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Assessment of rainwater management practices and land use land cover changes in the Meja watershed of Ethiopia

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Abstract: Poor rainwater management (RWM) practices and resultant problems of land degradation and low water productivity are severe problems in the rural highlands of Ethiopia. The current study was undertaken at Meja watershed, which is located in the Jeldu district of Oromia region. The study investigated rainwater management practices and associated socio-economic and biophysical conditions in the watershed. The existing RWM interventions, their extent and the nature of changes in land use and land cover (LULC) conditions were mapped and evaluated. Results indicated that over the two decades between 1990 and 2010 there was an increase in the extent of cultivated land and large expansion in eucalyptus plantation at the expense of natural forest and grazing lands. Results indicate that, with few exceptions of RWM interventions practised, there were mainly poor and inefficient rainwater management practices. The overall effect leads to inadequacy of water for household consumption, livestock and for intensifying agricultural production via small scale irrigation systems. Deforestation and poor resource management resulted in soil degradation, reduction of hydrological regimes and water productivities in the watershed.

Introduction

Water is one of the most useful natural resources for life and livelihood of human beings. Water is becoming a limiting factor for sustainable development in many parts of the world. Globally, the gap between demand and availability of water has become wide, necessitating immediate measures to be taken for its sustainable utilization and efficient management, especially in the developing world.

Rainwater is the main source of water and its current use efficiency for crop production ranges between 30 and 45% (Wani et al. 2003). According to Wani et al. (2003) 300 to 800 mm of seasonal rainfall is lost annually as surface runoff or deep drainage. Watershed is a logical unit for efficient rainwater management in the dry regions. Along with water, other natural resources such as soil, vegetation and biota can also be managed efficiently by adopting integrated watershed management (IWM) approach. The major advantages of adopting IWM approaches are the involvement of those most affected by the decisions (i.e. the stakeholders) in all phases of the development of their watershed and holistic planning that addresses issues which extend across subject matter disciplines (biophysical, social and economic) and administrative boundaries (village, *woreda* etc.) (UNEP 2002). So, watershed development seeks to manage hydrological relationships to optimize the use of natural resources for conservation, productivity and poverty alleviation. Achieving this requires the coordinated management of multiple resources within a watershed, including forests, pastures, agricultural land, surface water and groundwater, all linked through hydrology (World Bank 2007).

Water harvesting involves on farm-water harvesting and building small dams to capture runoff from upper watersheds after heavy rains. Reducing erosion minimizes silt in runoff water and in water harvesting ponds, thus lengthening their lifespan. Water harvesting in turn benefits farms further down the slope by providing irrigation, either via surface water or by recharging groundwater. These interventions are designed to eventually raise the productivity of all natural resources in the watershed. Soil becomes more productive for agriculture, water for irrigation and pastures and forests for more biomass. All livelihood activities that depend on these resources may be enhanced and employment may increase as agriculture becomes more productive and additional labour is needed for harvesting and other operations (Kerr 2002).

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The watershed under study being characterized by high rainfall is prone to sheet and rill erosion as well as to the formation of big and active gullies. Moreover, the current land use land cover change pattern characterized by the absence of natural forest/vegetation in the area has negatively influenced the infiltration of water into the soil profile. Poor land management practices and ineffective and inefficient rainwater management practices are characteristics of the watershed. Therefore, the adoption of sustainable participatory integrated watershed management as the platform for integrated land and rainwater management and improving the livelihood of community in Jeldu district is crucial. The objective of the present study was, therefore, to assess the major potentials and constraints for sustainable rainwater management through participatory integrated watershed management approach and to assess the land use land cover change pattern in the watershed.

Materials and methods

Description of the study area

The study was conducted in the Meja watershed which is located in Jeldu district, West Shewa zone of Oromia Regional State, Central Ethiopia (9°02'47" to 9°15'00" N and 38°05'00" to 38°12'16" E). The district has an undulating terrain nature with an altitude ranging from 2900–3200 meters above sea level. Rainfall pattern is bimodal with the main rainy season from June to September and the short rainy season from February to March. The mean annual rainfall of the area ranges from 1800 to 2200 mm. The maximum and minimum temperature of the area ranges from 17 to 22^{o}C. The farming system of the area is mainly rain-fed. The soil type is characteristic of clay and clay-loam type, but the riverbed has a loam and sandy-loam type of soil (Hurst et al. 1959 cited in Dereje 2010). *Eucalyptus globules* is the main tree planted in the area.

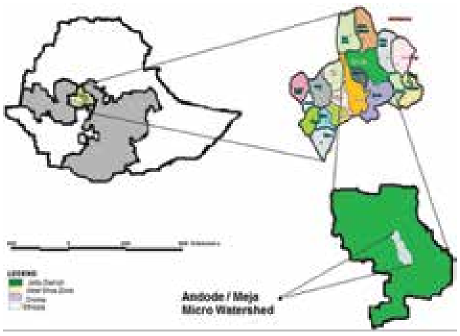

Figure 1. Location of map of study area

Socio-economic survey

Socio-economic study was conducted to assess biophysical, socio-economic constraints and rainwater management practices in the watershed. Structured and semi-structured interview questionnaires, group discussions with men and women representatives and key informant interviews were employed to gather relevant information. Moreover, discussion was held with government administrators at various levels and natural resource management officers to get the necessary information on history of the area, population dynamics, socio-economic activities and participation of the local people in conservation efforts.

Total number of households of the micro-catchment was registered from available secondary sources. The number of sample household farmers selected for the interviews was determined by using the formula developed by Kothari (2004).

$$n = \frac{Z^2 pqN}{e^2(N-1) + Z^2 pq}$$

Where: n = sample size

Z = 95% confidence limit (interval) under normal curve that is 1.96

P = 0.1 (proportion of the population to be included in the sample that is 10%)

q = None occurrence of event = 1–0.1 that is (0.9)

N = Size of population.

e = Margin of error or degree of accuracy (acceptable error term) (0.05)

In the catchment, sample households were selected using simple random sampling techniques from the list of households.

Identifying, assessing and mapping of existing RWM interventions

An inventory of past and recent RWM interventions in the study area was conducted through a review of the literature, interviews with key stakeholders and a field survey of RWM practices. During the field survey, data were collected through observations and interviews with farmers using a semi-structured questionnaire. The field survey was focused on the type of RWM practices, year of construction, farmers' experiences and constraints, duration of water storage, water uses and application methods. This enabled the bottlenecks and successes of RWM interventions to be identified. To map the existing RWM interventions in the watershed, transect walks through the catchment were conducted. The geographic locations of all the traditional RWM interventions were taken using Atlas Global Positioning System (GPS) and recorded in a recording sheet. The data were then processed using ERDAS imagine 9.1 and Arc GIS softwares to produce the map of RWM interventions.

Data base for land use land covers change

To assess the changes in LULC, multi temporal satellite images of 1990, 2000 and 2010 were used. In addition, household surveys were conducted to acquire data relating to the socio-economic conditions of rural households which would help to explain the changes observed in the LULC. The satellite images were systematically processed. This comprised of georeferencing, mosaicing, interpretation, classification (supervised), digitization and mapping (Daniel 2008). Global Positioning System (GPS) readings of the watershed boundary under study were collected for delineating the watershed. Ground control points were also collected from different land use types in the micro-catchment with GPS that was used for georeferencing the satellite images of the area. An automatic classification method was applied to identify and delineate the different LULC units for the satellite image. Then, satellite images were mosaiced and georeferenced to UTM coordinate system. Supervised classification was employed by using training sites (samples) on the image which were representative of each identified land cover category. Based on the predefined areas representing specific signatures the software classified the remaining pixels using classification decision rule. The interpretation and classification based on the satellite images was checked against ground data using ground truthing technique. The maximum likelihood classification method was applied for identifying land use and land cover types for the study area as a whole. Finally, the land use and land covers map of each year was produced and the LULC change was summarized.

Data analysis

Data obtained from the household questionnaire survey was analysed using statistical package for social sciences (SPSS) version 15.0 and the results are presented with descriptive statistics; tables, graphs and percentages. The qualitative information generated by the informal discussions was used to substantiate results from the questionnaires.

Results and discussion

RWM interventions practised in the study area

The survey results revealed that different types of RWM practices exist which a positive effect in increasing the amount of water has stored in the soil profile. The common traditional RWM interventions in the study watershed are the use of earthen/soil bunds, gully plugging, deep tillage, vegetative barriers, contour farming. Likewise, Alem (1999) cited in Girma (2009) reported the use of soil bunds, stone bunds and grass strips as commonly practised interventions used for controlling erosion as well as for *in-situ* water conservation in the central Rift Valley of Ethiopia. The current study also revealed that there were also few other RWM practices designed to store water for later use for supplementary irrigation and as a source of drinking water for people and livestock. The observed structures during the field survey included: ponds (3.2%), roof rainwater harvesting (35.5%), open wells locally called 'Ella' (3%) and check dams for stream stabilization and diversion (43.5%). Most of these RWM interventions were constructed individually by farmers where farmers contributed labour during the construction. The respondents with corrugated sheet of house commonly use roof rain water harvesting for water storage during the wet season.

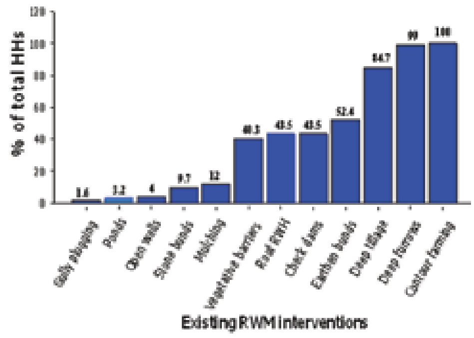

Figure 2. Existing RWM interventions in the watershed area

Only 3–7% of the respondents use ponds as a rainwater management intervention. In the study watershed, four ponds that are intended to store water for later use were identified of which three were constructed by community during the Derge regime (about 28 years ago). One pond was constructed privately in the recent time (3 years ago) in Tullu Gurra *kebele*. The private pond had a circular shape and was 3 m wide and 2 m deep whereas the community ponds which were found in Sariti and Tulu Gura *kebele* were circular in shape and about 6–9 m wide and 2–3 m deep.

Currently the community ponds were neglected without maintenance with grass growing in it and filled with sediment. The privately constructed pond was also not properly protected as it was filled with broken woods, leaves and grasses. Even though the ponds were not properly protected, they are still used mainly for livestock and small scale irrigation to grow potatoes, onion and vegetable and tree seedlings. A success story with the privately constructed pond was that the owner prevented the pond from drying off by diverting the stream which was about 180 m away from the pond and he was able to produce cabbage, onion, potatoes and seedling of eucalyptus tree on his farm in the dry season and was able to secure food at his household level (Figure 3). The report of Alem (1999), cited in Girma (2009), indicated that ponds were the main RWH structures in the Ethiopian Rift Valley where groundwater was deep and other sources of water were not available. According to his report, farmers used ponds to collect water for growing vegetables and fruits around homesteads for markets and home consumption.

(a) *(b)*

Figure 3. Privately constructed pond in Tulu Gura kebele (A) and unprotected community pond in Sariti kebele (B) of the watershed under study

The survey results showed that none of the ponds were performing as intended in terms of storing/retaining harvested runoff. The owners indicate that the poor performance was a consequence of high water losses arising mainly through seepage, evaporation, siltation problems occurring as a consequence of lack of maintenance. The same problems were reported by Girma (2009) in his study on identification of potential rainwater harvesting areas in the central Rift Valley of Ethiopia using a GIS based approach. In general, the ponds were left unprotected allowing livestock to drink directly from the pond and silt, leaves, grasses and woods were being accumulated in it. For well-functioning of such ponds, there had to be full participation of the entire community. Thus strong community organization was required to mobilize labour for operation and maintenance.

About 43.5% of the respondents practised perennial stream or river diversion by locally constructed check dams from locally available materials such as soil, stone, wood and leaves. Most of these structures were constructed privately in the upper parts of the watershed on nearby spring or streams for household consumption and for livestock. One locally constructed check dam diverted from Laga Shasi stream in Chillanko *kebele* was among a productive check dams observed in the study watershed. The check dam was constructed from eucalyptus tree. The diverted water was used for potato cultivation in the upper part of the watershed (Figure 4). The potato grower said that he had used the same stream for potato, onion and cabbage cultivation for about 16 years. However, he was no longer able to use it because of the reduction of the flow of the stream. This forced him to irrigate the current potato field by share arrangements with the owner of the land. Most of the respondents complained about the scarcity of water in the stream and short durability of the locally constructed check dam.

Figure 4. Privately constructed local check dam (left) and potatoes farm (B) being cultivated using the dam in Chillanko kebele

On the other hand, it was never tried to divert the big Meja River in the upper part of the watershed by constructing local check dams since it flows in a deep gorge. This prevented farmers from diverting water from the Meja River for irrigation. To solve these problems two respondents were using motor to cultivate potato and onion in the upper part of the watershed. The use of water pumps enabled them to maximize their yield and secure food at the household level. According to the perception of the owners of the water pumps, buying the fuel, spare parts and maintenance of the motors were among the major challenges they face.

In lower part of the watershed the use of check dams (Figure 5) were largely practised to divert perennial streams and Meja River. The terrain nature was suitable for wide range of small scale irrigation systems for production of potato, maize, barley, onion and cabbages. According to the respondents, the major limitation to use irrigation was the scarcity of water. The most widely used water sources for small scale irrigation systems in this lower part of the watershed were the Meja River, the Laga Kile and the Laga Jeba streams. With the help of these water sources, the beneficiary households were able to produce crops twice a year from their farm land.

(A) *(B)*

Figure 5. Irrigated maize and onion farms in Kolu Galan kebele (A) and locally constructed Meja check dam in Tulu Gurji kebele (B) in the watershed

Lega Jeba stream originated from Kollu Galan *kebele* and diverted from the upper part of the stream to serve as source of water for production of maize, potato and onion for about 200 households downstream. The power of the flow of the water from diverted stream decreases as it moves away from the point of diversion. At the diverting point the discharging rate, measured by volumetric method (Majumdar 2002) of the water, was 33 seconds with 44 micro seconds for 10 ml of water while it was 3 minutes with 32 seconds on average at the farm land site. This difference in discharging rate at both sites probably indicated water loss or existence of seepages along the course of the irrigation line. This showed that the required amount of water could not reach the farm land to be used for agriculture.

The Meja River which is the largest and only river in the study area is originated from Galessa area. It passes the watershed under study from top (around Sariti and Hinto Dale *kebele*) to bottom (Chobi Sirba and Kollu Galan *kebele* up to bridge on Chobi road). There were four check dams locally constructed mainly from stones, soil and woods at Bicho (one check dam), Tullu Gurji (two check dams) and Kollu Galan (one check dam) *kebele* at intervals along the course of Meja River every year during the dry seasons. The check dam in Tullu Gurji was constructed for small-scale irrigation purposes serving about 400 households which were organized into 5 zones from two *kebele* partly found in the watershed. These 5 zones were about 5 *gashas* (200 hectares) in area as reported by the respondents in the study watershed. The length of the check dam was approximately 12 m and was constructed by the communities from the 5 zones. Maize, potato and onion were the main crops cultivated in the irrigation system. As in the case of Laga Jaba, there was also water committees which were even further organized in hierarchical manner for wise use of Meja water for irrigation system. Most of the respondents mentioned that the main problems in using the Meja River were the difficulty to construct a dam, maintenance problem and scarcity of water for those farmers located furthest from the diversion. There was also the problem of breaking down of the check dams by water force every year during summer season.

The survey data showed that 4% of the sampled households had private open wells in their garden constructed by an expert paid by the owners themselves. The open wells, which the people call '*Ella*', were circular in shape and are on average about 1 m wide and 9 m deep (Figure 6). As most owners responded, the open wells were full of water during the rainy season and with very little water during the dry season. They used rope for lifting mechanisms without pulley system. All of the surveyed households with the open wells used water for washing and cooking purposes. They also use the stored water to irrigate small plots in the garden to produce vegetables for home consumption and to raise vegetable seedlings. One of the respondents in the Sariti *kebele* complained about the insufficient amount of water in the well during dry season even for household consumption and the problem of cleaning it without the expert. The other respondent in Hinto Dale *kebele* raised the problem associated with lifting mechanism in that the rope sometimes cut and fetching materials such as buckets left in the well.

Figure 6. Privately constructed open well in Hinto Dale Kebele in the study watershed

Fifty two point four (52.4%) and 9.7% of the respondents in the study watershed used earthen bunds and stone bunds on their farm land, respectively (Figure 7). Most of the earthen bunds were constructed during the Derge regime (about 28 years ago) by the community. The earthen bunds varied in length and height (on average about 50 m in length and 50–75 cm in height) and were constructed horizontally on the land which is prone to soil erosion by runoff water. High labour and the lengthy time required for construction were the reasons for not constructing the structure at the household level according to 11.3% of the respondents. Eight per cent (8%) of the respondents, however, reported lack of information and training about the structure for not being constructed at household level. The earthen bunds were mainly constructed for increasing the time for water infiltration into the soil and for runoff protection purposes. Besides this, most respondents used the structure as boundary for separation of pieces of plots from one another (wheat plots from Barley ones) and also for separation of land of one owner from another. In some places of the study watershed some of these structures were broken down by excessive runoff water and by livestock trampling. The stone bunds observed in the study watershed were constructed horizontally (in average 20 m in length and 1.25 m in height and used for similar function as that of earthen bunds. They were constructed in the current time privately.

Earthen bund (A) *Stone bund (B)*

Figure 7. Earthen (A) and stone (B) bunds used in the watershed under study

The undulating terrain nature and the high potential of rainfall in the study area were responsible for the formation of runoff following heavy rain. Following roads, furrows and rill erosion, there were a number of gullies being formed in the study watershed. According to the surveyed households, there were only 1.6% gully plugging structures constructed privately in Tullu Gurra and Bicho *kebele* from locally available structures such as wood, leaves, soil and stone in the past summer (Figure 8A). Even these existing structures, observed by walking through the catchment, were not fully constructed and hence runoff water may easily break them down. This implied that such type of gully erosion management by gully plugging needs community participation so as to fully construct and easily control the erosion problem in the area.

(A) *(B)*

Figure 8. Gully plugging (A) and deep tillage (B) used in the study watershed

According to most respondents, they practised deep tillage (about 15–20 cm deep by local ploughs) on their farm land on which they grow crops starting in October every year. This practice was common and used by the farmers mainly for preparing the land for crop production and for increasing the time for infiltration of rainwater into the soil profile (Figure 8B above). Deep furrows were on average 25 cm deep and constructed mostly by farmers themselves for diverting runoff to reduce the washing out of their farm land. This practice was also very common and adopted from parents and neighbours. The main problems in using deep furrows were that most farmers did not take care of the runoff water once it passed from their farm and they paid no attention to the direction of the furrows as downward directed once were further responsible for gully erosion formation.

Respondents of 40.3 and 12% in the study watershed have used vegetative barriers and mulching, respectively, as options for RWM methods. Mulching method was commonly practised during growing seedling of pepper and eucalyptus trees around springs, streams and homestead areas. It protected the soil from raindrop impact and reduced the velocity of runoff. Maintaining crop residues or mulches on the farm controls effectively soil erosion and has considerable potential for the restoration and maintenance of soil fertility and moisture (MoARD 2005). Most farmers planted eucalyptus trees on steep area around streams and rivers for runoff and land sliding protection while others simply planted on their crop land in order to sell the tree when it was matured. So eucalyptus tree plantation by the farmers was very common in the study area not only for run off protection but also for 'Hatena' purpose to attain food security situation at their household level by selling.

All respondents used contour farming for managing rainwater in order to increase their soil moisture content and soil productivity. According to all respondents, the use of these methods was adopted from their parents and neighbours. Contour farming reduced soil erosion and conserves soil moisture by minimizing the rate of runoff.

Map of selected RWM interventions practised

The most and widely used RWM interventions in Jeldu district are contour farming (100%), crop rotations (100%), deep furrows (99%) and deep tillage (84.7%). The other existing RWM practices in their order of prevalence are earthen bunds (52.4%), check dams (43.5%), roof rainwater harvesting (43.5%), vegetative barriers (40.3%), mulching (12%), stone bunds (9.7%), open wells (4%), ponds (3.2%), intercropping (2.4%) and gully plugging (1.6%). The map of some of the selected RWM interventions and other information were given in Figure 11.

Land use land covers distribution

The four major LULC types identified in the study watershed were riverine trees/vegetation, farm land, grazing land and tree plantation. Riverine trees include trees grown along river and stream courses, including indigenous tree species and exotic trees such as eucalyptus and junipers trees. Tree plantations mainly refer to eucalyptus trees that are not found near river courses. Lands that are used for growing annual crops such as wheat and barley including fallow land and homestead area (including settlement) were categorized under farm land in this study watershed. The proportions and distributions of LULC types in hectare and per cent for 1990, 2000 and 2010 years are given (Table 1).

Table 1. Land use land covers distribution (1990, 2000 and 2010)

Land use/land cover categories	1990		2000		2010	
	Area (ha.)	Area (%)	Area (ha.)	Area (%)	Area (ha.)	Area (%)
Farm land	5147.55	61.87	5697.36	68.48	5854.54	70.37
Grazing land	1206.99	14.5	301.41	3.62	285.13	3.43
Plantation	951.57	11.44	1261.26	15.16	2018.61	24.26
Riverine trees/ vegetation	1013.76	12.19	1059.84	12.74	161.59	1.94
Total	8319.87	100	8319.87	100	8319.87	100

Source: Field survey 2010.

Land used for farm land covers the highest proportion in the three periods considered in the study watershed. It covered 61.87% of the total area in 1990, followed by grassland (14.5%), riverine trees/vegetation (12%) and eucalyptus plantation (11.44%). In 2000, the coverage of farm land increased to 68.48% of the total area followed by Eucalyptus plantation which accounted for 15.16%. While riverine trees/vegetation and grazing land covered 12.74 and 3.62%, respectively. In 2010, 70.37% of the total land use and land cover was covered by farm land and the remaining area of 24.26, 3.43 and 1.94% was covered by eucalyptus plantation, grazing land and by riverine/vegetation, respectively (Table 1).

The highest percentage in area coverage of the farm land use type in the classification within the three periods considered indicated that the conversion of the grazing land and forest land into cultivated land, fallow and homestead areas was the long lasting problem in the study watershed. The same pattern of changes in area coverage of farm land was reported by Daniel (2008), in that land used for growing annual crops was more important in the Upper Dijo River catchment and increased in area coverage from 1972 to 2004 periods. The above analysis indicates that the pressure on the land is immense. Farming constitutes the major livelihood phenomena in the study watershed. With little or no rainwater management practices in the area, land and water resources management would be a great challenge.

Figure 9. Map of existing rain water management interventions practised in the study watershed

Pattern (nature) of changes in land use and land cover

An important aspect of change detection was to determine what was actually changing to what i.e. which land use class was changing to the other. This information would also serve as a vital tool in management decisions. This process involved a pixel to pixel comparison of the study year images through overlay. The loss or gain by each class of LULC between 1990 and 2010 particularly in the change in hectares was given in Table 2.

Table 2. Pattern of LULC changes between 1990 and 2000 and between 2000 and 2010 in the study watershed

Land use/land cover categories	Change b/n 1990 and 2000		Change b/n 2000 and 2010		Average rate of change (1990–2000)		Average rate of change (2000–2010)	
	(ha)	%	(ha)	%	ha/year	%	ha/year	%
Farm land	+549.81	+10.7	+157.18	+2.8	+49.98	+0.97	+14.29	+0.25
Grazing land	–905.58	–75.0	–16.28	–5.4	–82.33	–6.82	–1.48	–0.49
Plantation	+309.69	+32.5	+757.35	+60.5	+28.15	+2.95	+68.85	+5.46
Riverine trees/vegetation	–11.72	–1.6	–840.25	–83.9	–1.07	–0.10	–76.39	–7.62

It can be observed from Table 2 that farmland increased by 10.7 and 2.8% between 1990 and 2000 and between 2000 and 2010, respectively in the study watershed the cause of which is high population growth which demands more land for cultivation in the watershed under study. Eucalyptus plantation showed similar patterns of change, which increased from 32.5 and 60.5% between the 1990 and 2000 and between the 2000 and 2010 periods, respectively. Even if the area coverage of farm land was large from the beginning, its rate of expansion was lesser (0.97%) between 1990 and 2000 and 0.25% between 2000 and 2010 when compared to that of eucalyptus plantation (2.95% between 1990 and 2000 and 5.46% between 2000 and 2010). In contrast, grazing land and riverine tree/vegetation cover showed a reverse trend, reducing by 75 and 1.6%, respectively, between 1990 and 2000 and 5.4 and 83.9%, respectively, between 2000 and 2010. In general, the pattern showed that more land being used for farmland followed by eucalyptus plantations at the expense of grazing land and riverine trees/vegetation. Likewise, Daniel (2008) indicated that the pattern of land use and land cover changes between 1972 and 2004 in the Upper Dijo River catchment showed a tendency towards more land being brought under annual crops, while at the same time tree plantations became more important at the expense of shrub-grassland and riverine trees.

Land use land cover change detection results indicated that over the past 20–30 years there was gradual reduction and even near to the year of the present study almost a total disappearance of natural forest (1.94%) in the study watershed (Table 2). The main reason for the disappearance of natural forest in the study watershed was the conversion of forest to farmland (98.4%). As a result crop fields had taken the major areas even in hilly areas in the study watershed. Due to poor and inefficient utilization of RWM practices in the area, the expanded farmlands were highly prone to sheet and rill erosion as well as for the formation of big and active gullies which in turn led to low agricultural productivities in the study watershed.

The change detection result also revealed that there was reduction of grazing land in the study watershed within the periods considered. The shortage of grazing land for livestock was the main cause for increased crop residue removal for livestock feed purpose from crop fields which in turn resulted in soil fertility problems in the study watershed. Stream course deforestation for grazing purposes and other associated problems such as drying of streams and land sliding caused by livestock trampling were also consequences of grazing land reduction considered over the periods in the study watershed. Generally, variations in soil properties, livestock, agricultural and water productivities in the watershed under study were attributed to the observed differences in the LULC.

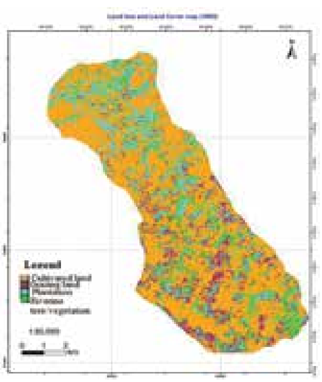

Figure 10 Map of LULC of the study watershed derived from landsat image of 1990

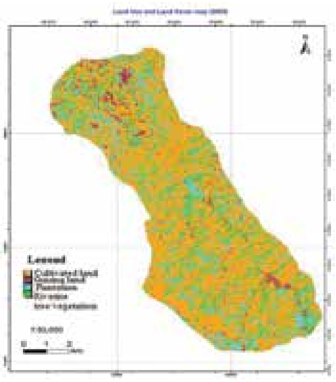

Figure 11 Map of LULC of the study watershed derived from landsat image of 2000

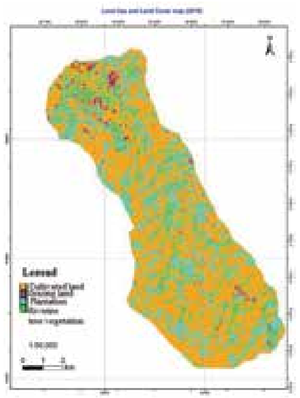

Figure 12. Map of LULC of the study watershed derived from landsat image of 2010

Conclusion

Inefficient applications of rainwater management practices in terms of both in *in-situ* rainwater conservation methods and via RWM for storing water for later use in water storage structures such as ponds were the main causes for water scarcity and water productivity problems in the watershed under study. Most respondents (66%) did not practise RWM interventions. Few RWM interventions such as check dams (43.5%) and ponds (3.2%) were implemented privately and in groups with valuable agricultural products being obtained with the use of these interventions to sustain food at household levels. However, the insufficient amount of water at the water sources (structures) and in diverted irrigation line are the main problems challenging the intensification of agricultural production via small scale irrigation systems in the watershed. Land conversion even at the steep slopes into cultivated land and the expansion of such land is a long time problem in the study watershed. The expansion of cultivated/arable land at the expense of forest and grazing lands was the main cause for the accelerated soil erosion, sedimentation, soil fertility loss and a resultant reduction in crop and livestock production and productivity in the study watershed. Therefore, strategies to secure food among the expanding population in the study areas will have to seek a sustainable solution that better addresses integrated rainwater and watershed management efforts.

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