Lessons From Watershed-Based Climate Smart Agricultural Practices In Jogo-Gudedo Watershed, Ethiopia

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Abstract: Land degradation is the most chronic problem in the Ethiopia. Soil erosion and denudation of vegetation covers are tending to enlarge the area of degraded and west land in semi-arid watersheds. It is, therefore, watershed management is believed as a holistic approach to create a climate smart landscape that integrate forestry, agriculture, pasture and soil water management, with an objective of sustainable management of natural resources to improve livelihood. This approach pursues to promote interactions among multiple stakeholders and their interests within and between the upstream and downstream locations of a watershed. Melkassa Agricultural Research Centre (MARC) has been implementing integrated watershed management research project in the Jogo-gudedo watershed from 2010-2014 and lessons from Jogo-gudedo watershed are presented in this research report. Participatory action research (PAR) was implemented on Soil and Water Conservation (SWC), area enclosure, Agroforestry (AF), Conservation Tillage (CT), energy saving stove, drought resistance crop varieties in the Jogo-gudedo watershed. Empirical research and action research at plot level and evaluation of introduced technologies with farmers through experimental learning approach and documentation were employed. The participatory evaluation and collective action of SWC and improved practices brought high degree of acceptance of the practices and technologies. This had been ratified by the implementation of comprehensive watershed management action research which in turn enabled to taste and exploit benefits of climate-smart agricultural practices. Eventually, significant reduction on soil loss and fuel wood consumption, improvements on vegetation cover and crop production were quantitatively recorded as a good indicator and success. Field visit, meetings, trainings and frequent dialogues between practitioners and communities at watershed level have had a help in promoting the climate smart agriculture practices and improving productivity that could help to improve the livelihoods of the local people and sustainable watershed resource management.

Key words: Watershed management, climate smart agriculture, stakeholders, soil erosion, conservation tillage, Action research

1 Introduction

Land degradation is occurring at an alarming rate in Ethiopia (Kidane, 2014; Temesgen *et al*., 2012), which causes for important social and economic problems (Bewket and Sterk, 2002; Kassie*et al.*, 2007; Hurni *et al*., 2005; Moges and Holden, 2008). Poverty and land degradation appear to feed off each other for many years. The excessive dependence of the Ethiopian rural population on natural resources, particularly land, as a means of livelihood has been the underlying cause for land and other natural resources degradation (EPA, 1998). Integrated watershed management approaches are now considered as innovative options for sustaining ecosystems while improving human welfare (Temesgen; et al., 2012; Alemu and Kidane, 2014; Kidane et al., 2015). It encompasses the holistic approach to managing watershed resources that integrates forestry, agriculture, pasture and water management which can be broadened to rural development with a strong link to the livelihoods of the local people (Desta *et al.,* 2005; Tefera and Sterk, 2010; Yitaferu, 2007). Similar to most part of the country, low adoption of the technology, sever soil erosion, denudation of trees and low productivity of the land had been the common features in the Jogo-gudedo watershed. This report synthesizes experiences and results of climate smart agricultural practices from action research that have specific relevance to resource management of the Jogo-gudedo watershed.

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2. Location

Jogo-Gudedo watershed is found in the central rift valley of Ethiopia at 8^0 33' 25'' N latitude and 39^0 12' 29'' E longitudes. It has an altitude ranging from 1644 - 2054 m.a.s.l. It is found East Shoa zone between Mojo and Nazareth town approximately 80 km away from the capital, Addis Ababa (Figure 1). The watershed has an area of 1824 ha.

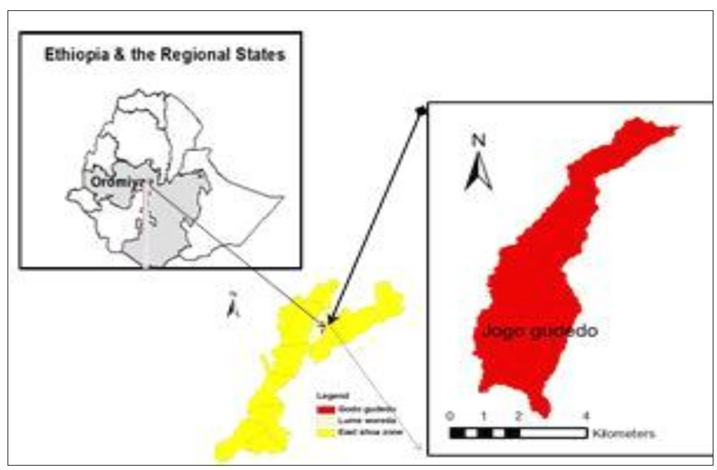

Figure 1: *Location of Jogo-Gudedo watershed*

3. Major Findings of watershed management action research

In order to synthesize the report, the authors used results of different research activities that have been done in the watershed. The various research reports previously completed and reported in the watershed believed to have some valuable data and information revealed regarding climate smart agricultural practices. There has been a tension on the roles of researchers engaging in action research oriented development activities. Integrated research protocols were developed for each cluster and sub-cluster that requires research and development. Action Research aims to contribute both to the practical concerns of people in an immediate problematic situation and by joint collaboration. Action research has been applied by researcher to deal with a variety of educational and social service problems. Researchers used action researches or experiments to merge local and scientific knowledge for the sake of social learning process. Therefore, researchers have been made an effort to generate and share the knowledge and identify socially acceptable solutions in depth and long term process. Researchers carried out quantitative research techniques such as questionnaire surveys, GIS-based analysis, erosion and runoff measurements and economic valuations in the action research process to validate working group hypotheses.

3.1. Adopted SWC practices

3.1.1 Farm land terraces
The farm land SWC technologies introduced and evaluated in the watershed has been predominantly subjective to standard structural SWC technologies. Common terrace practices like soil bund and *Fanyajuu* structures were done interchangeably on the farm in order to reduce excess runoff, soil loss and the slope gradient and extend the time span for water to infiltrate into the soil system. Based on the assumption of MMF model prediction the farm land terraces constructed on crop lands and tree planted on degraded mountainous area reduced soil loss by 15.5%. MMF model estimated that implemented different SWC measures have a performance to control soil erosion by reducing by more than 42 % and in arresting soil erosion through doing different SWC using model output. This could be attributed to the fact that there is a linkage with vast enormous km of soil bund and '*Fanya Juus'* conservation tillage and enclosure that has been done in the watershed.

3.2. Conservation Tillage practice
Although conservation tillage has been under demonstration for maize in the watershed before, both farmers and agricultural extension experts did not try the technology for other crop production. Participatory assessment of run-off and soil losses was carried out from the different tillage practices. Experiments were carried out in applied research concept to evaluate the technology at farmer's field (Figure 2 a, b, and c). Result shows that improved tied ridge tillage implementation reduced soil loss 2.85 ton $ha^{-1}$and runoff 863.3m^3ha^{-1} respectively (Figure 2,(a)).

Figure 2: *Runoff experimental plot of tillage implements, 2012*

a) Tied ridge treatment b) Farmers practice c) bareland

Treatments	Grain yield (kg ha^{-1})	Soil Loss (t ha^{-1})	Runoff (m^3 ha^{-1})
Tied-ridge	1724	1.32	539.32
Conventional or farmers practiced	613.8	4.17	1402.92
Bare land	……	3.83	2419.99

Table 1: *Effect of improved farm implement on grain yield of Haricot Bean through on-farm experiment*

It also, increased the grain yield 1110.2 $kgha^{-1}$ compared to conventional tillage (Table 1). Therefore, the economic benefit of Haricot bean production through conservation tillage was superior compared to the conventional tillage.

3.3 Hill side terracing
Identification of economical and appropriate micro-catchment water harvesting systems for the support of early survival of tree seedlings in the watershed was carried out. The design was randomized complete block design. Four types of promising multipurpose trees namely: *Azadirachta indica, Schinusmolle, Acacia saligna* and *Parkinsonia aculeata* were selected and randomly planted in each of the micro-catchment structures after the runoff have been harvested around the structures. The growth (height and diameter) and survival of the trees in each structures were recorded. All treatments were tested at 95% ($P < 0.05$) confidence limits. Hence, tree seedlings require additional moisture to rain water in dry areas for their early survival. Among the micro-catchment micro water harvesting structures used in this study the highest survival percentages were recorded in semicircular bund (81.7%) and followed by contour-bench terraces (76.7%), whereas infiltration pits performed the least (5%). They have different survival rates. Thus, it leads to variation with in the same treatment. Semi-circular bunds have also economic advantages that they are easy to construct and are labor efficient. Lower survival percentage was recorded (40%) for the eyebrow terraces, which also have different disadvantages.

Treatments	Survival Percentage (%)
Semi-circular bund	81.7
Contour-bench terraces	76.7
Eyebrow terraces	40
Infiltration pit	5
LSD	49.72
SE$\pm$	0.28
CV (%)	48.96

Table 2: *Micro catchment water harvesting structures*

3.4 Agroforestry practices
Farmers had the land used systems technologies where woody perennials (trees, shrubs, and palms) deliberately used as agricultural crops on the same land management units or home gardens (Figure 3).

Figure 3: *Agroforestry practices implemented in Jogo-Gudedo watershed*

Agroforestry practices that commonly farmers used for different purpose described in table 3. Mostly farmers practiced Agroforestry for income generation, forage and fire wood source.

Tree species used for AF practices	AF practices commonly practiced	Common feature	Direct AF trees serve as source of
Acacia albida *A. mellifera* *A. nilotica* *A. seyalstenocarpa* *A. tortillisraddiana* *Alnusacuminata* *A.nepalensis* *Anacardiumsenegalensis* *Annonasenegalnsis* *Anogessusleiocarpa* *Azadirachtaindica* *Borassvsaethiopium* *Calliandracalothyrsus* *Cajanuscajan* *Casuarinaequisetifolia* *Carica papaya* *Cedrelaserrata* *Citrus aurantium* *Citrus limon* *Citrus sinensis* *Colophospermummopane* *Leucaenaleucocephala* *Mangiferaindica* *Sesbaniasesban* *Perseaamericana*	-Alley cropping Wind breaks Fencing Scattered trees Woodlots	Tree seedling mortality Low level AF technology adoption Lack of information on species arrangement for better yield	Income Shelter and shade, Forage Fire wood

Table 3: *Agroforestry Practices and tree species list planted in Jogo-Gudedo watershed*

3.5 Area closure

Initially there was no any single vegetation cover observed in the degraded hilly. However, after the project implementation different grass, shrub and tree species were recorded in the watershed especially in the enclosure site (Table 7). Area enclosure followed by SWC practices and forage and tree seedling planting contributed to emergence and growth of different palatable grass or forage and tree species. Enclosure opens the possibility for regeneration from seed bank of different indigenous Acacia tree species and other tree species. This indicates the relevance of area closure with various interventions to improve the rehabilitation and development of the degraded hilly land. The plant composition become valuable for bee forage and tree plant in the rehabilitation site. With increased moisture and soil retention in the degraded area closure, the duration of bloom period of bee forage plants stayed longer than open areas. This result and Apiculture or bee keeping activity carried out by beekeepers' associations. This would be one of the main reasons for the substantial increase in honey production. The overriding concern was to rehabilitate degrade hillside with multipurpose trees in order to conserve biodiversity and/or use tree product, reducing erosion and carbon emission, to adapt and mitigate climate change as triple win strategy. Measurements of above and below ground carbon were conducted. For aboveground carbon two carbon pools (herbaceous biomass and tree/shrub growths) were identified and measured. And for below ground carbon, soil carbon measurements were done. From the total area of the enclosed hill land, a total of 7.9 ton/ha of carbon was sequestered/stored in the above ground carbon pool just after the area was enclosed.

Carbon pool	Biomass (ton)/ha
Herbaceous biomass	5.8
Existing & planted species	10
Total biomass	15.8
Aboveground carbon (total biomass*0.5 conversion factor)	7.9

Table 4: *Estimation of aboveground biomass and carbon stored*

3.6. Participatory drought resistant crop variety testing and adaptation

The participatory drought tolerant crop varieties adaptation research has tried to achieve an increment in farm production under temperature and water stress targeting a yearly percentage changes in farm production up to 50% from the baseline. In line with this outcome, a number of proven crop technologies and farm land water management were tested in the watershed. The tested crop varieties technology and adaptation results showed that yields have been increased tremendously. Yield of Maize (78.2–99.2%), Tef (10.8-11.9%), Haricot bean (13.6-14.3%), Wheat (29.2-100%) and Barley (0.4-12.2%) were higher than the current production system and variety. The technological options have boosted crop yields from 1830 Kg/ha of current wheat production to 3733 Kg/ha of wheat yield. The participated farmers have a chance to secure their food and sell the surplus which was a dream a year before.

3.7 Integrated Soil fertility Management Activity

In-line with the gap indicated at household survey and PRA, two farmers have been randomly selected to test the ISFM technologies in the watershed on Tef and Haricot bean fields Table 5. The result from the experiment showed that use of chemical fertilizers provided high yields in haricot bean. The combined use of half recommended chemical fertilizer and half recommended compost (organic fertilizer) however has showed a comparable yield advantage for haricot bean Table 5. The study on haricot bean has convinced farmers that compost can replace the cost they incur for chemical fertilizer by half and enhance organic agriculture. It has been also noted that compost alone didn't perform well in yield increment may be due to the slow ability to release nutrients and the advantage is mostly pronounced in the subsequent years.

Integrated soil fertility reseach activity on Haricot bean	
Treatments	Grain yield (ton/ha)
Control (with no fertilizer)	0.91
Compost (farmers practice)	0.94
Recommendation compost +1/2 Recommended chemical fertilizer	1.36
Full dose inorganic fertilizer	1.06

Table 5: *Effect of different sources of nutrients on the yield of Haricot bean*

3.8. Evaluation of Improved Energy Saving Wood-Burning Stoves in the Jogo-gudedo Watershed

Performance test of three different stoves was conducted, in order to quantitatively determine the efficiency. Evaluation was carried out between two improved energy saving stoves and the conventional one. Three types of stoves test were conducted three times. *Mirte, Gonziye* and traditional open fire stoves were the treatments. Finally, wood consumption, time to cook 10 *'Injera'* and rate of wood consumption of the three selected stoves was evaluated.

Parameters		Stove types			Statistics	
		Merti	Gonziye	Open fire		
	unit				(P= o.o5)	CV
Wood consumed	kg	3.43	2.2	5.6	0.0002	10.21
Time to cook 10 Injera	min	28	27	34	0.0487	11.86
wood consumption	kg/min	0.12	0.08	0.25		
Material Used		Cement	Mud	Mud		
Cost incur	birr	120	60	10		

SD = Standard deviation; CoV = Coefficient of variation; Calorific value (MJ/kg) of *Eucalyptus camaldulensis* = 29.500MJ/kg (FAO (1993))

Table 6, *Energy saving stove performance*

During *Injera* cooking test the result shows us *Gonziye* stove performed very well comparing with traditional open fire and *Miret* stove had relatively consistent in the three test phases. Although, there was large variability on initial time clod warm or to take time to make *Injera* starting from initial time. Fuel-wood and energy consumption in three repeat control cooking test CCT performed for each stoves type. Traditional open fire stoves showed a considerably higher fuel-wood and energy consumption compared to *Gonziye* and *Mirte* stoves. The experiment was carried out with three *"Mitad"* which media on the *Injera* is cooking on that have the same weight for minimizing the error. As indicated table 6, treatments have statistically significant difference among them on selected parameters. Selection of the best Energy saving stove has been completed accordingly *'Gonziye'* has been selected over *'Mirt'*.

Conclusion and recommendation

Soil and water conservation action research have reduced in soil erosion and runoff in the watershed areas. However, the quantification of soil loss after and before intervention using models is paramount important. The performances of SWC in the watersheds have scored better under most activities in soil erosion, and runoff reduction. However, it must be considered and checked out that these technologies implemented in the extreme environmental conditions and evaluated quantitatively. Hence, even this limited impact can be judged as positive. Nevertheless, there is a need to find out the gaps and reasons so as to make it even more effective and realize full benefits from them. It was found that there was good quality water harvesting structure but in some other watershed areas, it requires further attention. There is positive change in the land use pattern on hill reported in the watershed. The degraded hilly waste land was converted for productive use by the farmers. This has resulted increase in net potential area in the upper stream hilly land and exhibited as best triple win strategy for climate change mitigation and adaptation. Crop diversification and using improved variety with soil fertility management and conservation tillage is resulted in more production enhancement in the watershed areas. Agroforestry practices as watershed management option resulted positively in reducing the workload of women in terms of collecting fuel wood and fodder for livestock in little case. Also the income of the community members has increased to some extent. Action research via participation of beneficiaries in planning and execution of the watershed was seen more from watershed committee group. The socio-economic importance of watershed ecosystems goes far beyond local residents' interests. Erosion and excess runoff conserved at the upstream had a positive impact in a downstream organizations and inhabitants. Food, timber and fuel wood produced in the watershed may be needed by neighboring community. Emphasis should be on watershed natural resource management as part of local socio-economic development processes in the watershed.

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Table 7: *Naturally regenerated and planted species growths (height and diameter), number of stems, frequency and abundance*

Species local name	Scientific name	Average Height (cm)	DBH (cm)	No. of stems/ha	Frequency	Abundance
-	*Acacia saligna*	128.85	2.249	6619	15	
Sebesa	*Acacia senegal*	128.27	2.02	105	12	57.14
Tedecha	*Acacia tortilis*	105.57	1.4	543	21	100.00
Hate	*Dichrostachyuscinerea*	90	0.81	91	7	33.33
Kechachule	*Securinga virosa*	132.07	0.85	143	13	61.90
Baloli	-	117	1.25	95	1	4.76
Gora	*Acacia millifera*	116.01	0.78	43	5	23.81
Dodoti	*Acacia gerrardi*	58.5	0.78	19	3	14.29
Kankalcha	*Tephrosia spp*	131.33	1.03	14	4	19.05
Kassale	*Acacia etbaica*	93.6	1.3	24	3	14.29
Badano	*Balanitesaegyptica*	158	1.28	29	3	14.29
Eka	*Grewia spp.*	82.6	0.86	24	4	19.05
Gerbi	*Faidherbia albida*	57	1.1	5	1	4.76
Baladi	-	120	1.3	5	1	4.76
-	*Sesbania sesban*	85	1.7	12	5	