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EFFECTS OF LAND COVER DYNAMICS AND THE RELATIVE RESPONSE TO WATER RESOURCES IN MIDDLE HIGHLAND TIGRAY, ETHIOPIA: THE CASE OF AREAS AROUND LAELAY-KORARO

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ABSTRACT
This study summarizes the significant environmental and socioeconomic changes took place in middle highlands of Tigray, Ethiopia, focused on evaluating the relationship of land cover dynamics and changes in water resource potentials in areas around Laelay-Koraro. For this purpose, Socio-economic and time trend studies had been carried out to set up the relationship between land cover dynamics and water yield. Arial photo and satellite imagery of two periods 1994 and 2007, Meteorological data and a survey data of 400 households above age 56 and records using Delphi method have been deployed to detect the correlation between conservation practices and rates of changes in ground water level and the relative response of resource reversibility. Results indicate that the conversion of land cover types contributed to a number of observable challenges expressed in terms of high rates of land degradation influenced by factors such as an expansion of cultivated land, built up area and poor land management practices. The land cover dynamics assessed using remote sensing and the farmers view on trends of change support the overall changes overtime. Indeed, the assessment of change and the detail analysis of aerial photo and spot image illustrate the positive correlation between vegetation cover and ground water level depths. The mean value of ground water depth of high vegetation cover were 3.85-4.95 and 2.85-3.75 in 1994/2000 and 2001/2007 respectively. Similar trends have also been observed in the medium vegetation cover area, where the mean ground water depth were 5.75-6.35M and 5.75-5.75-5.90M during 1994/2000 and 2001/2007 respectively. The fate of ground water depth of low vegetation cover at the end of rainy season does not show any change of improvement, i.e. the mean ground table depth of low vegetation cover for both seasons were 7.75-8.28 and 7.75-8.75M respectively. Despite the trend of rainfall doesn't show significant difference through time.

KEY WORDS: Land cover dynamics, Water resource, remote sensing, and GIS, Resource recovery.

INTRODUCTION

This study has been aimed to evaluate changes of the middle highland areas of the Northern part of Ethiopia-Tigray, experiencing severe land degradation arose from excessive run-off and soil erosion. The major concern addressed here is, the human contribution and the effectiveness of the rehabilitation programs to answer questions related land cover dynamics based on data's obtained from aerial photo and satellite image over a 14 years period and field assessments using a questionnaire to gather information from farm households above age 56. Human activities, in most of the developing countries, directly or indirectly are causes of permanent flux at different scales. The human use of land contributes to significant modifications of hydrology, geomorphology, climate and biogeochemical cycles (Liverman and Cueta, 2008). According to Wu and Hobbs (2002), the relationships between water supply and spatio-temporal variations of vegetation on landscape pattern is critically important for the development and implementation of strategies to conserve biodiversity and maintenance ecosystem structure and function in arid regions. Understanding the relationship between de-vegetation and water resource potential promote and improve the responses to detect changes and the measures to be taken for water resource management. The land cover dynamics, especially the situations which have been a major concern with high rates of environmental degradation and the changes after a considerable intervention on land management and the outcomes after the implementation of resource protection of the systems of soil and water played a major role to perform trend analysis in the study area. The results of rainfall uncertainties have been manifested in terms of reduced crop production and food insecurity. In order to reduce risks arose due to climatic limitations, establishing land cover management strategies for sustainable use and development of water resource has been essential which eventually create sound understanding of the drivers of land degradation and to pointing out the remedial reactions. Understanding the dynamics and driving forces behind land use and land cover changes at local level is fundamental to development planning and the analysis of land related policies (Tekle and Hedlund, 2000). The above pointed out effects has been observed in the study area. Hence, the new paradigm has been directed towards ensuring resources management and reducing uncertainties, on how water resource potential of the study area is sensitive to land cover changes. The magnitude and rate of land degradation and the cause-effect linkage due to competing demand for resources, a rapid response in land cover dynamics has been typical in areas around Laelay-Koraro, middle highlands of Tigray, Ethiopia. According to many literatures related to land cover dynamics, a crucial link between land cover changes and water resource goes to the increasing worldwide concern of environmental changes. In line with this, promoting water resource management to maintain sustainability associated with efficient resource management principles and experiences has to be documented. Hence, these paper was, therefore, focused on water resource management and assess the trends in relation to land cover dynamics to assist immediate beneficiaries and stakeholders as well as policy makers to better understand the impacts as a case study in the mid-high land areas of Tigray, Ethiopia, with a view of intense rehabilitation programs and effects of land cover changes.

MATERIALS AND METHODS

Study area

The study was carried out in areas around Laelay-Koraro in North-Western part of Tigray regional state of Ethiopia. It lies between latitudes 14^0 to 14^0 10' 21" N and longitudes 38^0 24' 12" to 38^0 24' 36" E (Fig.1). The total area of the study site is 64512 ha. The area lies in the semi-arid agro-climatic zone with diverse topographic conditions characterized with undulating terrain having step and gentle slopes. The altitude of the study area ranges from 750M to 2300M above sea level.

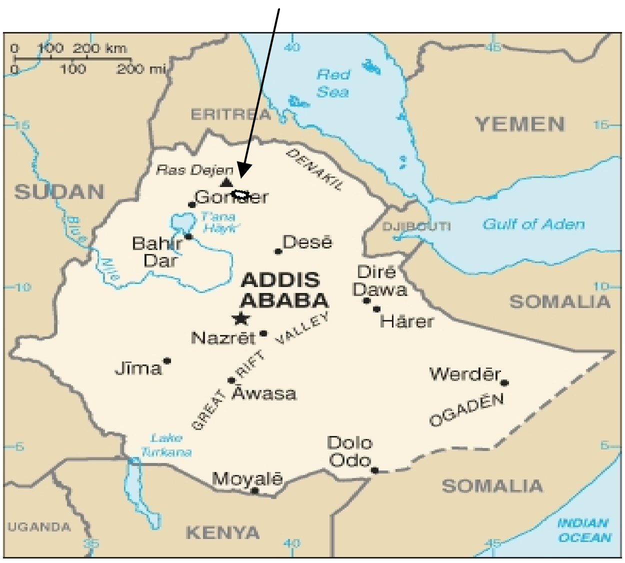


FIGURE.1 Location of the study area

The mean annual air temperature is 28^oc, the maximum temperature reaches its pick during the month of April and may, an annual precipitation ranges from 600mm to 900mm (Ethiopia Metrological service). The rainfall season is three to four months from June to September; and more than 80% of the total precipitation rains within these months. The rainfall is erratic in nature which impose early, mid or late season droughts. Soils are predominantly dark brown in the middle highland and light brown and grayish color in the low land areas.

Data analysis

The research mainly focuses on evaluating the changes of water resource potentials in relation to land cover dynamics in the study area. Four kinds of data were used in this study: aerial photo and satellite imagery of two periods 1994 and 2007 (Fig.2) by integrating GIS (Geographic Information System) to detect the land cover dynamics. Intensive field survey was carried out for the purpose of ground checks and to have a clear understanding to what it has been done so far and evaluate achievements gained through resource conservation. Meteorological data were recorded from nearby weather station, Selekeleka (altitude, 2000M above sea level and 14^o 11'N, 38^o48') at a daily rainfall basis for the period 1964 to 2007 obtained from the National Meteorology Service Agency (NMSA). The rainfall data was taken to test the significant impact of rainfall on ground water potential versus land cover dynamics in the study area, as recorded by the experts of the North Western Zone, Department of Water Resource, Tigray, Ethiopia. For the purpose of analysis, ground water level records of the past years at different land cover types were taken in terms of water volume and depth differences of wells and the significant potential of water used for irrigation purpose.

To detect changes after intervention, a 14 year interval were taken to test land cover dynamics before and after the implementation of resource conservation practices. The survey data records were conducted to quantify the temporal changes using the Delphi method coupled with interviews of 400 farm households in the study area. Despite of this, the correlation between conservation practices and rates of changes in ground water level in response to annual rainfall variations were tested.

TABLE 1	Description of the land cover types of the study area
Category	Description
Forest cover	Densely covered area with different species of forest trees on mountains. Canopies cover> 70%
Wood land	an area with tree crown and height with more than 70% and about 5M height tree respectively.
Shrub land	an area with scattered small trees not exceeding 3M in height. Bushes, shrubs mixed with grass.
Cultivated land	agricultural rain fed cultivated land with scattered trees.
Mixed trees crop land	rain fed crop land with less than 30% tree cover.
Irrigated land	land with annual and perennial crops.
Grass land	grass dominated land
Wooded grass Land	land covered with trees 40-70% crown not less than 5% height
Bare land	land composed of stones and soils.
Degraded land	land with observable frequent gullies.
Built up areas	Residences, land used for small industries and other trade enterprises

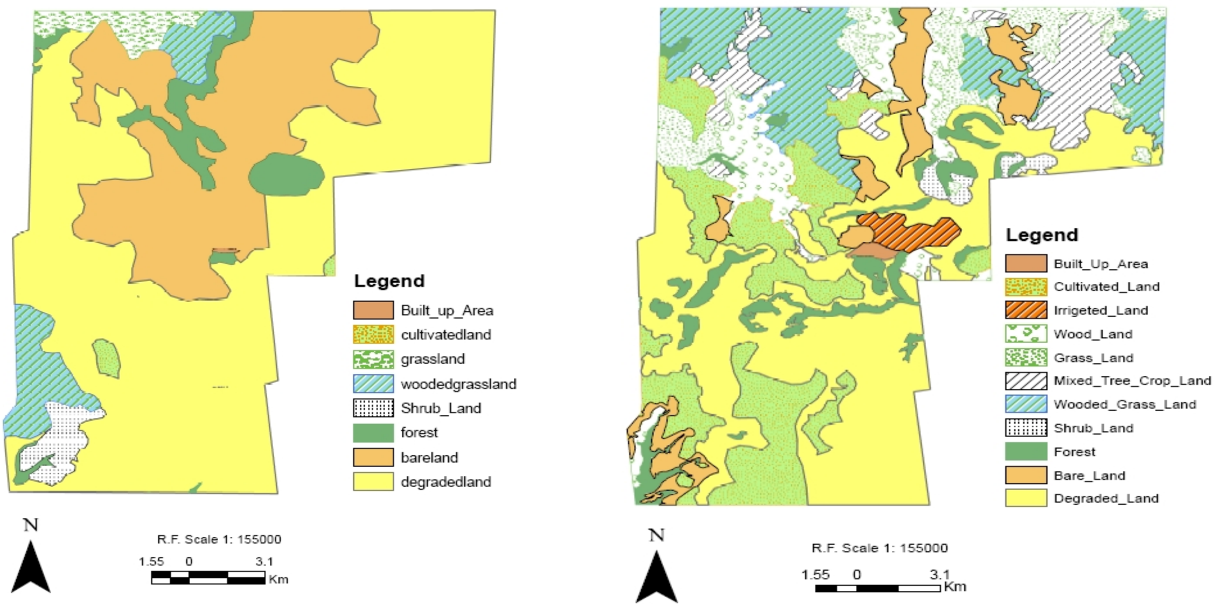
RESULT AND DISCUSSION

Major observed changes, 1994-2007

The influence of land use and cover depends very much on the nature of the land and level of management techniques used (Solomon, 1994). Table-2 illustrates the dynamics of land cover between the two periods 1994-2007. During the period, as remotely sensed data indicate (Fig. 2), much of the study area was pertinent to reflect the decline of natural resource and was the time to refocus the existing changes and gain knowledge on how to reverse the situation. It is during 1994, where the resilience of the entire land cover was clear and apparent. More than 50% of the total area was completely changed to bare and degraded land, due to mainly excessive removal of vegetation. At this period, in the study area, 81% of the household remain dependent on firewood for their energy (www.csa.gov.et). EFAP (1993) estimated the annual rate of deforestation ranged between 150,000 and 200,000 ha per annum in Ethiopia. Crop failure and repeated drought in the study area, forests and forest products were used as a means of income generating of households through sells of fuel wood which completely devastated the situation. Even though it has been recognized that biodiversity is important for the function of all ecosystems, and that excessive loss of biodiversity imposes real cost on resource users (Heywood, 1995).

TABLE-2 Land cover dynamics, in areas around Laelay-Koraro in middle highlands of Tigray, Ethiopia

Land cover categories	Trends of land cover change					
	Area - 1994		Area - 2007		Change between 1964 and 1994 (%)	Change between 1994 and 2007(%)
	ha	%	ha	%		
Forest cover	2249	3.50	9053	14.0	-11.60	+10.5
Woodland	-	-	4081	6.3	-12.20	+6.3
Shrub land	9369	14.58	9697	15.0	+2.08	+.42
Cultivated land	12203	18.98	14175	21.9	+3.23	+2.98
Mixed tree cropland	-	-	2312	3.5	-8.70	+3.5
Irrigated land	-	-	2210	3.4	-0.30	+3.4
Grassland	1959	3.0	1130	1.8	-15.00	-1.2
Wooded grassland	2375	3.70	3703	5.7	-8.70	+2
Bare land	14763	22.80	8320	12.9	-17.20	-9.9
Degraded land	20982	32.50	9355	14.5	-27.80	-18
Built up area	606	0.94	1254	1.9	+0.39	0.96
Total	64512	100	64512	100	-	-



Map-a (aerial photo) 1994 Map-b (Satellite image) 2007

FIGURE-2. land covers dynamics in areas around Laelay-Koraro 1994-2007

The forest cover in 1994 constituted only 3.5% of total area of 64512 ha. A decline in forest cover increased the decline in soil fertility since it aggravates soil erosion and reduces the potential of productivity. It has also been proved during the discussion made with soil and crop-science experts (using Delphi method); fertilizer application on degraded soils to improve soil fertility show insignificant effect on yield. It implicates that here is no gap to treat soil infertility in the presence of deforestation. Deforestation was always followed by a change in land use and land cover from forest to grassland and cropland (Hurni et al., 2010). Similarly, the substantial changes observed in the area, 33.56% of the total area was transformed to cultivated and shrub land (Table-2). As a result, this change may be regarded as the prevalence of barriers against sever land degradation. The situation and rate of soil erosion in the study area during this period had influenced the natural interactions of vegetation and ground water. Irrigated land was completely abolished due to a decline in water resource during the first period. The uneven distribution of rainfall with poor vegetation covers and degraded soils contributed to surface runoff, decrease in groundwater level and uneven surface flow of water. Vegetation has a considerable effect of water cycling in an ecological land system (McCulloh and Robinson, 1993).

The assessment of change and the detailed analysis of aerial photo and spot-image, with respect to vegetation cover show a positive change which indicates an overall improvement during the last periods of the study, 2007. Irrespective of the past period, the observed changes, in most cases show a significant improvement, though the status varies agro-ecologically within study area. From the technical, ecological and economic point of view, the extensive use of stone bunds, involving popular participation of Tigray, North Ethiopia, is positive operation (Nyssen et al., 2007a). In 2007, vis-à-vis 1994, considerable changes in vegetation cover has been observed in the study area. The trend shown an improvement, forest land increased by 10.5% of the total area, which was the largest proportion during the period. Similarly, areas of wood land and mixed tree crop land constitute 9.8% together. As it has been proved during the field survey and interviews, massive-involvement in soil and water conservation (SWC) activities and establishment of exclosures play a significant role in reducing human induced land degradation problems.

Soil and water conservation practices at individual and collective level have brought a positive response in improving ground water level. The area under irrigated land improved by3.5% which have been completely abolished in the past period. The ground water response was positive as the vegetation cover improved and increased infiltration. A new earth dams and ponds were observed for irrigation and other purposes. The intervention to establish water reservoir and ponds is increasing aimed at improving agricultural productivity.

Implications of soil and water conservation in the study area

Socio-economic stress is the result of reduced crop yield and is the immediate outcome of resource degradation. Soil loss, i.e. sever erosion and depletion of soil nutrients in most parts of the region, Tigray poses a significant decline in crop productivity. Hurni (1988) noted, average erosion of cultivated land has been estimated at 42Mg ha^{-1} per year. However, according to a processed and interpreted aerial photograph and satellite imagery during 1994-2007 (Fig-2) revels that there was an expansion of vegetation cover in major parts of the study area. The paradigm shift in understanding the causes and effect of resource degradation was an important development to scale-up research activities and participation of technical and professional skills in this field. Wider coverage of exclosures in slope areas was effective in reducing runoff and adoption of soil and water conservation (SWC) show positive improvements in household income. Anderson and Thampapillai (1990), mentioned factors that positively associated with adoption of soil and water conservation improve level of income with some additional benefits. Physical structures and reforestation program has been carried out for soil and water conservation at large scale at the beginning of the study period, which have been widely covered larger area at the end of the period. Fig.3 illustrates the trends of change of protected areas from excessive removal of vegetation cover and soil loss.

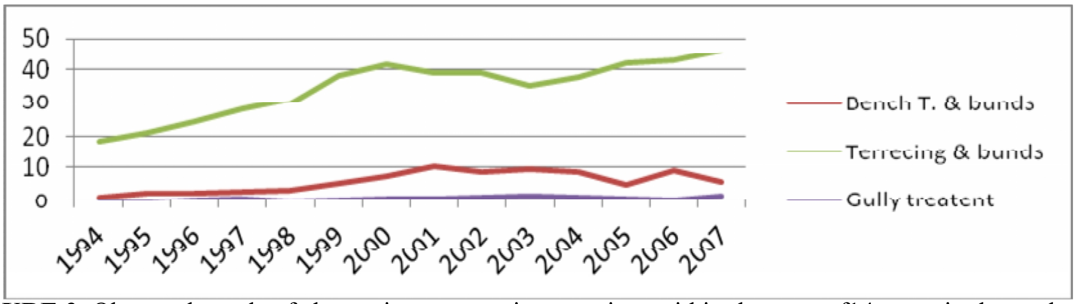


FIGURE 3. Observed trends of change in conservation practices within the span of14 years in the study area

Land cover dynamics and potential impact on rainfall and ground water resource

For the past 14 years, the land cover in areas around Laelay-Koraro, middle highlands of Tigray-Ethiopia, experienced extensive changes in water resource, rainfall and the expansion of farmland and other land cover types. In dry land areas, a major limitation for agricultural productivity is the constrained biophysical environment in terms of erratic rainfall (Appelgren, 2009). The 1994 aerial photo clearly illustrates that the water resource potential has been seriously affected, where the irrigation potential was completely abolished. The land cover mark was completely changed due to sever clearance of vegetation cover in the study area. Change in vegetation cover can alter surface flux of energy and water and modify surface climate (Mustard *et al*., 2005).

Rainfall trends are assumed to be dictated by existing changes in vegetation cover having a significant influence in precipitation. Surprisingly, the satellite imagery of 2007, show the expansion of protected area profile, indicating this increase as positive development in resource conservation. Hence, the data requirement to detect patterns of rainfall has been to value the trends of change through time and the relative change on ground water level to examine the analogous situation of the variables. Zeng *et al.* (1999) noted that, vegetation feedback might have enhanced the inter-decadal climate variability in the Sahel. The rainfall data observed in study area indicate the mean rainfall levels show a positive trend followed by a rapid decline in a certain period, though the trend doesn't show a significant difference through time.

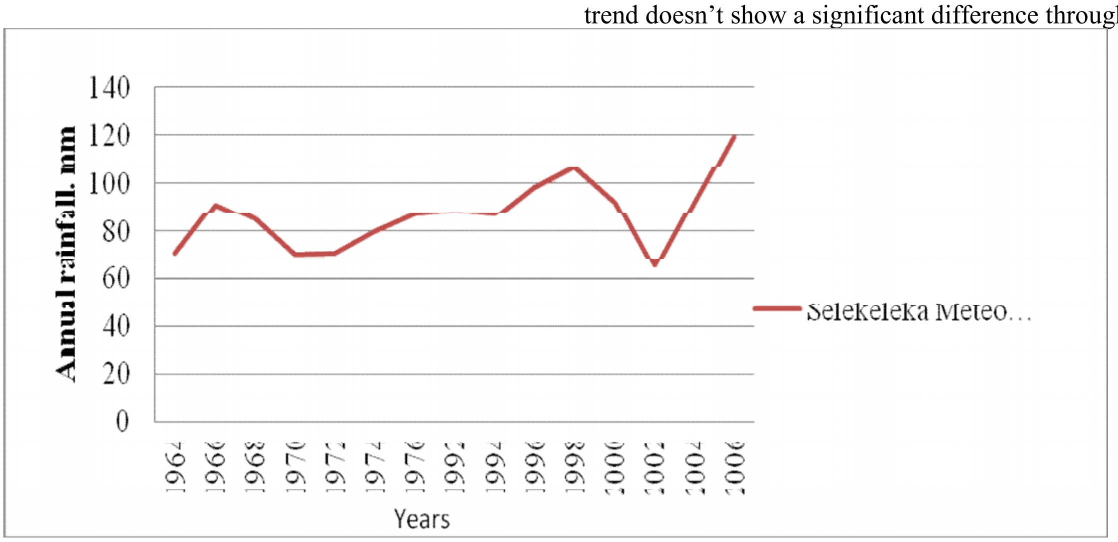


FIGURE.4 Annual rainfall distribution 1964-2006 (Ethiopian Meteorological Service Agency) In general terms, during 2007, essential changes in land cover were observed: forest cover, wood land, shrub land; the vegetation cover in general show a positive improvement. Similarly, the rainfall also indicates an increasing trend in an average rainfall pattern within the specific period of time. Precipitation and land cover changes seemingly have a positive correlation, though the trend of rainfall doesn't show a significant difference vis-à-vis the past two decades.

TABLE-3. Patterns of change of ground water level depths between 1994 and 2007 in middle highlands of Tigray, Ethiopia in areas around Laelay-Koraro

Land cover types	Range of the ground water level depth (in meter)					
	1994-2000			2001-2007		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Relatively high vegetation cover	4 - 5.75	3.5 - 4	3.85 - 4.95	3.5 - 4	2 – 3.25	2.85 - 3.75
Moderate vegetation cover	6.25 - 6.5	5.5 – 6.0	5.75 – 6.35	6 – 6.25	5 – 5.5	5.75 - 5.90
Low vegetation cover	8.0 – 8.5	7 – 7.5	7.75 – 8.25	8.0 – 8.25	7.25 – 7.5	7.75 - 8.75

SOURCE: Department of water resource North-Western Tigray, Ethiopia

Keeping the intensity and amount rainfall being constant, the land cover dynamics observed during the study period 1994 to 2007 and the rehabilitation efforts made greatly reduced runoff and showed an improvement in the rates of infiltration and soil moisture. It was evident that there was a significant difference of water yield in different vegetation cover in the study area. As per data obtained from the Department Water Resource of North-western Tigray- Ethiopia, the status of yields of ground water were maximum showing higher yields in higher vegetation cover (Table-3). The data further showed an improvement in ground-water depths as compared to 1994/2000 and 2001/2007, except for low vegetation cover. In the past decades, there has been an observable changes in land cover coupled with soil and water conservation practices which have been created a positive understanding in connection with water and resource conservation. Conservation efforts (Fig-5) implemented between 1994 and 2007 reduced runoff which in turn improved infiltration rates. The low vegetation cover, rates of runoff has been seriously affected the residents of the study area. During the field survey, erosion hazards and the problem of sedimentation indicates that the need of rigorous efforts in the implementation of resource management to reverse the situation. The rehabilitation program in the study area improved the ground water table at the expense of the reduced soil erosion and runoff.

FIGURE 5. View of ground water table in a relatively high vegetation cover area, 2010.

CONCLUSION

The land cover dynamics with span of 14 years experienced significant rates of conversion of land cover types, contributed to a number of observed challenges expressed in terms of high rates of degradation and related problems, such as erosion, runoff, loss of vegetation cover, and as consequence a serious decline of crop yield. The resilience of the land cover observed at the beginning of 1994 was clear and apparent. The changes have been dramatic and the impacts have been serious and reflected in the livelihood security of the community around the study area. The assessment of change and the detailed analysis of aerial photo and spot image illustrate, the vegetation cover show a positive change in an overall improvement during the last periods, 2007. The present and other similar studies related to soil and water conservation practices at regional and national level documented the effectiveness of the interventions (Hunri et al., 2009). After intervention, the land cover type showed observable improvements. Households perceived the gradual and significant changes in soil fertility and improvements in crop yield. The survey data further illustrates that any effort made to conserve natural resource significantly reduces the anomalies arises due to recurrent drought and misuse of resources. The temporal changes of vegetation cover and the combined effect of the two factors, the rainfall and ground water level showed a similar trend of change. Even the rainfall data revealed an increasing trend and a decline some time during the study period, the amount of rainfall and distribution significantly contributed to positive changes in ground water resources. Hence, the result illustrates the positive correlation of vegetation cover and ground water level depth. The land cover dynamics and rehabilitation efforts showed remarkable changes over time period. The study furthermore demonstrates clearly the changes in vegetation cover alter the water depths. This has been evidently proved during 1994-2000 and 2001-2007 when compared at different land cover types and at different ranges (minimum and maximum) of ground water level depths. The randomly selected 400 households of age 56 and above the Delphi method deployed to evaluate the consensus among group of experts in government offices demonstrated the growing need for sustainable resource management and proved that farmers' show positive attitudes on changes achieved so far. In summary, the introduction of proper land management system that reduces deforestation, removal of natural vegetation, and soils by erosion should get more emphasis. Up-scaling the measures proved successful such as soil and water conservation and the expansion of exclosures in an integrated approach would be essential.

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