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Integrated Watershed Management for Resource Conservation in the Maize-Based Farming System of Bako Area: A Case Study of the Fechea Sub-Watershed

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Abstract - Integrated watershed management (IWM) is a process of formulating and carrying out a series of actions to manage human activities in order to protect and rehabilitate natural resources and associated aquatic resources, while recognizing the benefits of orderly growth and development. This approach has multiple advantages: it allows concentration of efforts enhances community participation and allows systematic resource use and management. This project was initiated in the maize-based farming system of western Ethiopia with several objectives: establishing a shared understanding of IWM; delineating and mapping the watershed according to agro ecologies, farming systems and levels of land degradation; characterizing, identifying, prioritizing and analyzing biophysical and socioeconomic issues; and demonstrating different technologies and assessing opportunities for and constraints to the IWM approach as an intervention toward sustainable land use and food security. The project was designed with two aspects: the first involved survey and planning exercises and the second implementation. The first phase addressed 14 watershed issues that had been prioritized by the community: shortage of improved seed/crop varieties, feed shortage, deforestation, soil fertility decline, market fluctuations of grain prices, lack of quality drinking water, pests and plant diseases, soil and water loss due to excess runoff, lack of improved cross-breed livestock, lack of training/extension in different disciplines, insufficient veterinary services, shortage of water supply for livestock, lack of credit and shortage of labor.

In the implementation phase, multidisciplinary professional teams worked collaboratively to address these watershed issues. Various soil and water conservation structures were constructed and vetiver grass was planted on ridges to control soil loss due to erosion, soil fertility decline and water quality and quantity decline due to sedimentation. Multipurpose agroforestry tree species such as Cordia africana, acacia albida (fertilizer tree) and Grevillea robusta were planted on different land-use locations to minimize the problem of deforestation, land degradation, soil loss and climate change. Different forage crops Lucaena palida, Dolichos lablab, Rhodes grass and elephant grass were experimented with in plots of 6x6 m to see whether they hold the solution to the shortage of livestock feed. Improved seed varieties of teff and haricot beans were distributed to farmers and also demonstrated on plots of 25x25 m and 10x10 m respectively to address the issue of shortage of improved seed varieties, which was the top-ranked issue in the watershed. Different horticultural crops were planted on farmers' lands to examine a shift from maize mono cropping to agrisilviculture; also, bee-keeping development was done to improve the livelihoods of farmers in the watershed. The problem of soil erosion is complex and needs the integration of different innovations, especially policy, socioeconomic and technological interventions; implementation of the land use policy is the best option, especially for communal grazing lands in the Fechea sub watershed, to minimize the competition and conflict related to open resource use. Some of the identified issues were not addressed due to resource limitations and the nature of those problems; they need great attention from different offices administering agriculture and water, especially the Cooperative Association Bureau and the Animal Health Bureau, to solve problems related to the lack of credit and veterinary services.

1. INTRODUCTION

Eighty-five per cent of the population of Ethiopia is directly dependent on agriculture. However, agricultural productivity has been severely hampered by unsuitable land management practices, both in crop as well as grazing lands. The direct cost of the loss of soil and essential nutrients due to unsustainable land management is estimated to be about 3 per cent of Ethiopia's agricultural gross domestic product (GDP), or $106 million. Other modelling work suggests that the loss of agricultural value between 2000

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and 2010 has been a huge $7 billion (Berry 2003). To change this disastrous scenario, implementation of appropriate land utilization and management practices is the only option.

Efforts have been made in the past to reduce erosion through soil and water conservation works. However, they were scattered in a way that brought about no change. Besides the top-down approach of these efforts, the non inclusion of land users in the decision-making process was another reason for this failure. Bewket (2003) has suggested that conservation efforts at farms in the lower reaches can achieve little if those in the upper reaches are not conserved as well. This situation calls for a watershed approach to resource management.

Integrated watershed management (IWM) is a process of formulating and carrying out a course of actions to manage human activities in an area defined by watershed boundaries in order to protect and rehabilitate land and water and associated aquatic and terrestrial resources while recognizing the benefits of orderly growth and development. Thus, IWM is an integrated and holistic approach to the development of an area with the ultimate objective of improving the quality of life of the people who dwell within it (FAO 2001).

The approach of IWM has multiple advantages: it allows concentration of efforts, enhances community participation, and allows orderly and systematic resource use and management (i.e., it avoids scattered work by following a procedure), and optimal use of resources (Anonymous 2001). In a watershed, there is a strong physical interdependence between the upstream and downstream land uses. Given the interaction of resources and degradation problems and upstream-downstream interdependence, the IWM approach is the appropriate option for effective and sustainable resource management (Bewket 2003).

The watershed approach means different things to different professionals working on disparate objectives. To agronomists it is a means of scaling out technologies, primarily those of soil and water conservation or, generally, environmental protection (Hinchliffe et al. 1999). To practitioner's policy-makers in the water resource sector, it is a means for enhancing environmental services and public goods emanating from the catchments for the benefit of society at large (FAO 2001. Conservationists view it as a framework for enabling transboundary natural resource management in which livelihood concerns are often addressed only to the extent that they help to further conservation goals (Admasu et al. 2008). Among social scientists and others, watershed management is seen as a framework for enhancing collective action and equity in natural resource access and governance, or in livelihood problems that cannot be solved at the farm or household level (Tefera et al. 2002).

The unique characteristic of watersheds in developed countries is that people do not reside in the watershed. So the emphasis of watershed management in those countries is on off-site benefits (i.e., irrigation, hydroelectric power generation, city water supply, etc). But in developing countries, because the land use system is traditional and land use policy implementation is poor, people reside inside the watershed and tend to aggravate the resource depletion situation. Most of the arable land (70%) in the highlands of Ethiopia is used for cereal crops, with wheat and barley grown in the higher elevations, and teff, sorghum and maize in the lower elevations. All these crops leave the soil bare during some or all of the growing season, exposing it to erosion (Berry 2003). In the Fechea sub-watershed, soil fertility decline due to maize mono cropping, soil erosion and deforestation due to the shortage of livestock feed are the most prominent problems threatening agricultural productivity. They are doubtlessly the results of inappropriate land management.

This project was initiated with multiple objectives; establishing a shared understanding of IWM; delineating and mapping the watershed according to agro ecologies, farming systems and levels of land degradation; identifying, characterizing, prioritizing and analyzing biophysical and socioeconomic issues in the watershed; demonstrating different technologies; and assessing opportunities for and constraints to IWM an intervention toward sustainable land use and food security in the maize-based farming system of western Ethiopia.

2. MATERIAL AND METHODS

2.1. Description of the Study Area

The Fechea sub-watershed is located in Bako Tibbe district, in the western part of Oromia Regional State in western Ethiopia (Fig. 1). It lies 230 km west of Addis Ababa and 5 km from the town of Tibbe on the way to Addis Ababa. The total area of the watershed is 707.49 ha. The altitude ranges from 1600 m.a.s.l to 1780 m.a.s.l. Fechea is categorized as sub humid agro ecology. The watershed drains into the Fechea river and finally into the Gibe river.

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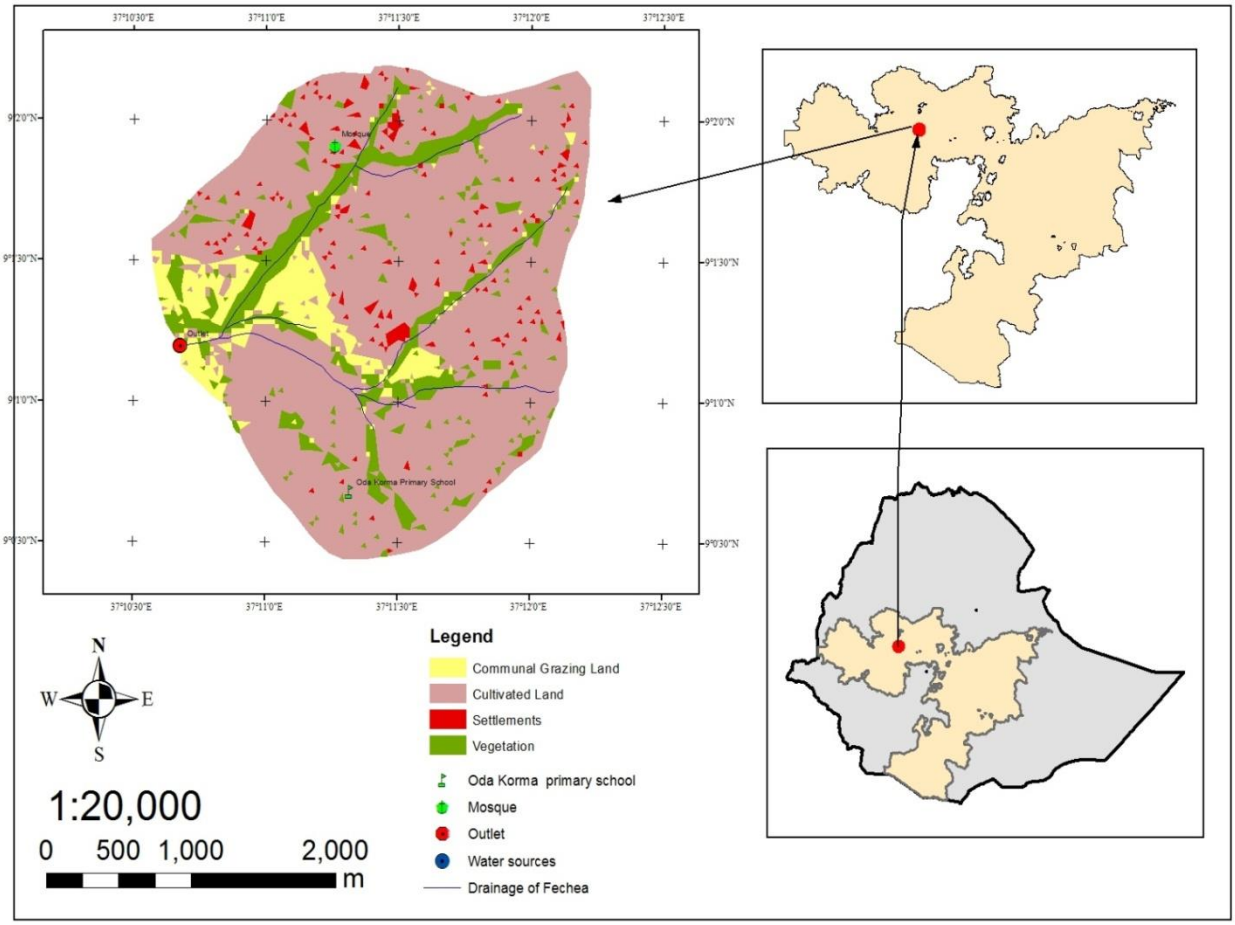


Figure 1. Study area of the Fechea sub-watershed in Ethiopia.

2.2. Project Phase Analysis

The project was implemented in two phases. The first was a survey and planning phase which was implemented in three activity categories; and the second was an intervention phase which was implemented in two activity categories.

2.2.1 Phase I: Survey and Planning

Site Selection and Mapping of the Watershed

The base map of the Fechea sub-watershed was developed and delineated from a 1:50,000 scale topographic map and aerial photographs/satellite images. Based on the preliminary outlet identified, the watershed boundary was delineated using primary data (GPS readings), secondary data and in consultation with the local communities. The delineated watershed was geo-referenced and digitized for its contours, roads, rivers and other features. The preliminary delineated boundaries were verified in the field using GPS and reference benchmarks were established for future operations.

Biophysical Resource Survey

Mapping and description of the past and current land use/land cover of the watershed was done depending upon the availability of historical data (existing maps, aerial photographs, knowledge of the local community and satellite images) and GPS readings. The whole watershed was then divided into uniform units using the same procedure, and then each land unit was characterized in terms of different parameters (quality indicators), which include soil physical and chemical properties, vegetation and topography.

Socioeconomic and Farming System Analysis

The study was conducted using participatory rural appraisal (PRA) group discussions with 100 farmers in 10 subgroups, trend analysis and problem ranking. Accordingly, local institutions, social and administrative boundaries were identified, described and

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analyzed with respect to the sub watershed boundaries. The existing farming system was assessed and the associated opportunities and constraints of production were identified. Important parameters for socioeconomic and farming system database establishment were identified.

2.2.2 Phase II: Implementation

Development Planning

Depending upon the biophysical and socioeconomic survey, appropriate NRM options and technologies were developed with full community participation. Land use/land cover classification and their limiting factors guided the conservation planning. Farmers' participation was allowed in decision-making.

Farmer Training/Capacity Building

Training was given to the established farmer research groups (FRGs), development workers, personnel of the Bako Tibbe Woreda Agricultural Rural Development and Health offices and community members regarding the specific technologies identified in the planning phase and about the awareness gap identified in the socioeconomic survey.

Demonstrations

Specific production and NRM technologies were selected based on the management options appraised by the established FRG for each land unit. This included improved technologies in agronomy, soil fertility improvement, conservation, agroforestry, forage crops and apiculture. Most of these production technologies were obtained from the center and demonstrated to selected farmers in order to inspire other farmers to adopt them.

3. RESULTS AND DISCUSSION

3.1. Watershed Problems Identified by Different Social Groups

Table 1 shows the watershed problems identified by different social groups. Each group ranked the problems differently, suggesting that interventions should be designed to satisfy the needs of different social groups. However, the aggregated result was used to identify the overall watershed problem. Thus, shortage of improved crop varieties, feed shortage, deforestation, soil fertility decline and grain market fluctuations were the most important problems of the Fechea sub-watershed.

Table 1. Ranking (using the pair-wise ranking method) of different watershed problems identified by different social groups in the Fechea sub-watershed, West Shoa, Ethiopia 2010-2012.

Watershed issue	Social group						Average (rank)	Overall priority
	Men	Women	Rich	Poor	Young	Old		
Shortage of improved crop varieties	1	1	4.5	2.5	1	1	1.84	1
Soil fertility decline	2.5	3	12.5	3.5	5	11	6.25	4
Lack of training/extension in different disciplines	7.5	8	14	12.5	6	6	8.42	9*
Shortage of labor	10.5	13	6.5	8	14	14	11.75	13
Pests and plant diseases	10	8	8.5	8	7	5	7.75	7
Market fluctuations	3.5	7.5	7	10.5	3.5	7.5	6.58	5

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Lack of credit services	11	13	10	8.5	9	10	10.25	12
Feed shortage	5	5.5	3.5	8	5	3	5.17	2
Shortage of water for livestock	9.5	10	5.5	11	9.5	6.5	8.67	11
Insufficient veterinary services	9.5	8.5	7	4.5	11.5	10.5	8.59	10
Lack of improved cross-bred cows	7.5	9	6	3	12.5	12.5	8.42	9*
Deforestation	7	3.5	6.5	10.5	3	2	5.42	3
Lack of quality drinking water	10.5	6	6	4.5	8.5	9	7.42	6
Soil and water loss due to runoff	8	7.5	4.5	7	8	10	8.02	8

***** Indicates problems that have the same rank level.

3.2. Land Use

Most of the area of the watershed is covered by cultivated land, with maize mono cropping being predominant. The upstream parts of the watershed were the most affected by soil erosion and had become unproductive. The middle parts were a bit less affected and were mostly occupied by settlements. The downstream areas were, however, more fertile due to the sediment deposits brought by runoff from upstream areas. These areas are used as grazing lands.

Table 2. Land use/land cover in the Fechea sub-watershed.

Current land use/land cover	Area (m^2)	Area (ha)	Area (%)
Communal grazing Land	573638.89	57.36	8.11
Cultivated land	5436420.66	543.64	76.84
Settlements	150046.22	15.00	2.12
Vegetation	914852.09	91.49	12.93
Total Area	7074957.86	707.49	100

Table 2 and Figure 2 show the land use/cover of the Fechea watershed. The current and potential land use/land cover (cultivated lands, vegetation cover, grazing lands and resettlement), drainage source, drainage lines and outlet were clearly mapped. The total area of the final delineated watershed (Fig.2) was 707.49 hectares. Most of the area of the watershed, 76.84%, is used for cultivation purposes.

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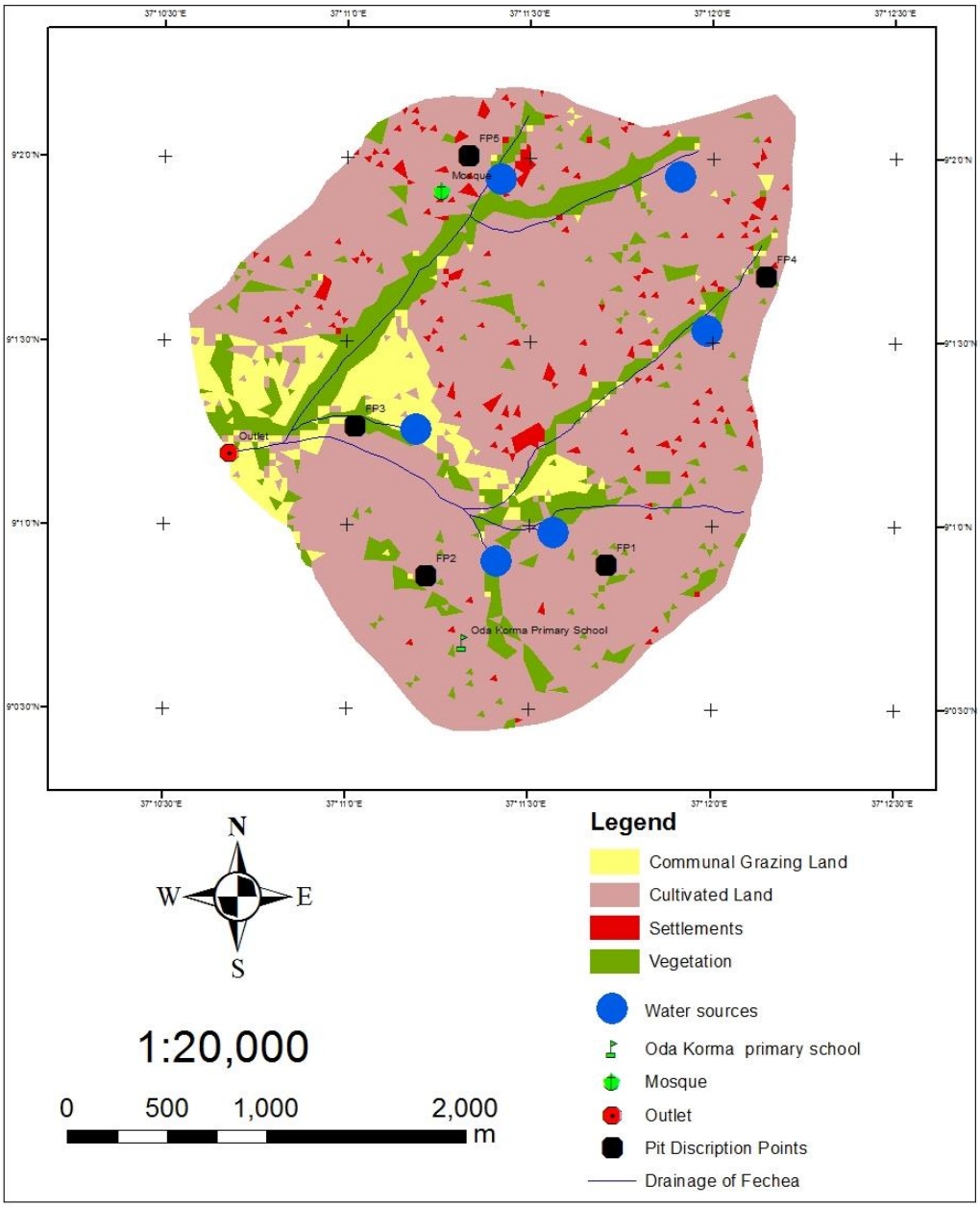


Figure 2. A land use map of the Fechea sub-watershed, 2012

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3.3. Development and Research Interventions

The planning methodology for development and research interventions consisted of clustering the identified issues according to strong functional relationships; identification of objectives and research questions; and development efforts, integration and interventions at the site and community levels. Accordingly, four main clusters were generated.

3.3.1. Cluster 1: Soil and Water Conservation

This cluster dealt with soil fertility decline, shortage of water for livestock, lack of quality drinking water and loss of soil and water due to excess runoff. The rationale behind these problems was the recognition that

- water quality and quantity is being affected by seed, fertilizer and soil loss from thefields;
- there was decreased infiltration of rain water into the ground;
- substitution of indigenous trees with eucalyptus had resulted in the depletion of ground water and drying up of springs; and
- soil fertility decline was mostly due to the removal of the top soil by runoff, mono cropping, less addition of inputs (organic and inorganic fertilizer), absence of crop residue on cultivated land (mulching) and absence of green manure.

Integration of appropriate tree planting and physical and biological soil and water conservation structures could enhance spring recharge (water quantity) and reduce water loss due to runoff, loss of seed, fertilizer and soil at different landscapes. Depending upon material availability and the nature of soil erosion at various sites, soil bunds were constructed on about 115 ha of cultivated lands with vetiver grass planted on the ridges of the bunds. The grass was also used as animal feed.

3.3.2. Cluster 2: Agroforestry

Depending on the species preference of the community, temporary nurseries were established near the Fechea sub-watershed and seedlings of different agroforestry tree species such as *Cordia africana, Acacia albida* nd *Grevillea robusta* were raised. All the nursery management options were carried out, starting from the establishment of the nursery up to the planting of seedlings on different land use types such as cultivated and communal grazing lands. A total of 9430 seedlings were raised; out of which 1,275 were of *C. africana*, 3055 of *Acacia albida* and 5100 of *G. robusta*. Their performance were judged during monitoring and evaluation by counting each planted species on ground and the result were 75.13%, 82.17% and 90% respectively (Table 3).

Table 3. Performance of multipurpose agroforestry tree species planted on different land use types.

Species	Land use type		Performance (%)	Remark
	Cultivated	Communal grazing land		
Cordia africana	160	1115	75.13	Good
Acacia albida	2855	200	82.17	Very good
Grevillea robusta	5100	-	90	Very good

3.3.3. Cluster 3: Crop and Crop-related Activities

To address the issues identified in the sub-watershed, different technologies relating to horticulture, pulses, oilseeds and cereal crops were implemented. The Fechea sub-watershed is characterized by maize mono cropping, and a shortage of other seed varieties had been identified as a major problem.

Improved Crop Varieties

Several improved crops varieties were demonstrated to farmers in the watershed (Table 4).

- Twenty-three model farmers were selected from the FRGs and given two varieties of teff seeds (Kenna to six farmers and Guduru to 17). The seeds were sown on 25 x 25 m plots during the 2009/10-2010/11 cropping season.
- Additionally, different varieties of haricot beans such as Gabisa, Tibbe (climbing bean) and Anger were distributed to three, three and four farmers respectively and sown on 10 x 10 plots in the 2009/10 cropping season.
- Of the teff varieties, Guduru gave the highest yield, followed by farmers' varieties and Kenna. Guduru is highly performed in mid-altitude agroecologies while Kenna showed high performance in the higher agroecology.

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- Among the haricot bean varieties, the highest grain yield was recorded by Gabisa (2500kg ha^{-1}), followed by Anger (2300kg ha^{-1}).
- The climbing bean variety Tibbe performed well across the test sites.

Table 4. Different crop varieties cultivated by model farmers as a demonstration.

Crop	Variety	No. of farmers	Cropping season	Plot size (m)	Yield (kg ha^{-1})
Teff	Local check	4	2009/10-2010/11	25x25	1550
Teff	Kenna	6	2009/10-2010/11	25x25	1400
Teff	Guduru	17	2009/10-2010/11	25x25	1900
Haricot bean	Gabisa	3	2009/10	10x10	2500
Haricot bean	Climbing bean	3	2009/10	10x10	1500
Haricot bean	Anger	4	2009/10	10x10	2300

Horticultural Crops

Similarly, different varieties of hot peppers, banana suckers and avocado seedlings were given (Table 5) to farmers with the objective of introducing agrisilviculture (tree planting with crops) into a cropping system based predominantly on maize mono cropping. In addition, this was an intervention with the purpose of reducing soil loss due to runoff, improving soil fertility by adding organic matter and maintaining moisture in the soil while adding another source of income to the farmers.

Seedlings of two varieties of hot pepper (Oda Haro and Bako local) were given to two model farmers each and planted on 10 x 10m plots in the 2009/10 cropping season. Fifty banana suckers were given to 25 farmers (2 each) and 20 suckers to 20 farmers (1 each) during the 2010/11 and 2011/12 cropping seasons accordingly. As for avocado seedlings, 248 were given to 62 farmers (4 each) and 249 to 83 farmers (3 each) during the 2010/11 and 2011/12 cropping seasons respectively. The banana and avocado seedlings were planted on cultivated lands as home garden crops. Of the planted banana suckers, 92% of them and 80% of the avocado seedlings showed high performance.

Table 5. Performance of different horticultural crops distributed to farmers.

Horticultural crop	No of farmers	Cropping season	Plot size (m)	Performance (%)
Hot pepper (Oda Haro)	2	2009/10	10 x 10	87
Hot pepper (Bako local)	2	2009/10	10 x 10	79
Banana suckers	70	2010/11& 2011/12	-	95
Avocado seedlings	145	2010/11& 2011/12	-	85

3.3.4. Cluster 4: Livestock Management

Integration of livestock in IWM is the most important option to manage natural resources, especially grazing lands because one of the root causes of natural resource depletion and grazing land degradation is overgrazing. Shortage of animal feed was ranked as one of the highest priority issues by the Fechea sub-watershed community. The communal grazing lands were not sufficient for the livestock population, and as a result had become severely degraded. The conflicts that result from free grazing have a spatial dimension related to the distribution of grazing lands and the administrative units from which grazing households emanate. During the cropping season, livestock are restricted on uncultivated lands, mainly fallow lands and communal grazing areas, whereas, during the dry season, grazing lands have open access. To address the problem related to animal feed, the following interventions were done:

Animal Feed/Forage Crops

- Rhodes grass was sown for 27 farmers on plots of 6 x 6 m and for two farmers on plots of 25 x 25 m during the 2010/11 cropping season.
- *Dolichos lablab* was sown for 16 farmers on plots 6 x 6 m on a total of 576 m^2.
- A total of 39 farmers were given 348 seedlings of *Lucaena palida*.

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- Fifty farmers were given 2000 cuttings of elephant grass to plant.
- The Rhodes grass, *Dolichos lablab, Lucaena palida* and elephant grass all performed well and minimized the shortage of animal feed.

Apiculture

Beekeeping was promoted at the site by distributing two transitional (Kenyan top bar) and four modern bee hives to model farmers. These beekeepers are currently engaged in improved beekeeping management by constructing separate houses, and keeping their hives clean. Increased honey production is expected in future because the shift from traditional beehives to transitional and modern beehives was carried out in October 2011.

4. CONCLUSION AND RECOMMENDATIONS

Stakeholders' involvement in problem identification, prioritization, planning and design, implementation, monitoring and evaluation can improve the effectiveness of integrated watershed management. The use of socially disaggregated problem identification and prioritization methods can help to show which social categories are affected by which problems. The problem of soil erosion is complex and needs the integration of different innovations, especially, policy, socioeconomic and technological interventions.

Implementation of the land use policy is the best option, especially for communal grazing lands in the Fechea sub-watershed to minimize competition and conflict over open resource use. Some of the watershed issues identified was not addressed due to resource limitation and the nature of the problems. It needs greater attention from different sectors of agricultural and water administration.

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