Evaluation of Different Water Harvesting Techniques in Improving the Survival Rate of Tree Seedlings in Simada Woreda

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Abstract
The progressive reduction of the capacity of land to sustain the welfare of human beings is a common phenomenon in Amhara region in particular and in Ethiopia at large, due to serious deforestation and further land degradation. The objective of this study was to evaluate the efficiency of different water harvesting techniques to increase the survival rate of three tree seedlings both indeginoius and exotic species; *Acacia saligna, Cordia africana and Croton machrostachyus* and to improve natural regeneration of degraded lands in Simada Wereda.
Three water harvesting structures namely, micro basin, eyebrow and trench were compared with the treatment without water harvesting structure (control) for better survival of tree seedlings. The treatments were arranged in RCBD with three replications. The area of each treatment data was 500m^2 (25x20m) and the spacing between treatments and replications were 2m and 5m respectively. Three fixed sampling plots (5m x 5m) in each large plots locating upper, middle and lower position with 5m spacing were used to determine regeneration of naturally existing trees, shrubs and grasses.
Data like survival rates, height

Hemra and North Wollo followed by North and South Gondar, Eastern parts of South Wollo and Northern parts of North Shewa zones (Desta and et al, 2000)

Accelerated soil erosion is a combination of natural factors such as topography, erratic and erosive rainfall patterns and the action of man including the devastation of vegetation through deforestation, overgrazing and inappropriate agricultural practices which are in harmony with the environmental conditions (Betru Nedassa, 2002).

The major causes of land degradation include practicing of agriculture production on steep slopes and fragile soils without soil conservation and/or vegetative cover, erosive and erratic rainfall patterns, absence of fallowing, total dung and crop residue removal, deforestation and overgrazing. The accelerating forces to land degradation are population pressure, poverty, low access to agricultural inputs, low profitability of the agricultural sector, productivity fragmented land holding and insecure land tenure system (Lakew Desta and etal, 2000).

According to IIRR (2002), the natural resources in drought prone areas faced problems due to overgrazing, deforestation and soil erosion. On the other hand, different research works showed that moisture deficit and dry lands are surprisingly resilient. Because degraded, overgrazed lands still have a good room and capacity to recover.

Moisture deficit has direct implication for the survival of the people and great relationship with land degradation, food insecurity and poverty (IIRR, 2002). Therefore, it has an impact on social and environmental livelihoods.

Water stress is also the major growth limiting factor, which highly reduces the survival rate of tree seedlings in semi-arid areas of the Amhara Region. The rainfall in these areas is low in amount and erratic in nature. Occasionally, high-intensity rain produces high runoff and less soil water storage. This excess runoff could have been temporarily stored by creating artificial micro water storage basins around tree seedlings. Because of absence or inappropriate design of such structures or systems, tree seedlings suffer from moisture stress during most part of the year, mainly in the dry spells. Ultimately, most of the seedlings died after short time.

In moist deficit areas of Amhara region like in south Gondar especially in Simada, the area is marked with soil fertility depletion due to high and torrential rainfall with low vegetation cover. There is always unreliable and erratic rainfall in such areas of the region. The area is predominantly covered with acidic and have low inherent fertility. Continuous cropping, nutrient losses through harvest, soil erosion by rainfall and leaching result in natural degradation in general and the forest cover in particular. This severity has resulted in shortage of food for human beings and feed for animals and consequently, migration of the local people is increased.

Shrinking of land holding and declining of animal productivity with traditional farming practice has a contribution to natural resources base drying out. Off-farm activities in the area are limited investment in agricultural and other industrial practice is lacking so that unemployment is high in the area.

There are many different techniques practiced in drier parts of Africa adopted by farmers of which have given good results in experiment and are worth further trials (Muya, 1997). In Kenya different water harvesting techniques were used for moisture conservation in dry land areas of the country. Construction of water harvesting structures is an attempt to optimize the survival of tree seedling in drought prone areas. Since the most crucial and limiting factor in drought affected areas is moisture for the survival and growth of plants and/or seedlings.

One of the recent approaches to overcome such problems in semi-arid areas is use of different water harvesting structures. This includes the methods able to increase water availability to plants such as rainfall multiplier systems and micro runoff storage mechanisms. Volli (2000) indicated that in Ethiopia, there is limited information and experience in Ethiopia on the potentials of water harvesting techniques and its possible uses. In most cases tree seedlings are planted without any water harvesting methods or using the common half-moon (micro-basin), which in most cases has not been constructed carefully following its design. Hence, the objective of this experiment was to evaluate efficiency of the different water harvesting techniques that can store rainfall and runoff water to increase survival rate of the tree seedlings in the semi-arid areas.

Materials and Method

The trial was established at the beginning of August 2001. The final inventory was taken in December 2004. Sites on hillsides with a slope of 20%, where their soils are not too rocky which has shallow depth were selected for the trial. Originally the area was stony and have scattered grasses dominated by herbs, *Wariyat grass species* and some *Kotetina herb species* were found in the area.

Three water-harvesting structures namely micro-basin, eyebrow, water collection trenches and control treatment were arranged in RCBD with three replications. Each plot was splited into three for the three species used in the trial (*Acacia saligna, Cordia africana* and *Croton macrostachyus).*

The construction of the techniques described by Volli Carucci (2000) was employed for the study. The dimension of the area for one treatment was 20mx25m (500m^2) and the spacing between treatments and replications (blocks) was 2 and 5 meters, respectively.

Multi-purpose tree species for the area were selected as test plants. Each site was not fenced because there is shortage of locally available materials but was guarded to avoid interference of the free grazing and reduced stealing of grasses by the local people.

The structures were spaced 3mx4m (3m across the slope and 4m along the slope). The distance between two structures was measured from the center of the structure. Wider spacing was used with the density of 833 trees per hectare. Wider spacing is used because the area is moisture deficit so that to reduce moisture competition between seedlings planted in the area. The lateral distance between two consecutive structures was 50cm.

In this study a total of three species were used: one exotic species, *Acacia saligna* and two indigenous species, *Cordia africana* and *Croton macrostachyus*. These species were selected with preference of the local people. The number of seedlings per plot ranges from 37 to 56 and the number of seedlings per each species varied from 12 to 18 in each plot. Arrangement of species in each species was systematic. In each treatment the species has got different position in arrangement at each plot.

Three different water harvesting techniques, namely micro-basin (half-moon), eyebrow and trench were used as treatments and compared against control (without water harvesting).

Micro-basins are semi-circular structures made out of soil constructed along the contours for the main purpose of collecting and storing rainfall water to support the survival of plants in water deficit areas (Volli, 2000; IIRR, 2002). It can be used on gentle slopes to collect runoff from smaller rainstorms for tree seedlings. They have small catchments with 2-4 meter across or the diameter of the structures. The lateral spacing between two half-moon structures is 50cm. And the spacing between the centers of two consecutive micro-basins was 3m. This spacing is measured from the center of the two consecutive micro-basins. The water collection ditch was 1mx1mx30cm deep and the volume of each water collection ditch ranged from $0.25m^3$ to $0.30\ m^3$ (Volli, 2002) and the planting pit was dug on the lower position of the water collection ditch.

Eyebrow is semi-circular structure made out of stones constructed along the contours. They are suitable for shallow and stony soils of the dry areas due to their water harvesting effect. These structures can substitute replace micro-basins in low rainfall areas like Simada. It is constructed by digging a foundation of about 15-20cm deep and 20cm wide at the base and then decreased uphill. Large stones were placed in the center of the foundation. Water collection pit within the structure was dug 1m width x1m length and 25cm depth and the volume of each water collection ditch ranges from $0.25m^3$ to $0.30\ m^3$ (Volli, 2000). The lateral spacing between two eyebrow structures was 50cm. And the spacing between two consecutive eyebrows was 3m.

Trenches are large and deep pits constructed along contours for the main objective of collecting and storing rainfall water, which are useful to the survival and growth of tree/shrub seedlings in dry areas and also can control erosion (Volli, 2000). They can and have a capacity to collect and store considerable amount of runoff water and/or soil. Each trench has a size of 2mx0.5mx0.25m to 0.3m. Therefore, each trench has got a capacity of collecting 0.25-0.30 m^3 soil and runoff in the area. After lay is out a contour line across the slope the soil was dug and the soil was piled up 25cm at the lower end of the trench. The dimension of the trench was 2m-lengthx50cm-width and then the planting pit was dug 20-30cm deep at the center of the structure. The soil dug was piled down the planting pit.

The control treatment without water harvesting is simple planting pit. The pit has 20-30cm depth and doubled diameter to the size of the pot i.e. 20cm to 30cm. No water harvesting structures were used but the arrangement of the planting pits was in a staggered arrangement as it has been done for the water harvesting techniques. The spacing between two planting pits was 3mx4m like the spacing arrangement of the structures. The area used for one seedling was 12 m^2.

Arrangement of the water harvesting techniques

All the structures were arranged in a staggered arrangement on alternate rows so that the overflow from one row runs into the next row down slope. And the assumption was no water and soil loss exists with this arrangement. This is the common arrangement of water harvesting structures in the field condition for planting purpose of tree seedlings.

Methods of data collection and sampling

Baseline data of the site was collected at initial stage of the experiment supported with photograph documentation of each site. Experimental data was collected on average every six months starting from establishment. But the initial data was taken after three and half months. No beating up was taken after the establishment of the plantation.

Baseline data i.e. soil (soil depth, texture, pH, major physical and chemical characteristics, Available grass and tree/ shrub species, surface topography and photograph documentation. The area was staffed with scattered grasses and the soil depth was not more than 30cm.

Survival rate (SR) of tree seedlings, height, root collar diameter (RCD) were collected. The height and root collar diameters were measured using wooden tape and metallic caliper, respectively. Survival rate was measured in percent. Unit for measurement for height and RCD was in centimeters. For better precision, readings of two measurements were taken in a perpendicular direction of the standing seedlings. Data of maximum ten tree seedlings was taken for the aforementioned parameters. But for the survival measurement total count was taken. Ten seedlings were taken to take the parameters such as height and root collar diameter. This was done when the survived seedlings were above ten. If the number of survived seedlings were below ten, total counts were taken to measure the height and root collar diameter. But total count of survived seedlings was taken to compute the survival rate in percent for each species and comparison was made between the test tree species.

Data of maximum regenerated tree or shrub species under each treatment were recorded. Regeneration of natural existing trees, shrubs and grasses species (both type and abundance) was recorded using the following sampling method.

Three fixed sampling plots (5mx5m) in each plot were established. The sampling plots are located, upper, middle and lower position in each plot. Spacing between upper, middle and lower fixed sampling plots was 5 meters.

When the sampling plot location according to the measurement falls on the structures, we moved up or down or sideways so that it can be in between structures. The data measurement was not fixed but it is at the time where grasses and herbs start to dry and during the beginning of summer. Annually, the grass biomass was harvested (cut at about 15 cm heights) from each fixed plot and weighed. As part of the experiment the total grass biomass was harvested, weighed, piled and distributed among farmers. The cost of the grass/herb biomass was estimated depending on the existing and current cost to estimate the benefits gained from the trial.

Results and Discussion

Performance of tree species with water harvesting techniques

The survival rate of the different tree species in different water harvesting structures is presented in Table 1. The different species differ in their survival rates with the same water harvesting techniques. Acacia saligna was superior in its survival rates (up to 91%) followed by Croton *macrostachyus (62%) while Cordia africana was the least survived species (only 11%).* The impact of the different water harvesting techniques on the survival of seedlings was significant as shown in the table. Cordia Africana seedlings failed to survive in eyebrow and micro-basin structures as that of without water harvesting measures, while Croton *macrostachyus* failed completely in the treatment without water harvesting. As it is observed in the field the species dried from top to down i.e. a sort of die back was observed and due to moisture deficit seedlings wilted and looked unhealthy as compared to in other treatments. The survival rate of Croton *macrostachyus* in micro-basin and eyebrow was 48% and 35% respectively which was much better than the control but still below 50%. It appeared to survive better in trench water harvesting techniques (62%) while the same water harvesting structure was helped to survive only 11% of the Cordia seedlings at the end of the 39 months age.

Table 1: Effects of different water harvesting techniques on survival rates (%) of *Croton Macrostachyus*, *Cordia africana* and *Acacia saligna* at Simada *woreda*

Age in months	**Croton**				**Cordia**				**A.Saligma**			
	Control	Micro-basin	Eye-brow	Trench	Control	Micro-basin	Eye-brow	Trench	Control	Micro-basin	Eye-brow	Trench
3.5	26.0	76.0	58.0	70.0	45.0	51.0	36.0	53.0	86.0	91.0	97.0	73.0
8.5	35.0	62.0	58.0	70.0	17.0	38.0	35.0	51.0	78.0	91.0	98.0	71.0
15.5	3.0	52.0	46.0	62.0	7.0	22.0	26.0	40.0	75.0	89.0	92.0	70.0
23	3.0	47.0	43.7	65.0	2.0	14.0	18.0	18.0	54.3	81.0	92.0	62.0
30	2.7	47.0	35.0	62.3	2.0	2.3	0.0	10.7	54.3	77.3	92.0	62.0
35	0.0	48.3	35.0	62.7	1.7	2.3	0.0	10.7	28.3	77.7	90.7	62.0
39	0.0	48.3	35.0	62.3	1.7	2.3	0.0	10.7	28.3	77.7	90.7	62.0

Acacia saligna showed a survival rate of 78% at the age of 39 months in micro-basin. Eyebrow technique was superior, about 91% for the survival of *A. saligna* seedlings at the end of the experiment to all the tested water harvesting structures. The survival rate increment helps to increase the density of the species per unit area and the plantation remained almost the same as it was planted. Surprisingly, *Acacia saligna* performs poorer in trench than in micro-basin and eyebrow structures. The survival rate was only 62% at the end of the experiment. Perhaps, A. Saligna is sensitive to more moisture than the other species which have showed the opposite trends. Its survival without water harvesting, was 28% at the end of the experiment which was much better than the survival rates of Cordia in all the tested water harvesting techniques.

Table 2 shows the influence of different water harvesting structures on plant height for the three tree species.

Table 2: Effects of different water harvesting techniques on plant height of *Croton macrostachyus* Cordia africana and Acacia saligna at Simada *woreda*

Age in months	Croton				Cordia				A. Saligma			
	Control	**Micro-basin**	**Eye-brow**	**Trench**	**Control**	**Micro-basin**	**Eye-brow**	**Trench**	**Control**	**Micro-basin**	**Eye-brow**	**Trench**
3.5	8.7	11.6	12.7	10.5	9.4	8.5	8.8	22.3	27.9	31.5	31.6	37.0
8.5	8.6	11.1	11.0	9.9	11.7	8.3	7.4	16.1	16.4	25.7	21.5	34.0
15.5	2.7	17.7	20.2	25.6	11.8	15.4	12.8	25.9	39.6	70.8	80.3	95.7
23	2.7	21.0	18.5	29.5	11.3	22.0	14.2	25.0	44.8	101.9	112.7	92.2
30	0.0	24.7	26.7	38.1	11.3	16.7	0.0	12.7	84.4	148.9	136.9	116.7
35	3.3	23.9	26.3	34.3	2.7	18.7	0.0	18.5	110.5	136.7	123.4	118.0
39	0.0	27.6	31.7	39.1	15.0	17.7	0.0	19.0	141.2	180.2	136.7	128.5

Each species attained similar plant height at the end of the 39 months age. The different in plant growth seems to be highly dependent on the species type rather than the water harvesting techniques.

A. Saligna reached a maximum height of 180 cm at the end of 39 months experimental period which is equivalent to an annual growth of nearly 50 cm. Cordia africana achieved only 19 cm height after 3 years with an annual growth rate of 3.6 cm while Croton was better in growth than Cordia (annual growth rate of 6.3 cm).

Generally the impact of the different water harvesting structures on plant growth seems to be insignificant. Once seedlings are well established its growth is entirely affected by the tree species. Treatments that led to high survival rate of the respective species didn't necessarily influence plant growth.

The influence of water harvesting techniques on root color diameter (RCD) is shown in Table 3. RCD followed the some trend as plant height for the different tree species. A. Saligna achieved RCD of 3.5-5. 8 cm while Cordia reached only a maximum of 1.5 cm. Croton with RCD of 1.6-2.2 took middle position. For croton and cordial, one can say that treatments with better survival rate showed better plant growth and RCD while this generalization can't apply for the A. Saligna.

Table 3: Effects of different water harvesting techniques on root collar diameter (RCD) of *Croton macrostachyus* Cordia africana and Acacia saligna at Simada *woreda*

Age in months	**Croton**				**Cordia**				**A. Saligma**			
	Control	**Micro-basin**	**Eye-brow**	**Trench**	**Control**	**Micro-basin**	**Eye-brow**	**Trench**	**Control**	**Micro-basin**	**Eye-brow**	**Trench**
3.5	0.4	0.5	0.5	0.5	0.5	0.6	0.5	0.9	0.4	0.5	0.5	0.6
8.5	0.3	0.5	0.4	0.5	0.7	0.6	0.5	0.8	0.5	0.7	0.6	0.9
15.5	0.1	0.7	0.7	1.1	0.6	0.6	0.6	1.3	0.9	1.3	1.3	1.6
23	0.2	1.1	0.7	2.3	0.5	0.8	0.5	1.1	1.3	2.1	2.2	2.3
30	0.0	1.2	1.1	2.5	0.5	0.5	0.0	1.5	1.8	3.1	3.1	3.2
35	0.2	1.6	1.2	1.8	0.1	0.6	0.0	1.0	2.9	4.4	3.4	3.7
39	0.0	1.6	1.7	2.2	1.5	0.8	0.0	1.4	3.5	4.8	3.6	5.8

Though the growth of A. saligna seedlings was very restricted in trench water harvesting techniques as compared to other techniques, it gave the highest RCD of 5.8 cm.

Generally, survival rate of both exotic and indigenous species was very low or near zero in the treatment without water harvesting as compared to all the three water harvesting structures. However, *A. saligna* with a survival rate of 28% after 39 months was much better than the other two species. Water harvesting structures improved the survival rate of all species to a certain extent though there were also variations among the different structures and the species. Trench appeared to be better than the other two techniques for the survival of Croton seedlings but also to certain extent for Cordia. Acacia saligna is a drought tolerant species and survived good in all structured but exceptionally better in eyebrow techniques.

Biomass production

The regeneration status of the closed area was also measured at 15.5 and 30 months time interval which is given in Tables 4, 5, 6, 7 and 8. Field observations showed that the originally bare land recovered after 15.5 months of area closure. Grasses and herbs regenerated and invaded the area, which are used as a feed for animals during peak periods of dry seasons. Farmers were also able to get additional income through sells of grasses. The soil seed bank was obviously contributed for the fast regeneration of the area. The regeneration of new grasses and/or herbs species increased the biodiversity of the area. The coverage of invading species increased year after year as long as the area was protected from any animal and human interference.

Moreover, the structures collected runoff and soil sediment within the dug out pits. The structures stabilize the area through supporting the land from being eroded and loss of moisture.

Table 4**:** Regenerated Species on Micro-basin

At the age of 15.5 months				At the age of 30 months			
Tree/ Shrub	No	Grasses/ Herbs	Grasses/ Herbs	Tree/ Shrub	No	Grasses/ Herbs	Grasses/ Herbs
Alashume	28	Chifrig	Kesie	Girar	2	Murie	Chifrig
Girar	1	Yediha akomada	Yetota kolet	Kitkita	6	Gaja	Akirima
Kitkita	4	Enshilalit	Murie	Alashume	4	Yezinjero fes	Yewusha milas
Embacho	1	Senkelo	Gaja	Embacho	1	Yemeret wesfat	Kesie
Metete	25	Akirima	Yewef teff	Atat	1	Sirsira	Kotetina
		Tosign	Lambut	Duaduatie	11	Anterifa	
							Shemgegit
		Machid seber	Yetota Murie	Kega	1		
		Senbelet	Chigogot				
		Wajima	Kotetina				
		Yemidir embuay	Yetef akomada				
		Yebeg lat	Gorteb				
		Serdo	Nech arem				
		Ret	Sirsira				

About five tree/shrub species were regenerated at the age of 15.5 months and more than 26 grass/herb species have been identified which are listed in Table 4 with their local names.

More grasses and herbs have invaded the micro-basin immediately after the construction. But gradually at the age of 30 months, after establishment of the structures the number of tree/shrub species increased by one i.e. 7 species but individual number per each species decreased. But the number of grass/herb species decreased from 27 to 13 after 2.5 years.

As indicated on the Table 4 at the age of 15.5 months time, trees/shrubs were newly emerged and invaded the area. About 24 locally known grasses and herbs and 5 trees/shrubs regenerated and invaded the area. Farmers took the grass using cut-and-carry system. But they mowed without selecting the regenerated species. This has been done during drier seasons of the area when there is shortage of feed for their cattle.

All pioneer as well as newly emerged species invading the area have been uprooted and given to their cattle. With the same trend of the micro-basin at the age of 30 months the area was grazed without the permission of the guard. And hence, the initial tree/shrub species regenerated missed and another four tree/shrub species regenerated. The grass/herb species also reduced from 24 grass/herb species known before to 16 in number.

Table 5: Regenerated Spaces on eyebrow

At the age of 15.5 months				At the age of 30 months			
Tree/ Shrub	No	Grasses/ Herbs	Grasses/ Herbs	Tree/ shrub	No	Grasses/ herbs	Grasses/ herbs
Alashume	22	Chifrig	Yeshiwuta-medihanit	Agam	1	Yemidir embuay	Yezinjero fes
Kitkita	6	Yewef teff	Gaja	Atat	1	Chifrig	Murie
Girar	2	Maget	Serdo	Kega	1	Gaja	Birbir sar
Embacho	1	Yeberie kolet	Yeferes zeng	alashume	1	Yewef teff	Yemeret-wosifat
Metete	7	Kotetina	Kesie			Gorteb	Ret
		Senbelet	Yebet sar			Akirima	Gejeme
		Yetota kolet	Bunign			Sirsira	Senkelo sar
		Senkelo	Wajima			Serdo	Kotetina
		Yebeg lat	Akirima				
		Murie	Anteref				
		Adey abeba	Amerarie				
		Nech arem					

Water collection trench encouraged regeneration 7-tree/shrub specie and 18 grass/herb species and were identified with their local name and recorded within 15.5 months after establishment of the trial. But after 30 months, the number of tree/shrub species and grass/herb specie decreased from 7 to 5 and 18 to 13 respectively. The reason was the local people left their cattle to graze by refusing the guard.

Table 6: Regenerated species on water collection trench

At the age of 15.5 months				At the age of 30 months			
Tree/ Shrub	No	Grasses/ herbs	Grasses/ Herbs	Tree/ Shrub	No	Grasses/ herbs	Grasses/ herbs
Alashume	50	Kesie	Gaja	Embacho	6	Gaja	Wariat
Lute	1	Chifrig	Wariat	Alashume	2	Goriteb	Kesie
Meteto	3	Gicha	Serdo	Weyira	1	Gume	Kotetina
Yewusha-milas	1	Akirima	Yebeg lat	Girar	3	Keskeso	Yezinjero fes
Metetie	16	Mrie	Kutetina	Kitkita	5	Chifrig	Murie
Kitkita	3	Yetota kolet	Senbelet			Wariyat	Senbelet
Atat	1	Lambut	Goriteb			Ret	
		Nech sar	Tosign				
		Yezinjero-kimem	wajima				

On the treatment control (without water harvesting techniques), some five tree/shrub species and 21 grass/herb species regenerated during one and quarter year. Since the area was not well protected by the guard, the number of species regenerated and invading the area decreased as time goes up. Hence, at the age of two and half years the number of grass/shrub species decreased from 21 to 14. Some of the tree/shrubs disappeared and another new species (which were not present at the age of 15.5 months) regenerated. For example, Kitkita and Embacho newly regenerated, but Metetie and Yezinjero kimem disappeared after one and quarter years after emerging in the area.

Table 7: Regenerated Species on control

At the age of 15.5 months				At the age of 30 months			
Tree/ Shrub	No	Grasses/ herbs	Grasses/ herbs	Tree/ Shrub	No	Grasses/ herbs	Grasses/ herbs
Alashume	16	Chifrig	Kutetina	Kitkita	8	Yetota kolet	Tosign
Yezinjero-kimem	44	Yetota kolet	Yewef teff	Kega	3	Yezinjero fes	Geram tinjut
Metetie	33	Senbelet	Gaja	Girar	4	Murie	Senbelet
Kega	1	Murie	Lambut	Alashume	1	Yewef teff	Akirima
Girar	2	Maget	Yebere kolet	Embacho	1	Ret	Gejem sar
		Yebeg lat	Adey abeba			Kuando-hareg	Yemeret wesfat
		Amirar	Tosign			Gune	Sirsira
		Wajima	Kesie				
		Chigogot	Gereamo				
		Goriteb	Amererie				

Economic Benefit (income gained)

As indicated on the Table 8, the method of biomass collection for fodder was a cut-and-carry system and was found to be practical and economical. Previously, farmers used the land for free grazing with very limited benefits. After 39 months, the data of biomass was not taken because farmers cut and took grasses for their cattle and thatching their house without prior permission of the guard assigned for the trial.

But as the data of 15.5 and 30 months indicated, the biomass produced can support their cattle from being starved in off-season. Farmers can also have an opportunity to get high prices by selling the grass for roof thatching purposes. At the age of 15.5 months, the biomass gained in micro-basin, eyebrow, water collection trench and control was 600kg/ha, 708kg/ha, 868kg/ha and 332kg/ha, respectively. The estimated income gained from trench and eyebrow for example was 130 and 106 Birr respectively. The control still did not encourage the biomass production as compared to the water harvesting structures. At 30 months period, both the control and eyebrow gave similar grass amount and income while trench with an income amount of 148 Birr/ha was again superior to all the other treatments

Table 8: Compassion of economic benefits from different water harvesting structures

Treatments	At the age of 15.5 months			At the age of 30 months		
	Biomass (kg/ 25 m$^{2)}$	Biomass (kg/ha)	Estimated income gained (Birr/ha)	Biomass (kg/ 25 m^2)	Biomass (kg/ha)	Estimated income gained (Birr/ha)
Micro-basin	1.5	600	90^{aa}	1.18	472	94.40^{bb}
Eyebrow	1.77	708	106.2 ^{a}	1.31	524	104.80 ^{b}
Trench	2.17	868	130.2 ^{a}	1.86	744	148.80 ^{b}
Control	0.83	332	49.8 ^{a}	1.32	528	105.60 ^{b}

a = 0.15Birr per kilogram, b = 0.20 Birr per kilogram (Current cost of grasses during data was taken)

The water harvesting structures constructed in these degraded lands conserved soil and water and keeps the area from loss of nutrients. The conservation of water with the help of water harvesting techniques increased the vegetation cover of the area. The biodiversity increased from year to year in kind and amount. Especially the plants like herbs and grasses increased.

The structures were filled with woody species existing in soil seed bank regenerate and started to invade the land found above the micro-catchment. Therefore water-harvesting structures for water deficit areas has a potential to reduce erosion and runoff on degraded areas like Simada so that increased the existence of different species.

From the results of the experiment, it is possible to conclude that developing water harvesting structures for the growth of important tree crops is the best option for the survival and growth parameters of seedlings in drought affected and moisture deficit areas, such as Simada and the like.

From the results of the experiment it is possible to recommend the following:

Water harvesting structures could incease the survival rates of seedlings in drought prone areas. Survival rate of seedlings appeared to be also species depenedent. Growing *Acacia saligna* is best for moisture deficit areas and its survival rates can be improved by three folds (91%) using water harvesting structures like eyebrow. Though there are quite huge differences among them, *Croton Macrostachyus and Cordia africana* performed better under trech techniques with survival rates of 62% and 11% respectively. Croton didn't survive at all without water harvesting measures. Degraded hills recovered through area closure and more rapidely in combination with water harvesting activities. Water harvesting structures can also retard erosion in addition to conserving moisture. The over all result showed that the performance of all species under treatment without water harvesting structure was very low in all parameters used in the experiment. Hence, developing water harvesting structure for the growth of important tree crops and for natural regeneration is the better option for the survival and growth of seedlings in drought affected and moisture deficit areas.

Reference

Betru Nedassa. 2002. Soil and Water Conservation Program in the Amhara National Regional State. WFP National Coordinator, Ministry of Agriculture. Addis Ababa, Ethiopia.

Carucci Volli. 2000. Guidelines on water harvesting and soil conservation for moisture deficit areas in Ethiopia: The productive use of water and soil. Manual for trainers, first draft Addis Ababa, Ethiopia

Lakew Desta, Menale Kassie, S.Benin and J.Pender. 2000. Land degradation and strategies for sustainable development in the Ethiopian highlands: Amhara Region. International Livestock Research Institute. Amhara National Regional State Bureau of Agriculture, Working paper No. 32.

Anonymous. 2003. Proceedings of the conference on: Natural Resource Degradation and Environmental Concerns in Amhara National Regional State, Impact on Food Security, Bahar Dar, Ethiopia.