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Land Use Land Cover Change of Qotto-Asanao Micro Watershed

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Abstract

The dependency of farming community on the natural resource base aggravates its degradation and deterioration. To reverse and mitigate such natural resource degradation integrated watershed management has been implemented as one of the best strategies. Integrated watershed management is an action oriented development intervention in which farming communities are actively participated in all process starting from its planning to implementation. In southern Ethiopia, a micro-watershed known as Qotto-Asano was identified and integrated watershed management has been implemented since 2011. The land use and land cover change of the micro watershed was detected using Geographical Information System (GIS) and remote sensing techniques. The major land cover categories statistically compared in to two periods, i.e., before the intervention (1986 to 2010) and during the intervention (2011 to 2015) were cultivated land, forest, shrub, grass land, wet land and area allocated for built up. As a result of watershed intervention between the period 2011 and 2015, both positive and negative changes had occurred in the micro watershed. Positive land cover pattern was observed in forest (0.73%), grass land (0.35%) and cultivated land (1.12%) while shrub (-2.42%) and bare land (0.86%) showed negative increment. In conclusion, integrated watershed management should be given due emphasis by development practitioners as a remedy action to maintain and conserve the natural resource base.

Keywords: Integrated watershed management, Land use/land cover, Geographical Information System.

Introduction

Integrated watershed management is one of the top 'green economy strategy' of Ethiopian government to mitigate the fast and vast degradation of natural resource base. It has been implemented in all part of the country, of which special emphasis has been given in cereal based farming system and densely populated areas of the country. The Southern Nations, Nationalities and Peoples' Region (SNNPR) of Ethiopia, is not an exceptional of which the natural resource degradation notably soil erosion, soil fertility decline, deforestation, bio-diversity destruction has been the commonly environmental and socio-economic threats of the region. To halt such environmental and socio-economic threats various efforts has been done for the last three decades. Among the interventions, integrated watershed management is implementing since 2011 with mass participation and active involvement of the community. Apart from the public massive intervention, the Southern Agricultural Research Institute (SARI) had implemented two mini model integrated watershed management namely Qotto-Asano and Ojoje micro watershed. The Qotto-Asano micro-watershed is located in the Silitie zone in Siliti wereda (district) 183 km northeast of Hawassa, the capital of SNNPR, and 150 km southwest of Addis ababa. It intervention area covers 350 ha of land, of which about 60 ha is a communal enclosed area while the rest is private farmland (Genene and Anteneh, 2015).

The impacts, land use/land cover changes of Qotto-Asano micro-watershed is reported here using Geographical Information System (GIS) and remote sensing techniques. Geographical Information System (GIS) and remote sensing techniques for land use/cover mapping has been used and detailed way to improve the selection of areas designed to agricultural, urban and/or industrial areas by different researchers (Selcuk *et al.*, 2003). According to (Chilar, 2000) application of remotely sensed data made possible to study the changes in land cover in less time, at low cost and with better accuracy in association with GIS that provides suitable platform for data analysis, update and retrieval. Similarly, Remote Sensing (Lo and Choi, 2004) has been widely used in updating land use/cover maps and land use/cover mapping has become one of the most important applications of remote sensing.

The entire Landsat archive is now available to the scientific public for identifying and monitoring changes in manmade and physical environments (Chander et al., 2009; El Bastawesy, 2014). These available data have its respective processing procedures and several studies acknowledged the importance of pre-processing (i.e., data selection, co-registration, radiometric calibration and normalization) in performing accurate and reliable change detection analysis (Jensen, 2005; El Bastawesy et al., 2013).

Study Area

The Qotto-Asano micro watershed (Fig. 1) is found in Siltie Zone in SNNPR and it extends between $38^0 14'$ E to $38^0 19'$ E longitude and $7^0 58'$ N to $8^0 02'$ N latitude and encompasses an area of 4137.44 ha. The mean daily temperatures range from 18°C to 25°C with annual average rainfall of 850 to1000mm.

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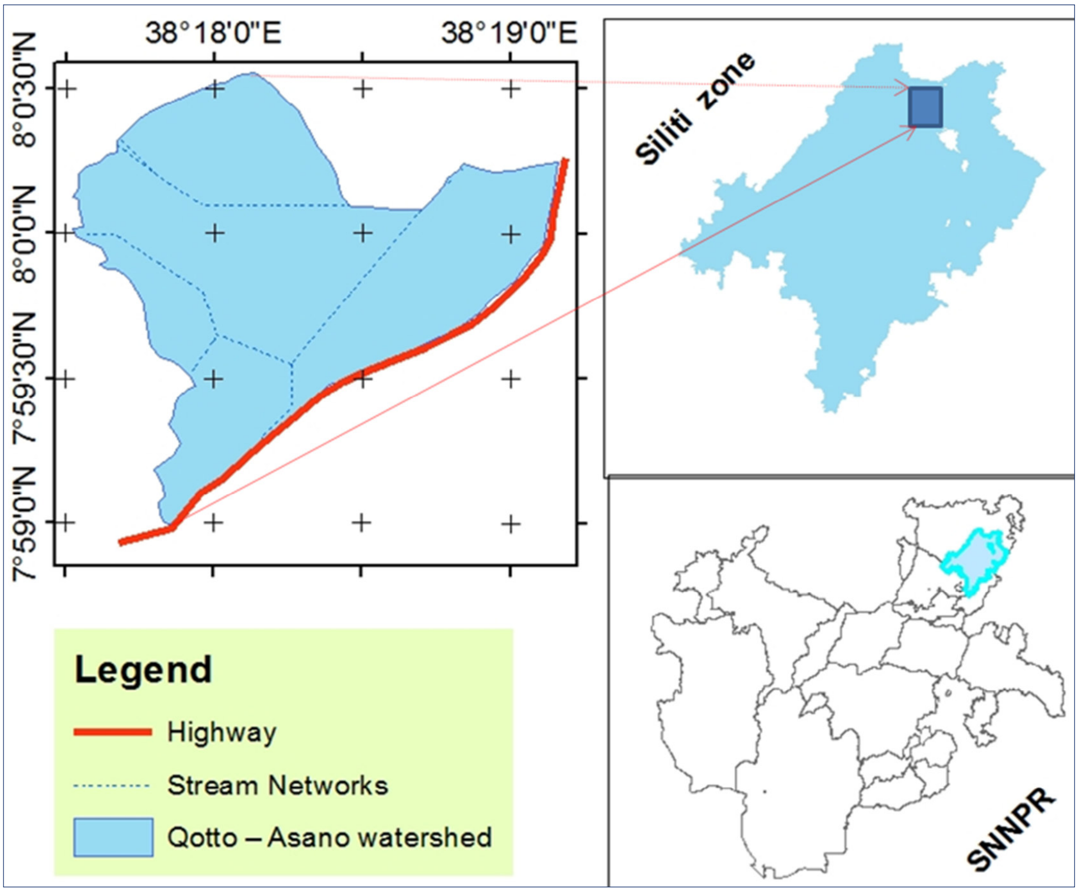
Fig 1 Location map of Qotto-Asano micro watershed



Database preparation

Landsat Thematic Mapper (TM, TM+ and others) at a resolution of 30 m of 1986, 2000, 2011 and 2015 were used for land use/cover classification. The satellite data covering Qotto-Asano micro watershed were obtained from global land cover facility (GLCF) (http://glcfapp.glcf.umd.edu:8080/esdi/) and earth explorer site http://earthexplorer.usgs.gov/). These datasets were imported in ERDAS Imagine version 10.0, satellite image processing software to create a false colour composite (FCC). The layer stack option in image interpreter toolbox was used to generate FCCs for the Qotto-Asano micro-watershed areas. The sub-setting of satellite images was performed for extracting watershed area from images and supervised classification were applied to classify the Landsat images.

To work out the land use/cover classification, supervised classification method with maximum likelihood algorithm was applied in the ERDAS Imagine 10.0 Software. Maximum likelihood algorithm (MLC) is one of the most popular supervised classification methods used with remote sensing image data. This method is based on the probability that a pixel belongs to a particular class. The basic theory assumes that these probabilities are equal for all classes and that the input bands have normal distributions. However, this method needs long time of computation, relies heavily on a normal distribution of the data in each input band and tends to over-classify signatures with relatively large values in the covariance matrix.

Ground verification was done during field visit of the watershed area. Based on the ground truthing, the misclassified areas were corrected using recode option in ERDAS Imagine. Seven land use/cover types are identified in the study area. These are (i) Shrub (ii) Cultivated (iii) Built up area (iv) grass (v) wetland and (v)forest.

For performing land use/cover change detection, a post-classification detection method was employed. A pixel-based comparison was used to produce change information on pixel basis and thus, interpret the changes more efficiently taking the advantage of ''-from, -to'' information. Classified image pairs of two different decade data were compared using cross-tabulation in order to determine qualitative and quantitative aspects of the changes for the periods from 1986 to2015. A change matrix was produced based on (Weng, 2001) with the help of ERDAS Imagine software. Quantitative areal data of the overall land use/cover changes as well as gains and losses in each category between 1986 to 2011 and 2011 to 2015 were then compiled.

Table 1 Land cover classes considered during classification and interpretation keys from the used satellite images adopted from (Woldeamlak, 2002)

Land cover	Description	Key	
		Tone	Texture
Cultivated land	This category includes areas under crop and land under preparation. Unless mapping scale allows, physical boundaries are broadly defined to encompass the main areas of agricultural activity and are not defined on exact field boundaries. The class may include small inter-field cover types (e.g. hedges, grass strips, small windbreaks, etc.) as well as farm infrastructure.	Invisible white	Smooth
Grass land	Grasslands are those areas that are predominantly covered with grass. Areas covered with grass with some scattered trees and pastures are assumed as grassland.	Light White	Medium coarse
Shrub land	Areas covered with small trees, bushes and shrubs, mainly ranged from closed canopy to open canopy areas are considered as shrub land.	Light red	Medium coarse
Forest	It is land that is completely covered with manmade and plantation trees planted with regular arrangement.	Light-deep red	Smooth
Bare land	Areas with a cover of stunted and scant grass, and wastelands with exposed rocks and badlands.	Light-gray	Coarse

Land Use/Land Cover Change Analysis
According to (Foody, 2001) for effective change detection using post-classification technique classification with high accuracy is a prerequisite. To achieve the required accuracy images of different reference years were first independently classified. In the change detection process classified images with highest accuracy were used.

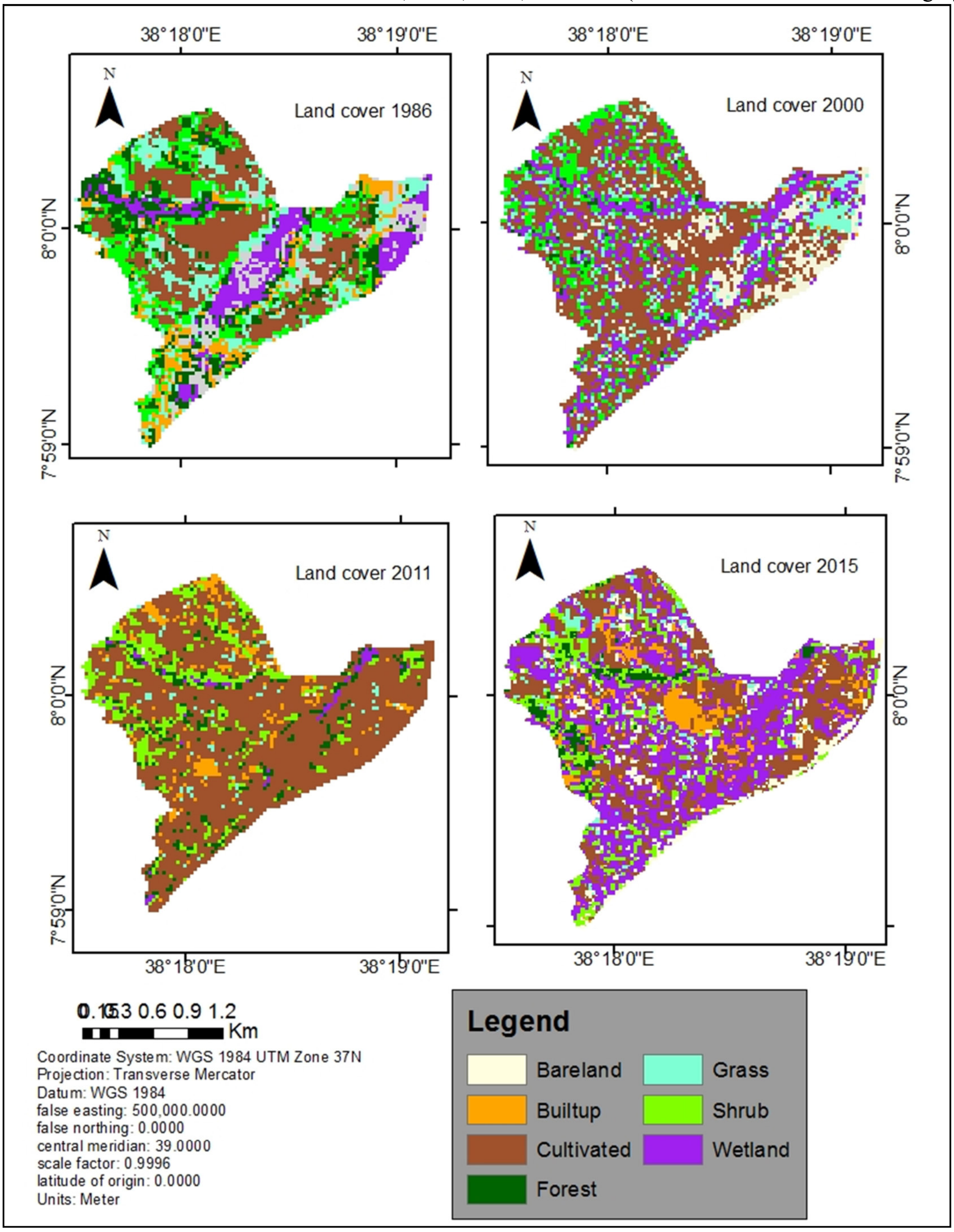
The classified images were statistically compared in two periods (*i.e.*, 1986 to 2011 and 2011 to 2015). Statistical changes were computed by comparing image values of one data set with the corresponding value of the second data set in each period and presented in a summary table of the overall changes per class. The values were noted in terms of hectares and percentages. The LULC changes in percentage were computed using the following equation:

$$\%\ of\ LCLU = \left(\frac{(Area_{\ final\,yeas} - Area_{\ initial\,year})}{Area_{\ initial\,year}}\right) X100 \text{ -- (xy)}$$

Where, area is extent spatial coverage of each LULC (Land Use Land Cover). The negative values imply a decrease whereas the positive values suggest an increase in spatial extent. ArcGIS version 10.2 software was used to generate LULC conversion matrix between 1986 and 2015 and values are compiled in a matrix table. The values were presented in terms of hectares.

Results and Discussions
The results obtained through the analysis of multi-temporal satellite imageries were diagrammatically illustrated in Figure 2 and corresponding data with respective year land cover are shown in Table 2. Land use/cover change in different land use categories and the magnitude of change in different land categories are discussed below. These major land cover categories are cultivated (agricultural) land, forest, shrub, grassland, wetland, bare land and built-up.

Fig 2 Land cover status of the watershed in 1986, 2000, 2011, and 2015 (based on Landsat Satellite Imagery).



Area and amount of change in different land use /land cover categories in the Qotto-Asano watershed during 1986 to 2015 is presented below at Table 2.

Data collected and analyzed revealed that in1986 the land use of Qotto-Asano micro watershed was 21.12% (87.22 ha) under cultivated (agricultural) land, 15.99% (66.04ha) under forest, 14.77% (61 ha) under shrub, 12.36% (51.06 ha) under grassland, 10.56% (43.62ha) under wetland, 6.17% (25.47ha) under bare land and 3.78% (15.60ha) was utilized for residence and social services.

During 2000 the area under these land categories was found about 31.43% (110.00 ha) under cultivated (agricultural) land, 14.32% (50.12ha) under grassland, 14.06% (49.22ha) under shrub, 12.73% (44.55ha) under forest, 11.92% (41.71ha) under wetland, 9.39% (32.867ha) under bare land and 6.16% (21.540ha) under built-up (Table 2).

In 2011 the area under same land categories was found to be about 32.65% (114.29 ha) under cultivated (agricultural) land, 16.57% (58.01ha) under grassland, 15.11% (52.89ha) under shrub, 10.91% (38.17ha) under bareland,10.45% (36.57ha) under wetland, 7.90% (27.66ha) under forest and 6.40% (22.41 ha) under built-up.

In 2015 where intervention is made by SARI, the land use/cover change showed that 44.44 ha (12.7%) under shrub, 30.23 ha (8.64%) under forest, 36.53 ha (10.44%) under wet land, 35.17 ha (10.05%) under bare land, 26.21 ha (7.49%) under built up, 59.24 ha (16.93%) under grass land and 118.19 ha (33.77%) was under agricultural cultivated land (Table 2).

Between 2011 and 2015 the Southern Agricultural Research Institute (SARI) namely Hawassa Agricultural Research Center had executed integrated watershed management specially integrated soil and water conservation interventions. Based on these intervention land degradation has reduced, forest and cultivated land increased. As the result of integrated watershed management intervention, the land use/cover change showed that 44.44 ha (12.7%) under shrub, 30.23 ha (8.64%) under forest, 36.53 ha (10.44%) under wet land, 35.17 ha (10.05%) under bare land, 26.21 ha (7.49%) under built up, 59.24 ha (16.93%) under grass land and 118.19 ha (33.77%) was under agricultural cultivated land (Table 2). Data registered in Table 2 and Figure 2 revealed that both positive and negative changes occurred in the land use/cover pattern of the Qotto-Asano watershed. During the three decades, the forest coverage in the study area has decreased from 66.04 ha in 1986 to 27.66 ha in 2010, which accounts for 3.51% of the total watershed. Though some interventions in afforestation was done, due to the population growth in the watershed farmers were giving more emphasis to change less productive and infertile land to fertile and productive by introducing and applying different soil fertility enhancing technologies.

Table 2 Area and land use/cover change of Qotto-Asano micro watershed (1986 to 2015)

Land cover	1986		2000		2011		2015		Change 1986 to 2011		Change 2011 to 2015	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Shrub	61.00	14.77	49.22	14.06	52.89	15.11	44.44	12.70	-8.11	-2.32	-8.45	-2.42
Forest	66.04	15.99	44.55	12.73	27.66	7.90	30.23	8.64	-38.38	-10.96	2.57	0.73
Wetland	43.62	10.56	41.71	11.92	36.57	10.45	36.53	10.44	-7.05	-2.01	-0.05	-0.01
Bareland	25.47	6.17	32.86	9.39	38.17	10.91	35.17	10.05	12.70	3.63	-3.00	-0.86
Built-up	15.60	3.78	21.54	6.16	22.41	6.40	26.21	7.49	6.81	1.95	3.80	1.08
Grassland	51.06	12.36	50.12	14.32	58.01	16.57	59.24	16.93	6.95	1.99	1.23	0.35
Cultivated	87.22	21.12	110.00	31.43	114.29	32.65	118.19	33.77	27.07	7.74	3.90	1.12
Total	350.00	100.00	350.00	100.00	350.00	100.00	350.00	100.00	0.00	0.00	0.00	0.00

Intervention in Qotto-Asano micro watershed

Various efforts had been done to improve the natural resource deterioration of the micro-watershed identified and thereby to improve the livelihood of farming communities living in and surrounding the watershed. The interventions made in the Qotto-Asano micro watershed had four integrated components: mobilization of communities, technology introduction and evaluation, soil and water conservation and afforestation activities and technology demonstration and pre-scale up (Genene and Anteneh, 2015).

Mobilization of Community for Collective Action (CA): is one of the initial massive intervention to create ownership sense and to implement labor-intensive work in any IWM initiative. In the process, discussions with farming communities, organizing communities into working groups, formulations of community bylaws, conducting baseline survey was the main activities done in the micro watershed (Genene and Anteneh, 2015).

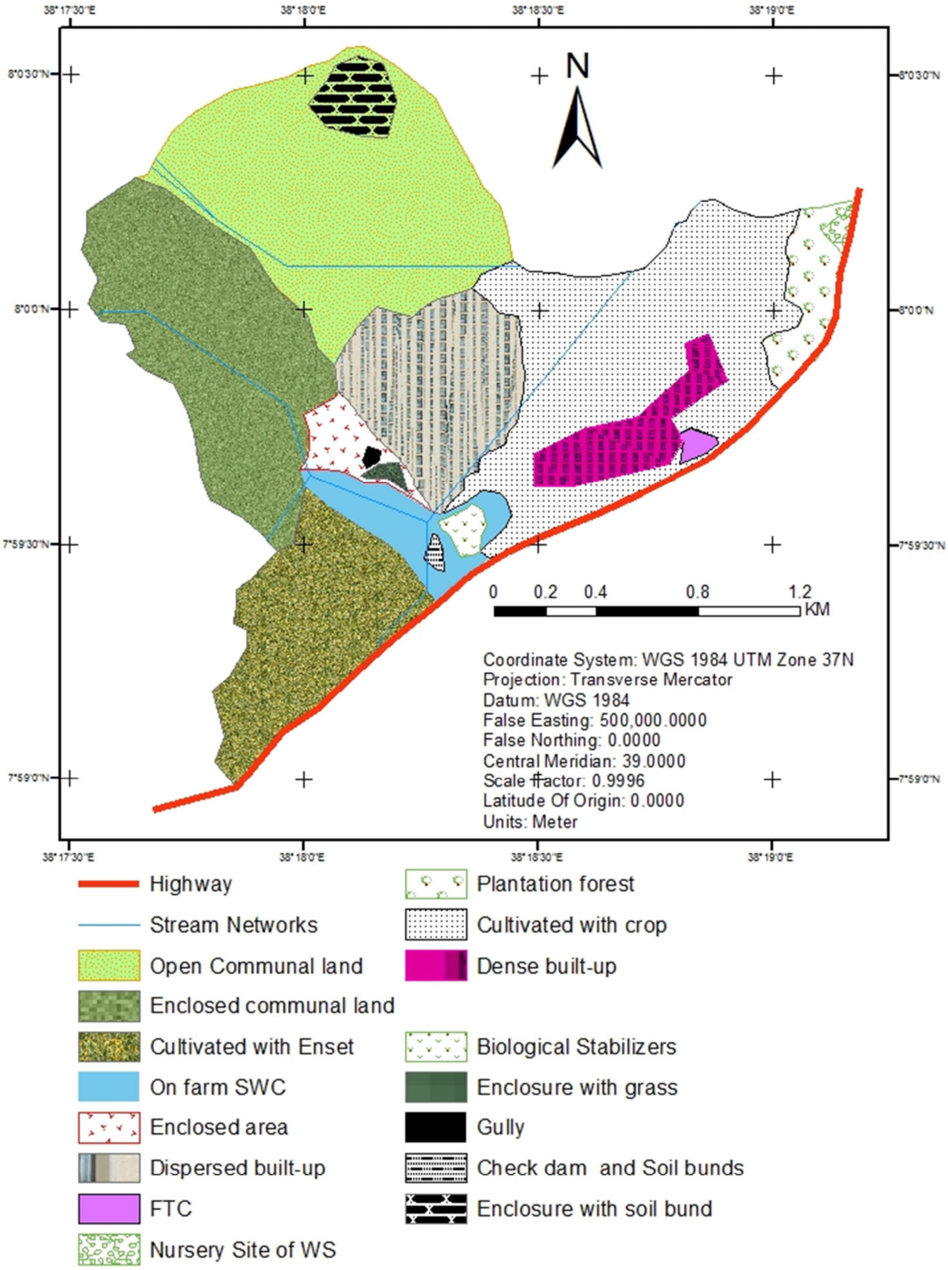
Introduction and Evaluation of Technologies: based on the prioritized constraints, different agricultural technologies were introduced, demonstrated to the farming community. Some of the important technologies were: common bean, *teff*, bread wheat, sorghum, finger millet, *enset* bacterial wilt disease management, integrated soil fertility management, on-farm soil and water conservation, agroforestry management, improved home garden technologies, poultry technologies, animal forage and feed practices. The technologies introduced and evaluated were scaled up for wider dissemination and thereby to increase the farm income of the farming community. In all process of technology evaluation and scale out women were actively participated and benefited.

Soil and Water Conservation and Afforestation: clearing of forests, removal of crop residues, open grazing and overgrazing, use of marginal lands, poor soil management, weak adoption and/or inadequate soil and water conservation practices are the major environmental constraints and threats to the sustainability of land and water resources.

The on-farm soil and water conservation (SWC) techniques commonly employed by the community at Qotto-Asano micro watershed included soil bunds with forage trees and grasses, ditches and agroforestry practices. The SWC implemented as part of the IWM included soil and stone bunds, trench bunds, micro basins, ibro basins, *fanya juu terracing* and check dams constructed using gabions and stone. All the physical structures constructed were fully supported by biological stabilizers like multipurpose trees, fodder grasses and legumes. Apart from exotic SWC techniques, indigenous conservation activities such as planting bushes and shrubs on farm borders, digging ditches, building cutoff drains, contour plowing, manuring, crop rotation and a few traditional fallow techniques were also applied by the farming community.

Afforestation of the watershed: apart from planting biological stabilizers to support the physical SWC structures, multipurpose seedlings such as *Acacia albida, Acacia saligina, Grevillea robusta, Casuarina equisetifolia,* and *Croton macrostachyus*– were planted on enclosed communal lands in the watershed since 2011.

Fig 3 Intervention areas with different enclosures methods.



Conclusion

Integrated watershed management had been implemented at Qotto-Asano micro watershed to halt soil erosion and soil fertility decline. The micro watershed covers an area of 350 ha. Integrated soil and water conservation, agricultural technologies introduction, evaluation and demonstration were some of the important interventions implemented in the micro watershed. In all the process the farming community was actively participated and simultaneously a sense of ownership was created for its sustainability. The land use and land cover change of the watershed was detected using Geographical Information System and remote sensing techniques. The detections showed there was positive and negative impacts during the intervention periods.

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