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Review of Water Harvesting Technologies for Food Security in Ethiopia: Challenges and Opportunities for the Research System

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Abstract
Water harvesting has been promoted in Ethiopia on the basis of augmenting rainfed agriculture following 1971-1974 droughts in Tigray, Wollo and Hararge regions. A large number of water harvesting technologies have also been implemented with support from the Government. For instance, this assessment report indicated that more than 300, 000 shallow wells, about 206, 200 house hold level structural ponds, 49, 311 community ponds, 5,635 cisterns have been constructed and a total of 32, 727 springs have been developed. But these works have not been proven as successful as expected, because of technical and socioeconomic problems. The structural failures are connected with poor design, water lose due to evaporation and seepage, low technical capacity and subsequently low adoption by user. Another report indicated that there was only 22% functional water harvesting structures out of the constructed ones between the periods 2003-2004 in Amhara regional state. The most critical of all the problems is the water loses due to seepage resulting from poor lining materials of the harvesting storage structures. Hence technologies providing good protection towards seepage loss have been given a priority. With a view of this, some research works have been conducted to identify the best lining materials that reduce water lose due to seepage. Accordingly, a study showed that mortar performed best (1.4 mm/day) followed by salt with compaction (7.88 mm/day) and local ash (9.33 mm). Another study also concluded that the rich mixture (1:3 Cement to sand ratio) was better in controlling seepage rate than the lean mixture (1:5 cement to sand ratio). A study on local materials for seepage control showed that the bio-plastic made up cow dung better reduced the seepage loss significantly (i.e. about 3.55 cm/day) than the untreated silt clay soil which had an observed 6.65 cm/day of seepage rate for a particular study site. The Ethiopian Institute of Agricultural Research has also now recently been working on the demonstration of low cost drip irrigation systems combined with water harvesting schemes for it has an advantage of greatly maximizing water use efficiency and significant results have been obtained in convincing farmers to use the combined technology . For example, when combined with
drip irrigation, the use of shallow ground water becomes quite economical and the resource can be exploited on a sustainable manner for crop production . The use of such drip irrigation system permits reduction of water loss (up to 50%) as compared to flood irrigation showing water savings of 50% and a yield increase of 30%, with no substantial differences with the conventional drip irrigation systems .
In general, the importance of water harvesting works either in augmenting rainfed agriculture or supporting double cropping cannot be overemphasized as long as the critical problems resulting in the failure of the structures have been resolved. Thus identification of low cost and effective lining materials and promotion of low cost drip irrigation systems should be given top priority in order to extend those technologies with the fastest level of adoption.
Keywords: Water harvesting, lining material

1. Inroduction

Agriculture in Ethiopia is heavily reliant on rainfall and productivity and production are strongly influenced by climatic and hydrological variability that are reflected as dry spells, droughts and floods. Droughts and floods are becoming common, with significant events every 3 to 5 years, with increasing frequency compared to two or three decades ago. Droughts destroy watersheds, farmlands, and pastures, contributing to land degradation and causing crops to fail and livestock to perish. In Ethiopia, there are four major categories of productive use of water in agriculture: (1) 'rain-fed agriculture', (2) 'supplementary irrigation', (3) 'irrigated agriculture', and (4) 'livestock' (Awulachew et al., 2005), but rainfed agriculture is the major one. Although the country has huge water resources; 12 river basins with an annual runoff volume of 122 billion cubic meter of water with an estimated 2.6 billion m3 of ground water potential, the effort made so far to exploit these resources is extremely low. According to Hugo (2003), mean annual rainfall reaches approximately 1090 mm which is also supposed to be supporting double cropping in at least some regions or areas of the country

The ministry of water resources (MOWR, 2002) reported that about 67% of the country's landmass are categorized as arid and semi arid which are characterized by acute water shortage because of erratic rainfall distribution and resulting in recurrent drought and famine. As agriculture is the highest consumer of water (CTA, 1999), efficient water management is necessary to sustain life and livelihood. Excluding the purely pastoralist areas, more than 90 woredas with a total of more than 2 million households in the country are drought prone and regularly hit by severe water shortages. This seriously threatens the lives of more than 12 million people (Hugo, 2003). The major factors contributing to the current food insecurity include widening gap between the level of food production and the rapid population growth, degradation of natural resource base and dominance of cereal based farming system which is exclusively dependent on the erratic and unreliable rain fall.

Rain water harvesting during the surplus periods for use during the critical periods has become a feasible strategy in different parts of the world. This is to bridge dry spells through supplemental irrigation of rain fed crops in smallholder farming systems to improve the lives of rural people at low cost and with minimal outside inputs. This could be achieved with water harvesting system, which involves collecting runoff in small storage structures. Water harvesting can reduce the risk of crop failure by facilitating early planting which allows the maximum use of the rainfall, thereby insuring the crop against rainfall irregularities. Efficient collection and storage of rainwater is critical in food insecure areas with increasing pressure on land. Capturing of more runoff from rainfall and the efficient storage and use of the water has become the component of the national strategy in combating drought and famine (OFS,

2002).

The government of Ethiopia has recently formulated the Water Policy of the country. Basin wide integrated master plan studies which envisage development activities over the coming 30 to 50 years have been undertaken for most of the major rivers. Other option to increase water productivity at production system was also proposed as a main pillar in the national food security strategy (FDRE, 2002). For instance, in 2002/2003 and 2003/2004 fiscal years only, the federal government has allocated ETB 100 Million and 1 Billon for food security programs, respectively, to all regions. Much of this money was used by the regions for the implementation of water harvesting programs, which were construction of household ponds and cisterns (Hugo, 2003).

The objective of this paper was therefore to review the efforts done, achievements obtained and roles played by promotion of water harvesting technologies in sustaining agricultural production during the previous two decades. The review work also discussed the challenges remaining for the research system intervention.

1.1 History of Water Harvesting

Storage of water in small ponds, tanks or cisterns has been practiced widely through out the world for millennia. Water stored in ponds or tanks is used for a variety of purposes in North Africa since the Roman times. Some of these are reported to be in operation in Tunisia and Egypt (Gharp, 2003). There are also evidences proving the Ur area in Iraq was practicing simple forms of rainwater around 4500 BC. In some of the very earliest agriculture, in the Negev Desert of Israel, water-harvesting systems dating back 4000 years or more have been discovered (Evanari et al., 1971). Researchers also have found signs of early rainwater harvesting structures constructed over 9000 years ago in the Edom Mountains of Southern Jordan (Bruins et al., 1986). Interest of using water harvesting technologies was also developed in North America during droughts in the 1930's and has continued since then to provide some levels of agricultural security (Begahew, 2005). A growing awareness about the potential of rainwater harvesting for improved crop production was observed in Africa during the 1970s and 1980s when there was a wide spread droughts that resulted in crop failures. A number of rainwater harvesting projects were constructed in sub-Saharan Africa during the past three decades which costed considerable amount of money, time, and efforts. Their objective was to combat the effects of droughts by improving plant production and rehabilitating abandoned and degraded land (Critchley and Reij, 1989).

Rainwater harvesting in Ethiopia has a long history with strong attachment to the ancient Orthodox churches (Habtamu, 1999). Getachew and Habtamu (1999) indicated that the history of rainwater harvesting in Ethiopia date back to pre Axumit period (560 BC). During this period rainwater was harvested and stored in ponds and tanks for agriculture and water supply purposes. The remains of an ancient roof- water harvesting system is still visible in the oldest palaces in Axum. Other evidences include the remains of one of the old castles in Gondar, constructed in the 15 and16th century and Lalibela Rock hewn churches (over 800 years ago), including a pool that was used to store water used for religious rituals. Rainwater harvesting systems in monasteries like Mahbre Selassie in Gondar and Debrekerbe in Shoa can be mentioned as examples. In south of the country, the Konso people have had a long and well established tradition of building level terraces to harvest rainwater that is used to produce sorghum successfully under extremely harsh environment characterized by low, erratic and unreliable rainfall (Gharp,2003).

In the Ogaden (Eastern Ethiopia), Brikas are used to store rainwater. People in North Omo

(Gatto Valley), Eastern Hararghe, and other parts of the country have been practicing the art of conserving soil and water (Habtamu, 1999). The promotion and application of rainwater harvesting systems as an alternative to address water scarcity were started in Ethiopia through government initiatives of soil and water conservation programs in response to the 1971-74 droughts with the introduction of the Food-for–Work (FFW) program. The initial rainwater harvesting activities included construction of ponds, micro dams, bunds, and terraces in most parts of the drought affected areas (Kebede, 1995). Recently a number of initiatives have been undertaken to investigate its potential in the drier areas at national level in all regions of the country (BOA, 2002).

1.2. Definition and Scope of Water Harvesting

The term “water harvesting” was comprehensively defined as defined by Reijntjes (1983) to mean all the different techniques to collect runoff or flood water for storage in the soil profile or in tanks so that it can be used for the production of crops, trees or fodder.

Water harvesting techniques are broadly classified as: rain water harvesting, flood water harvesting, dry weather flow river diversion and groundwater harvesting.

Rainwater harvesting: It is a method of inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions. Water can be collected from rooftops, courtyards and similar compacted or treated surfaces.

Floodwater harvesting (Spate irrigation or large catchment water harvesting): the collection and storage of creek flow for irrigation use. This technique is subdivided in to two.

Floodwater harvesting within - the stream is dammed as a result inundates the valley bottom of the flood plain. The water is forced to infiltrate and the wetted area can be used for agriculture and pasture improvement.

Floodwater diversion: the wadi water is forced to leave its natural course and conveyed to nearby cropping fields.

Dry weather flow river diversion: is commonly used in Ethiopian highlands where sustained base-flow is available in a river. Water harvesting in this technique is the construction of diversion structures (permanent or temporary) across/ on part of the river and canalling to an irrigation command area.

Ground water harvesting: Some consists of a horizontal tunnel that taps underground water in an alluvial fan, brings it to the surface due to gravitational effect. A tunnel may have an inclination of 1-2% and a length of up to 30 km. some obstruct the flow of ephemeral streams in a river bed; the water is stored in the sediment below ground surface and can be used for aquifer recharge.

Water harvesting techniques in general are aimed at increasing agricultural production and improving agricultural productivity. Therefore, it provides an opportunity to stabilize agricultural production particularly in arid, semi-arid and semi-humid areas where water is a limiting factor. For instance, supplemental irrigation for dry-spell to mitigate rain fed agriculture is quit useful (Young et al., 2003). Fax et al. (2003) reported that supplemental irrigation ranging from 60 to 90 mm per season showed significant effect on grain yield and biomass production resulted in on average grain yield of 712 kg/ha, while fertilizer application alone resulted in an average grain yield of 975 kg/ha. Supplemental irrigation combined with fertilizer application also observed to result in an average grain yield of 1403 kg/ha which is higher than the farmers’ practices by factor of three.

The benefits obtained from water harvesting in improving soil fertility are also investigated. Silt, manure, and other organic matters can be “harvested” or kept in place together with the water. If the soil profile stays moist for longer time, microorganisms in the soil can be stimulated so that the formation of stable humus, the nutrient availability, and the water holding capacity of the soil can be improved (LEIS, 2005).

2. Methodology of Review

To the success of this work, different sources such as journals, proceedings, thesis works and reports related to water harvesting have been used. The history, scope, success and achievements in disseminating water harvesting technologies have been properly documented. The review work also pinpoints the bottle neck that has been observed in the extension of water harvesting technologies.

3. Results and Discussions

3.1. Success and achievements in promoting water harvesting techniques

Water harvesting has been promoted in Ethiopia based on augmenting Rainfed agriculture following 1971-1974 droughts in Tigray, Wollo and Hararge regions (Rebeka, 2005). A large number of water harvesting technologies have also been implemented with support from the Government of the Federal Democratic Republic of Ethiopia (FDRE, 2000). For instance, an assessment report by Lakew (2004) indicated that more than 300, 000 shallow wells, about 206, 200 house hold level structural ponds, 49, 311 community ponds, 5,635 cisterns have been constructed and a total of 32, 727 springs have been developed. It was further reported that the technologies were supposed to benefit 732,336 households and 93,326 hectare of land has been supported under this scheme only in a physical year of 2004/05. During the year 2002/03,it was planned to develop 90,000 different water-harvesting structures benefiting the same number of households of which 83,400 were ponds (OIDA, 2001; Dereje, 2006) in Oromia Regional state alone. In Amhara region from the total completed water harvesting structures, reaching 242,000 in , over 42,000 have started production. And as a result 21,194 ha of land is under irrigation and 148, 244 farm households are benefiting (Lakew, 2004).

In general, Table 1 explicitly illustrates the types of water harvesting techniques used in different parts of the country and the purpose of use is also indicated. From the total constructed water harvesting structures in different regions of the country, the number of ponds is observed to be the highest (Table2).

Similarly, Table 3 illustrates the Percentage (%) of the liming materials used for the water harvesting technologies. Most regions used plastic (GOV supported). Clay must been available in Tigray and unlined ones were extensively used in Oromia (may be due to the suitability of the existing natural material).

The most notable achievements registered in promotion of the water harvesting technologies range from raising tree seedlings for fruit production in some parts of the country during the dry season, establishing of nurseries, supplementary irrigation and diversification of crops and use of improved agricultural technologies. Hence the importance of water harvesting technologies is implicitly unquestionable in addressing those pressing problems as shortage of water during a rainy season. These technologies provide assistance to attain food security in several ways. For instance it serves as supplementing the rainy season at times in Tigray (Figure: 1). The full irrigation service of the water harvesting technologies is also observed to be of paramount importance in some areas of the country (Figure 2)

Water harvesting technologies have been quite helpful in rehabilitating degraded hill sides in Harar where the advantage of this kind of is tow fold: the first advantage is conserving water for seedling establishment in the upstream area while the other is protecting the down streams from flood damage (Dereje, 2006). The study by Mitiku and Sorssa (2002) also revealed that runoff harvesting benefited in conserving of soil, taping unused water, ground water recharge, improve re-afforestation and crop production (Figure 4).

Despite the very important roles played by the water harvesting technologies to attain food security, some critical problems yet require immediate actions. The structural failures are connected with poor design, water lose due to evaporation and seepage, low technical capacity and subsequently low adoption by users (Rami, 2003: Goshu, 2007, Asegedew, 2005). Begashaw (2005) indicated that there was only 22% functional water harvesting structures out of the constructed ones between the periods 2003-2004 in Amhara regional state. All the reviewed papers indicated that dissemination of the technologies has to consider: geology and the geography of areas, human capacity, the types of inputs and the cost connected in construction of the technologies. The technical problems: seepage, cracking, catchments selection have to be seriously worked, a failure otherwise (Figres: 5, 6, and 7).

The most critical of all the problems is the water loses due to seepage resulting from poor lining materials of the harvesting storage structures (Rami, 2003 and Tafa, 2002). Hence technologies providing good protection towards seepage loss have been given a priority (Rami, 2003, Goshu, 2007, Yiasoumi, 2004). With a view of this, some research works have been conducted to identify the best lining materials that substantially reduce water lose due to seepage. Goshu (2007) found that mortar performed best (1.4 mm/day) followed by salt with compaction (7.88 mm/day) and local ash (9.33 mm), as indicated in Table 4. Asegedew (2005) also concluded that the rich mixture (1:3 Cement to sand ratio) was better in controlling seepage rate than the lean mixture (1:5 cement to sand ratio).

In a similar study, Dereje (2005) reported that the bio-plastic made up cow dung better reduced the seepage loss significantly (i.e. about 3.55 cm/day) than the untreated silt clay soil which had an observed 6.65 cm/day of seepage rate for a particular study site.

Saving of water from small reservoirs should be an economical solution; seepage and evaporation losses have been reducing the performance of the farm ponds in many areas.

Hence, water management holds one of the most important keys to be improved for achieving improved productivity of the land at the house hold level. Thus connecting the water harvesting technologies with efficient irrigation systems will be a great advantage for reducing loses while applying water to the field. In this regard, the Ethiopian Institute of Agricultural Research has been working on the demonstration of low cost drip irrigation systems combined with water harvesting schemes for it has an advantage of maximizing water use efficiency and significant results have been obtained in convincing farmers to use the combined technology (EAIR, 2010).

4. Conclusion and Recommendations

- Water harvesting can have an important role in achieving food security of Ethiopia
- It helps bridge the dry times between the rainy season to the benefit of human and livestock consumption and for agricultural and garden production through irrigation
- All the reviewed papers emphasized that water-harvesting schemes have limitations to different degrees
- The natural environment and Human capacity plays major roles.

- Design, type of technology, inputs, size and cost are also factors contributing to success and failure of water harvesting projects
- The implementation of different types of technologies has to consider the geology and the geography of the target areas
- The most important problem, seepage has to be resolved with low cost and effective lining materials that convince the users economy and wins `their psychology
- Promoting drip system combined with water harvesting should also be strengthened
- The research system has to take part in further dissemination work of the water harvesting technologies
- Close supervision of expertise during construction is extremely essential

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Table 1. Table: 1 Overview of some commonly used Water harvesting (WH) technologies in different parts of the country (Ylema and Yesuf, 2005)

WH technologies	Water sources	Uses	Category	Users	Regions
Above ground tanker	Roof	Drinking	Modern	School, Family	Oromia, South
Underground tanker	Roof	Drinking	Modern	School, hotel	Oromia, South
Ponds	Surface Runoff	Domestic, Livestock	Indigenous, Modern	Community	Somali, Oromia, South
Haffirs (Embankment)	Runoff	Domestic, Livestock	Indigenous	Family, individual	Somali
Cistern	Runoff	Domestic, Livestock	Indigenous	Community	Yabelo
Birk(Tank)	Runoff	Domestic, Livestock	Indigenous	Family	Somali
Earthen dam	Runoff	Crop production	Modern	Community	Somali
Micro dams	Runoff/streams	Irrigation	Modern	Community	Tigray
Bore holes	Ground water	Domestic, Livestock	Modern	Community	Somali
Shallow wells	Ground water	Crop production	Indigenous	Family	Kemisse
Ella (Deep well)	Ground water	Domestic, Livestock	Indigenous	Community	Borena
Bench terrace	Runoff	Crop production	Indigenous	Individuals, family	Konso
Runoff diversions	Runoff	Crop production	Indigenous	Individuals, family	Konso

Table 2: Relative proportion (%) of the different Water harvesting Technologies constructed in different parts of the country (MOA, 2004)

Type of WHT	Tigray	Amhara	Oromia	SNNPR	Total
Ponds	66	79	83	73	76
Well	22	15	4	24	16
Rives diversion	5	4	3	1	3
Multiple and others	7	2	10	2	5

Table 3: Percentage of lining materials used for water harvesting technologies in different regions of the country (2004)

Lining materials	Tigray	Amhara	Oromia	SNNPR	Total
Plastic	65	50	24	39	45
Clay	22	1	1	1	6
Cement	8	45	12	54	30
Unlined	5	4	63	6	19

Table 4 Seepage rates of different of lining materials (Goshu, 2007)

Treatment	Seepage (mm/day)
Mortar	1.4
Ash	9.3
Salt+ compaction	7.8
Compaction	15.8
Salt alone	12.8

Table 5 Seepage in mixtures of cement (Asegedew 2005)

Treatment	Seepage rate (mm/day)
1;3 Cement to sand (5cm thick)	1.18
1.5 Cement to sand(5cm thick	2.31
1.3 Cement to sand(2.5cm thick	1.7
unlined	9.46

Table 6 Seepage rate in local lining materials (Dereje (2005)

Treatment	Seepage rate (cm/day)
Bio-plastic sandwich	3.54
Termite mount soil	5.25
Compaction	5.39

Figure 1. Supplementary irrigation during dry spells: Farmer with his plastic lined pond, covered by stones in Wukro district, North Ethiopia (photo H. Rämi, UN-OCHA, Oct. 2003).

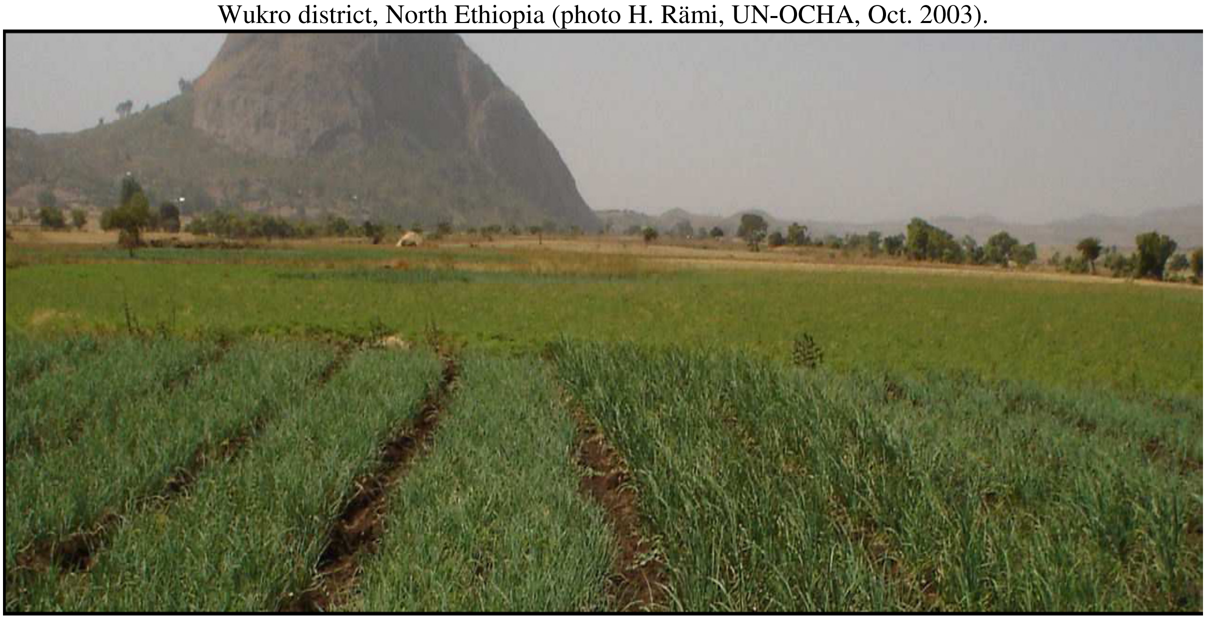

Figure:2 Onion field irrigated from pond water in , Libo-Kemkem disrtict, Nothr Ethiopia (Begashaw, 2005)

Figure: 3 A typical water harvesting structures constructed for rehabilitating denuded areas in Hararghe, East Ethiopia (Dereje, 2006)

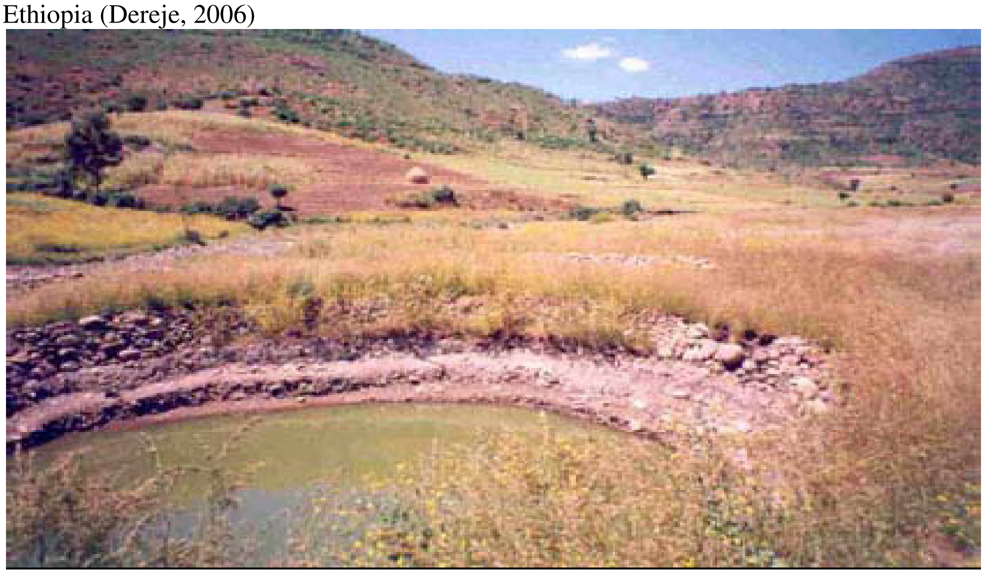

Figure 4 Benefits of water harvesting in conservation and ground water recharge (Mitiku and Sorssa, 2002)


Figure 5 Cracks in the water-harvesting structure (left) (photo H. Rämi, UN-OCHA, Oct. 2003) and Leaking from outside (right) (Rami, 2002)

Figure 6: In appropriate catchments (never filled up) by Rami (2003)

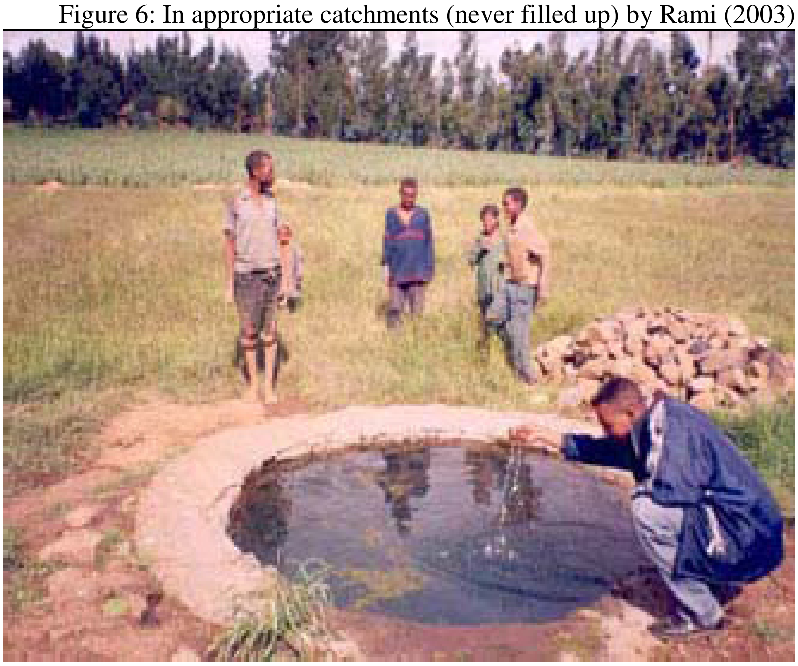

Figure 7 Overflow-Shallow wells (Rami, 2003)

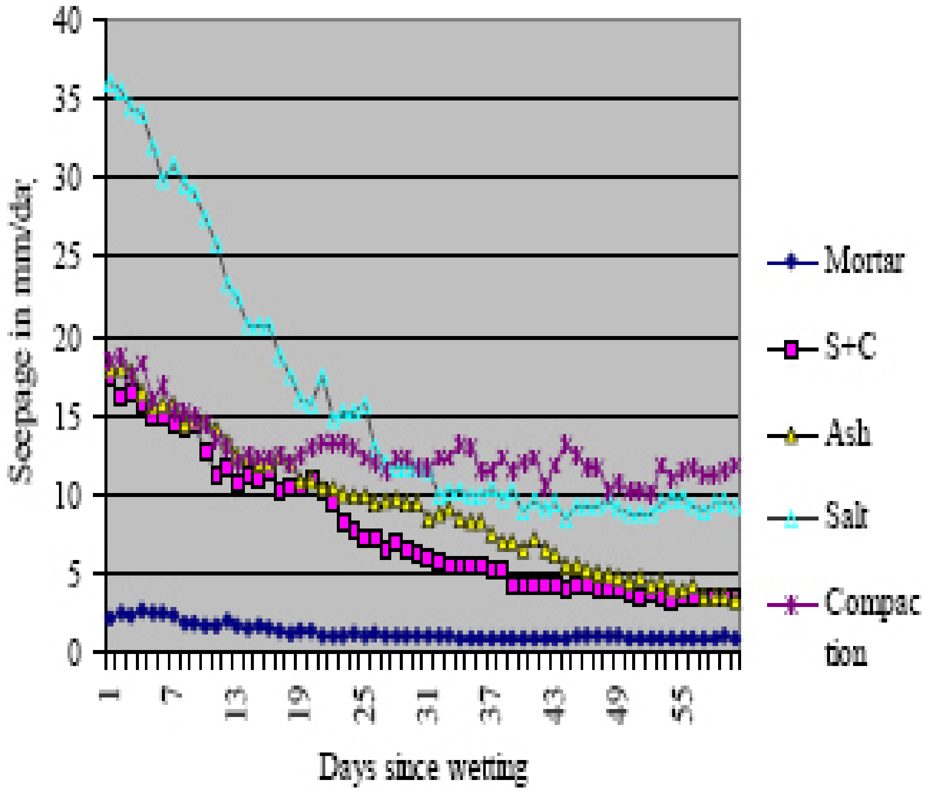

Figure 7 Seepage gradient in the lining materials after fits wetting (Goshu, 2007)

Figure 8: Successful model farmer on the trial site in Adama: Drip irrigation for vegetable production (photo H. Rämi, UN-OCHA, Sept. 2003)