dug wells that are feasible in terms of cost are stone riprap, lining with cement and stone and shallow tube well. Previous improvement method of protecting the hand-dug wells from collapsing, were done on few wells with wooden and plastic material. But the method used for improving, didn't last for long period and has been showed in Figure 5.22. Therefore on this thesis three methods of work done for improving or recommending alternative technologies of ground water abstraction three scenarios are created; shallow tube well implementation, stone riprap and lining of existing hand-dug wells with cement.

For implementation of shallow-tube well, from the number of listed method of digging in part 4.5.1, sludging was chosen due to its applicability in range of different soil formation. And materials for construction can easily be accessible, from an area near to Koka, called Ziway. It is also to find well trained person for construction of the shallow-tube well. In West Africa, shallow aquifers have been making an increasing contribution to the expansion of small-scale irrigation, particularly in Nigeria. The presence of groundwater resources at shallow alluvial depths, less than 20 meters in most of the fadamas throughout the dry season plays a key role. (http://www.fao.org/docrep/w7314e/w7314e0v.htm).

5.4. Model Result and Discussion

AquaCrop model needed to be calibrated before simulation. For most of crops, calibration was already made in AquaCrop mannual (FAO 66 paper) but not for onion. And due to inexistence of sufficient practical measured results for few parameters, default calibrated vales for potato crop were used. Potato crop were chosen, for the reason that it is the closest type of crop from the calibrated crops. Most of the parameters result do match or are close to consider their resemblance and classification of crop type; which is under root/tube crops as onion crop. The major crop planted in koka area is onion; it is also planted by few farmers two times per year. Onion crop is selected from existing planted crops, as it is major crop planted by different farmers and it is an important cash crop in Ethiopia, especially in the central Rift valley region. Therefore to make the model in line with local condition of onion crop, a simulation has been made. The values which were changed and default data can be seen in Table 5.8 & 5.9.

Table 5.8 Crop default data to simulate onion

Description	Units	Value
Canopy cover per seedling at 90 % emergence (CC_o)	%	6.25
Canopy growth coefficient (CGC)	% /day	13
Maximum canopy cover (CC_x)	%	92
Canopy decline coefficient (CDC)	%/day	1.9
Water productivity (WP)	g/m^2	18
Upper threshold for canopy expansion (P_{upper})	-	0.25
Lower threshold for canopy expansion (P_{lower})	-	0.6
Leaf expansion stress coefficient curve shape	-	3
Upper threshold for stomata closure	-	0.7
Stomata stress coefficient curve shape	-	3
Canopy senescence stress coefficient (P_{upper})	-	0.55
Senescence stress coefficient curve shape	-	3
Reference harvest index	-	2
Aeration stress when waterlogged	Vol.%	5

Crop phenological data were inserted from farmers respond and literature review. The literature found on onion was from Melkasa agricultural research center which is found in Nazreth and general literature made in Ethiopia on onion. The research center has made number of research on onion cultivar, Adama red and Bombay red which are implemented in koka area. In addition in

Table 5.9 Phenological data for onion crop

Phenology	Growing days	Source
Transplanting to recover (days)	7	Farmer/Literature
Transplanting to maximum canopy (days)	47	Literature
Transplanting to senescence (days)	90	Farmer/Literature
Transplanting to maturity (days)	120	Farmer/Literature
Transplanting to start yield formation (days)	38	Literature
Maximum root depth (cm)	70	Literature

a = source is from Melkasa agricultural research center

Simulation of the model is started by considering the optimal result that can be found. Optimal condition refers to no stress condition due to salinity and water stress in soil. Which is, farmers apply fertilizer and irrigate under 50 % RAW, that is irrigation starts when 50 % of water in soil, which is ready to be abstracted by root, is depleted. The result from the model is shown in Figure 5.23, with yield of 38.791 ton/ha.

This research identified three categories of farmers (Farmers A, B and C). Farmers type A represents farmers who are following proper fertilizer application and irrigation schedule. Net irrigation application being 29 mm, and they irrigate per three, five and eight days interval. Whereas, farmer type B and C doesn't apply fertilizer. Irrigation schedule followed by farmer type B was per five and ten day's interval. In the

case of farmer type C, irrigation schedule were still like farmer type B but they quickly start ten days interval.
The variation in fertilizer application and irrigation between farmers comes from number of reasons. The first one is, shortage of income for fertilizer or fuel pump, irrigation source and farmers doesn't give proper attention. Irrigation source; those farmers which they use river water because the flow decrease, it will be difficult sometimes to get water.

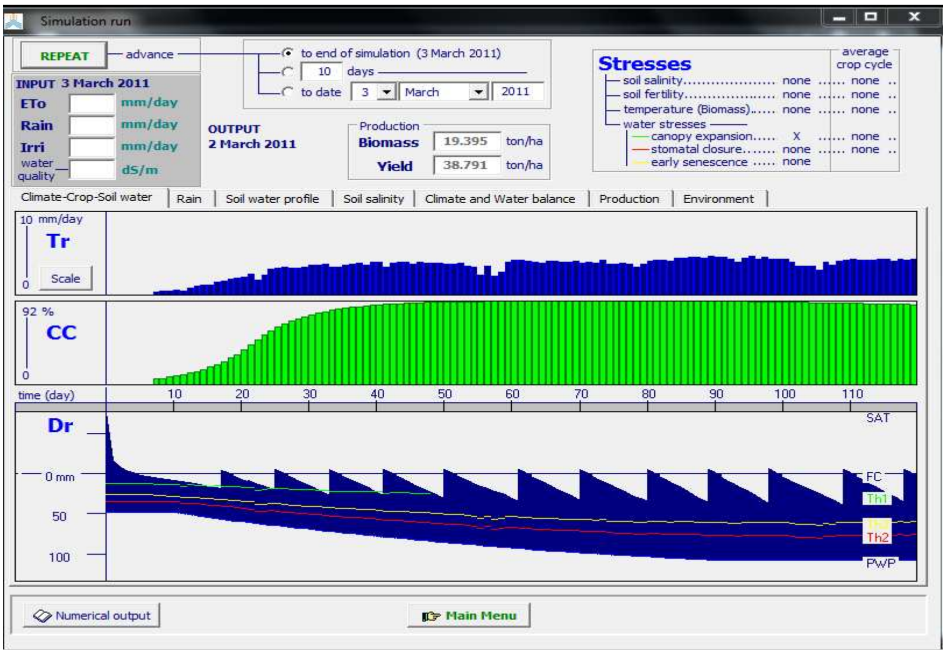


Figure 5.23 Optimization of onion crop result

5.4.1. Farmer type A

Simulation of the model by considering farmer type A was done. These farmers apply fertilizer and the irrigation schedule as expressed above was updated on the model. These types of farmers has an irrigation schedule follow up of; three days interval for initial growth, then five days interval till flowering and bulb formation then lastly 8 days interval for later season. The other parameters kept constant, the model has resulted as shown in Figure 5.24.

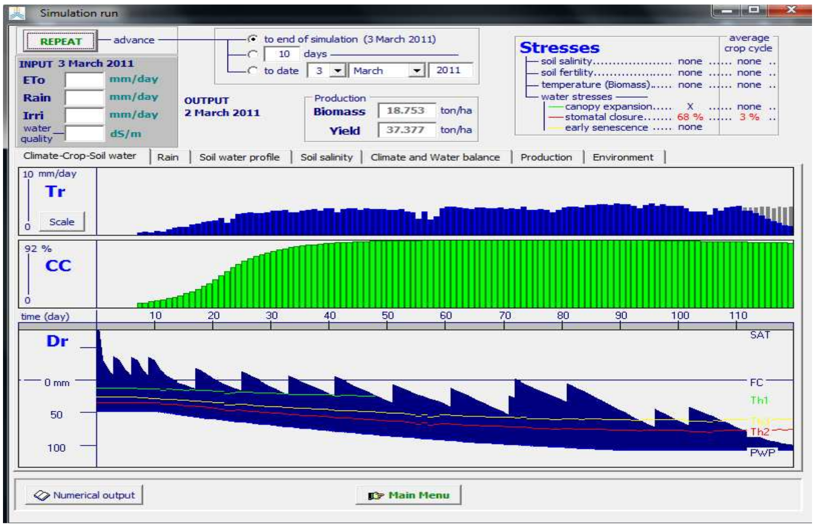


Figure 5.24 Farmer type A simulation

The result shows that due to the new irrigation schedule, there occur 68 percent of stomatal closure. These farmers, type A farmers has capacity to produce 37.377 ton/ha.

5.4.2. Farmer type B

Farmer type B differs with application of fertlizer and irrigation schedule from type A farmer. The farmers doesn't apply fertilizer, therefore in the model soil fertility and salinity stress on biomass production were considered. The irrigation schedule being implemented were; at initial growth 5 days interval application then for mid and late season 10 days interval irrigation application. For this farmer type; due to un applicability of fertilizer, root depth were considered 30 cm depth as root depth growth affected by fertility and this will result to a shallow root depth growth. The result obtained is shown on Figure 5.25, showing both canopy expansion and stomatal closure are under stress. The yield obtained was 30.492 ton/ha.

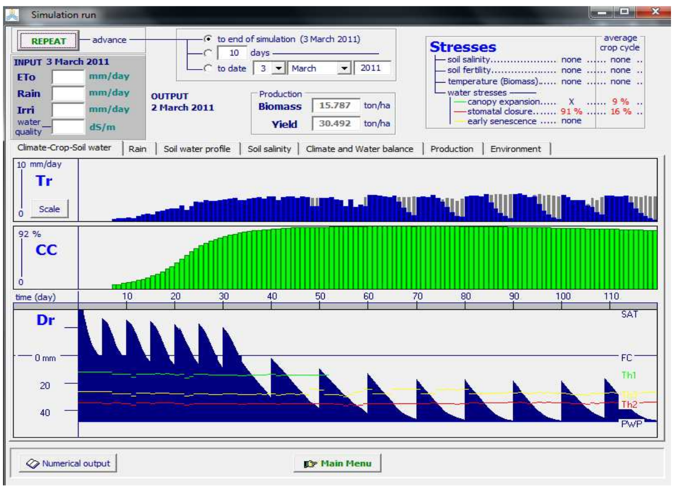


Figure 5.25 Farmer type B simulated

5.4.3. Farmer type C

For farmeter type C, deafult parameter being the same, the model were run with difference in irrigation schedule. Which is irrigation was under same interival with farmer type B, but the different apperas in engaging 10 days interval earlier. The result can be observed in Figure 5.26, yield being 19.4 ton/ha and canopy expansion and stomatal closure stress 49 and 26 % consecutively.

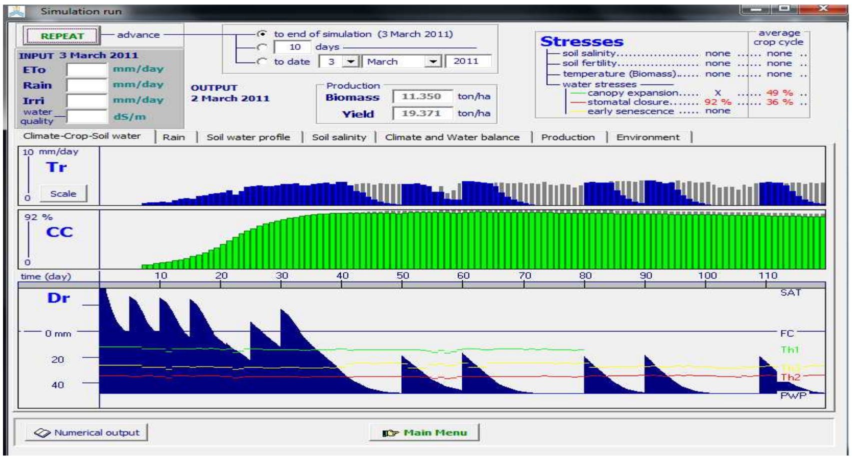


Figure 5.26 Farmer type C simulated

Table 5.10 Model result for different farmer

Result	**Farmer type A**	**Farmer type B**	**Farmer type C**
Yield (ton/ha)	37.4	30.5	19.4
Stomata closure stress (%)	none	91	92
Canopy expansion (%)	none	9	49

The model therefore, doesn't gave us yield that is correlated with locally produce ton/ha. Therefore, in order to evaluate the benefit-cost analysis for existing condition, existing yield obtained by farmers were assumed. The yield obtained per farmers locally can be observed in Table 5.11.

Table 5.11 Variation of yield obtained per farmers

Farmer type	Total cost	Revenue	Yield (ton/ha)	Source of information
1	56,000	116,000	48 ton/ha	Farmers
2	54,000	112,000	36 ton/ha	Farmers
3	49,200	116,000	24 ton/ha	Farmers
4	44,000	92,000	15 ton/ha	Farmers
5	56,000	88,000	20 ton/ha	Farmers
6	31,880	61,500	12 ton/ha	Farmers

5.5. Cost-benefit Analysis

Analyses of BCR were made through considering existing irrigation followed and method of water extraction used. The costs for agronomic practices are listed in Table 5.12. Farmers practicing agronomic activity were divided in to three as stated in part 5.12. Which are; farmer type A, B and C. The costs related to these farmers vary due to variation in application of fertilizer, irrigation schedule and ploughing. Farmer type A, implement all agronomic activities, while B and C skip application of fertilizer. In case of ploughing, farmer type A and B plough the land three times, whereas C only two times. Irrigation application is one of applied agronomic practice different within farmers; that is frequency of application.

Table 5.12 Agronomic activity cost per different farmers

Activities Agronomic	Farmer type A	Farmer type B	Farmer type C
Removing of lilies or debris	120	120	120
Ploughing	372	372[a]	352[b]
Planting	252	252	252
Irrigation & spraying	800	400[c]	256[d]
Weeding	120	120	120
Harvesting and Curing	340.8	340.8	340.8
TOTAL COST (Euro)	**2,004.8**	**1,604.8**	**1,440.8**

a & b = Ploughing three and two times consecutively c & d = No fertilizer application and different irrigation schedule

The cost of hand-dug well construction is listed in Table 5.13. Hand-dug well, after it is constructed, every year there will be maintenance cost for removing of sediment deposited. In case of wells which are very sensitive to flood, collapsing cost encored every year. The wells viewed as PW and UPW, which PW are those wells with protection material and UPW are those without protecting materials.

Table 5.13 Construction and maintenance cost of existing hand-dug well

Description	Protected well	Unprotected well
Construction cost	82.4	48
Maintenance cost	34.4	34.4
TOTAL COST	**116.8**	**82.4**

As stated in the methodology part, three new technologies were suggested to upgrade sustainability of wells and implementation of shallow tube wells on area where there weren't any wells. The technologies are; lining of existing wells, stone riprap and shallow tube wells. LW is using cement and stone to make the existing wells lined up to 2 meter depth. SRR is implementing on existing hand-dug wells, different graded size stones. In case of ST well, it is constructed through sludging using small diameter pipe for digging. The costs for installation of these technologies are listed in Table 5.14.

Table 5.14 New technologies of well

Description	Lining of existing wells	Stone riprap	Shallow-tube well
Construction cost	140[a]	28[b]	600
Maintenance cost	45	12	
Total cost (Euro)	**185**	**40**	**600**

a = Total cost of stone and cement b = Different graded size of stone

Based on the above tables, existing farmers' activities were created as scenario listed in Table 5.15. The farmers which doesn't have hand-dug wells; those farmers which are found within 100 - 200 meter distance from Mojo River were also considered.

Table 5.15 Existing farmer type and their method irrigation

Farmer type	Agronomic activity	Irrigation water source
Scenario 1	Farmer type A	Protected hand-dug wells

Scenario 2	Farmer type A	Unprotected hand-dug wells
Scenario 3	Farmer type B	Protected hand-dug wells
Scenario 4	Farmer type B	Unprotected hand-dug wells
Scenario 5	Farmer type C	Unprotected hand-dug wells
Scenario 6	Farmer type A	Mojo River water
Scenario 7	Farmer type B	Mojo River water
Scenario 8	Farmer type C	Mojo River water

Existing condition of benefit-cost analysis

COST OF EXISTING CONDITION

Well	Protected well (PW)				Unprotected well(UPW)			
	Unit	Qty	Price per Qty	Total Price	Unit	Qty	Price per Qty	Total Price
Description								
1. Cost								
1.1. Construction cost	well	3	82.4	247.2	well	5	48	240
1.2. Maintenance cost	well	6	34.4	206.4	well	6	34.4	34.4
Total Cost	Euro			**453.6**				**274.4**

EXISTING AGRONOMIC COST

Agronomy	Farmer type A				Farmer type B				Farmer type C			
	Unit	Qty	Price per Qty	Total Price	Unit	Qty	Price per Qty	Total Price	Unit	Qty	Price per Qty	Total Pr
Description												
1. Cost												
Cleaning		10	120	1,200.0		10	120	1,200.0		10	120	1,200.
Plowing		10	372	3,720.0		10	372	3,720.0		10	352	3,520.
Planting		10	252	2,520.0		10	252	2,520.0		10	252	2,520.
Irrigation & Spraying		10	800	8,000.0		10	400	4,000.0		10	256	2,560.
Weeding		10	120	1,200.0		10	120	1,200.0		10	120	1,200.
Harvesting & Curing		10	340.8	3,408.0		10	340.8	3,408.0		10	340.8	3,408.
Total Cost	Euro			***20,048.0***				***16,048.0***				***14,40***
2. Income												
Onion	kg/ha	36,000.0	0.2	86,400.0	kg/ha	24,000.0	0.2	57,600.0	kg/ha	15,000.0	0.2	36,000
Total Revenue	Euro			***86,400.0***				***57,600.0***				***36,00***

Figure 5.27 Existing agricultural cost and revenue obtained

In Figure 5.27 the cost spent for constructing and maintaining of hand-dug wells are listed. In addition agronomic practice cost for the three types of farmers are included and in order to see the benefit in long term, it is made for ten years. The final row shows, onion selling price 0.24 Euro/kg and total revenue for each type of farmers. Then summing up the total cost; agronomic cost and hand-dug well cost for each scenario and by subtracting the cost from revenue, benefit is obtained as shown in Figure 5.28.

BENFIT-COST ANALYSIS FOR EXISTING CONDITION			
Senarios	Total Cost	Total Benfit	Benfit/Cost
Farmer type A & Protected well	20,501.6	65,898.4	3.2
Farmer type A & unprotected well	20,322.4	66,077.6	3.3
Farmer type B & Protected well	16,501.6	41,098.4	2.5
Farmer type B & unprotected well	16,322.4	41,277.6	2.5
Farmer type C & unprotected well	14,682.4	21,317.6	1.5
Farmer type A	20,048.0	66,352.0	3.3
Farmer type B	16,048.0	41,552.0	2.6
Farmer type C	14,408.0	21,592.0	1.5

Figure 5.28 Benefit-Cost ratio of existing agricultural practice

From Figure 5.28 it can be observed that scenario 2 and 6 has highest value that is 3.3. It shows that currently farmer type A practice is benefiting.

Improved technology benefit-cost ratio

In the next Figure 5.29 the cost for implementing the new suggested technologies are listed. The cost for shallow-tube well implementation was found as it is implemented in Ziway; an area close to Koka town.

COST OF NEW TECHNOLOGY (SCENARIO)												
Well	Lining of existing wells(L)				Stone riprap(SR)				Shallow-tube well(SH)			
	Unit	Qty	Price per Qty	Total Price	Unit	Qty	Price per Qty	Total Price	Unit	Qty	Price per Qty	Total Price
Description												
1. Cost												
1.1. Construction cost	well	1	140	140	well	1	28	28	well	1	600	600
1.2. Maintenance cost	well	2	45	90		4	12	48				
Total Cost	Euro			**230**				**76**				**600**
Agronomy	**Farmer type A**				**Farmer type A**				**Farmer type A**			
	Unit	Qty	Price per Qty	Total Price	Unit	Qty	Price per Qty	Total Price	Unit	Qty	Price per Qty	Total Price
Description												
1. Cost												
Cleaning		10.0	120.0	1,200.0		10.0	120	1,200.0		10.0	120.0	1,200.0
Plowing		10.0	372.0	3,720.0		10.0	372	3,720.0		10.0	352.0	3,520.0
Planting		10.0	252.0	2,520.0		10.0	252	2,520.0		10.0	252.0	2,520.0
Irrigation & Spraying		10.0	800.0	8,000.0		10.0	400	4,000.0		10.0	256.0	2,560.0
Weeding		10.0	120.0	1,200.0		10.0	120	1,200.0		10.0	120.0	1,200.0
Harvesting & Curing		10.0	340.8	3,408.0		10.0	340.8	3,408.0		10.0	340.8	3,408.0
Total Cost				***20,048.0***				***16,048.0***				***14,408.0***
2. Income												
Onion	kg/ha	36,000.0	0.2	86,400.0	kg/ha	24,000.0	0.2	57,600.0	kg/ha	15,000.0	0.2	36,000.0
Cheakpi												
Total Revenue	Euro			***86,400.0***				***57,600.0***				***36,000.0***

Figure 5.29 Cost of new technology with agronomic practise

BENFIT-COST ANALYSIS			
Senarios	Total Cost	Total Benfit	Benfit/Cost
Farmer type A & Lining of wells	20,278.0	66,122.0	3.3
Farmer type A & Stone riprap	20,124.0	66,276.0	3.3
Farmer type A & shallow tube wells	20,648.0	65,752.0	3.2
Farmer type B & Lining of wells	16,278.0	41,322.0	2.5
Farmer type B & Stone riprap	16,124.0	41,476.0	2.6
Farmer type B & shallow tube wells	16,648.0	40,952.0	2.5
Farmer type C & Lining of wells	14,638.0	21,362.0	1.5
Farmer type C & Stone riprap	14,484.0	21,516.0	1.5
Farmer type C & shallow tube wells	15,008.0	20,992.0	1.4

Figure 5.30 Benefit-cost ratio for implementing new suggested technologies

From Figure 5.30, stone riprap and lining of wells has maximum benefit-cost ratio value of 3.3. Therefore, their applicability worth farmers, especially for those farmers whose wells are located in ground water depth of above 8 meter. The variation in the benefit-cost ratio between shallow-tube well and stone riprap is 3%.

CHAPTER 6

Conclusion and recommendation

6.1. Conclusion

In Koka floodplain area, supplemental irrigation source are hand-dug wells and river water. Even if the farm areas which are near to the river are also suitable for installation of hand-dug wells, farmers have chosen to use river water due to frequent collapsing. But river water couldn't supply the full required water, especially in second cropping period, due to less flow. In areas where farmers install hand-dug wells, still collapsing and sediment deposition are the problem faced. Protection materials, like wooden and plastic, were only applied by few farmers and since the method didn't last for long time its applicability were stopped from dispersing. The farmers also didn't seem to try different solution due to; most of stakeholders are investors renting the land from farmers or who works by sharing with farmers, farmers didn't have the chance to be exposed for different solution, low income and maintenance or construction cost of hand-dug well are less for farmers, especially farmers with huge cultivable area as compared to the revenue they get.

For alleviating the problem the three methods were introduced; which are stone riprap, shallow tube well and lining of existing hand-dug wells. Through comparison of their benefit-cost ratio for ten year, highest value (3.3) were obtained for stone riprap and lining of wells. Therefore, upgrading the technical set up of the hand-dug wells either by lining or stone riprap will benefit farmers. Whereas for those farmers, which are found within 100 meter distance from the river and farm areas with ground water depth less than 8 meter, installation of shallow-tube well would be better solution, as the benefit-cost ratio difference between the lining of wells and shallow-tube well is 3 %.

Agronomic activities implemented in the area, have also variation which caused farmers to obtain different yield. The main activities which vary within farmers are; ploughing, irrigation and fertilizer application. For instance, ploughing was applied two and three times, fertilizer applications were also applied by few farmers whereas other farmers skip to apply. The third activity that differentiates farmers were application of irrigation, that is farmers apply in the interval of 3, 5 and 8 days and others apply 5 and 10 days interval. These differences resulted in variation of yield between 15 ton/ha to 40 ton/ha. The variation resulted from number of reasons; which are farmers are in lack of money to buy chemical, fertilizer and fuel for pump, there are also farmers which are reluctant in giving attention to the schedule due to lack of knowledge or less attention, there are also farmers with huge hectare of land, that is up to 8 hectare, and most of their land will be in non-flooded area so if production of Teff were successful, then they will think supporting their livelihood will be covered by the income.

The identified large yield gap obtained from the area could not be simulated in AquaCrop. The reason is that, the model calculates the biomass production by multiplying sum of transpiration by water productivity. Whereas, in case of onion it doesn't have wide leaf area from where transpiration can undergone and most of its production must be in building up of the bulb. And it can be concluded that the model has to be overlooked again for kind of crops like onion. According to Muhammad N., and Hussain A. (2012), they have concluded that the model overestimated biomass and yield as well as underestimated water productivity for all irrigation treatments, comparison between observed and simulated results for four different irrigation treatments showed unreliable result and model evaluation using RMSE and NCE showed that model performed unsatisfactory for biomass, yield and water productivity.

In case of comparison of existing crop production, BCR for farmer type A by using unprotected well and farmer type A irrigating from river resulted 3.3, which shows that some farmers irrigation schedule plan was good and application of fertilizer increase the yield obtained. This also can be reason to be deducted for farmers to not consider about new technology yet. According to Martina de Santa Olalla (2004) inducing water deficits at the bulbification and ripening stages of onion crops lead to significant difference on yields. Therefore farmer need to be alerted in implementing irrigation.

6.2. Recommendation

In regard to improving existing hand-dug wells; the new suggested technologies will benefits farmers if applicability made in two ways. Which means, areas with ground water depth more than 8 meters, lining existing wells improves or alleviates existing problems. In addition problem of losing cultivable area, which was created from digging in different areas every year, will be improved. Whereas, in areas where ground water depth below 8 meter depth, will benefit considering shallow-tube well implementation. Since the method creates job opportunity for preparing material, like work shop to weld the pipes, it is good to consider as solution. Together with implementation of shallow-tube wells, detail study on the current and future abstraction of ground water and re-charging ground water study must be implemented.

While in the case of agronomic practices, farmers need to be alerted about the characteristics of the crop. Such as frequent irrigation, especially in early growing stage; during bulb formation and fertilizer application has very positive impact on yield. In addition, if experimental research done in the area, it will also help to identify detail information on the crop growth.

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Appendices

Appendix A Questionnaries

1. Does your farm plot found in floodplain area?
2. When does flood inundate and recede back?
3. How much hectare of land do you own?
4. What kind of crop do you produce?
5. Do you use hand-dug wells?
6. What is depth and diameter of your well?
7. What are the results of flood to your wells, how frequent does it happen?
8. How much cost do you spent for your well?
9. Have you used protection material for your well, why not?
10. When do you plant, irrigate and costs related to the agronomic activities?
11. What kind of pump do you use?
12. How much did you produce per your hectare?
13. How many people are there in your family?