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Assessment of Land Cover and Water Resources Changes in Igunga District: A Strategy towards Policy Reform and Sustainable District Development

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ABSTRACT

Vegetation cover and water resources play an important role in determining soil characteristics and serves as the energy source for the vast array of animal species. This study is focused in the investigation of the problem of vegetation cover and water resources depletion resulting from increased population pressure and its associated socio-economic activities. The study area is the Igunga District, in Tabora Region. The land area covered by the District is 6,788 Sq-km which is 8.9 per cent of the area covered by the region. The altitude varies from 1000m to 1800m above sea level, and annual rainfall ranges between 500mm and 800mm. Vegetation in this area consists of the grassland and acacia species; hence the District is semi-arid in nature. The objective of this study was to assess and model the vegetation cover and water resources changes that had occurred in between 1985-1990, 1990-1995, 1995-2000 and 2000- 2010 epochs, as the results of increased population pressure and the human socio-economic activities conducted in the study area. The data used for the research was Landsat Satellite Imageries of 1985, 1990, 1995, 2000, 2005, and 2010. The ERDAS Imagine 9.1 Software was used in the pre-processing and processing of the image data. The classification technique used was the Hybrid Classification method, which utilizes both features of unsupervised and supervised classifications. The Accuracy Assessment results for all classified image were above 80%. Change detection was applied to detect changes between the epochs. The findings show that the vegetation cover, especially the forest and woodland cover changed to bush-land vegetation cover type and to bareland This means that, forest and woodlands had a decreasing trend of change while the bushland and bareland had an increasing trend of change. The water resources showed a slight depletion.

Key words: Vegetation cover, water resources, sustainability, policy reform.

INTRODUCTION

The primary goal of studying changes in land cover and water resources is to understand the future scenario of the ecosystems and the ecosystem services that relate to vegetation and water resources. Vegetation supports critical functions in the biosphere; it plays a big role in local and global energy balances, strongly affects soil characteristics, and serves as a wildlife habitat and the energy source for the vast array of animal species on the planet. Vegetation is also important to the world for the production of food, wood, fuel, construction materials, shelter, and medicine. Vegetation and water resources are however exhaustible, which means that the ecosystems have a finite quantity, and can be depleted if not managed properly.

The dynamics in land use changes are brought about by a number of interacting factors including socio-economic, political and environmental factors; and have prominent effects on the balance of ecosystem on human productivity and welfare (Mertens & Lambin, 1999). The control, management and prediction of future trends in environmental change, natural resources and food security are among

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the issues that require detailed information on land use and its changes over different spatial extents.

Tanzania is endowed with a wide variety of vegetation cover and water resources, whichplay big roles in the economy in terms of social and economic goods and services they provide. In recent years, the depletion of vegetation cover and water resources has become a major focus of Tanzania Government and other institutions like universities (Wampembe, 2009).

Tanzania's fast growing population has led to higher and varied consumption demands, that in turn cause major changes in the use of land and natural resources to meet these demands (Mbwambo, 2004; PPU, 2007). The changes are reflected in the growing number and size of settlements due to rapid population growth (PPU, 2005), deforestation (FOSA, 2000), decline in agricultural productivity (Amani, 2005), environmental degradation and changing climatic conditions (Hubacek & Sun, 2001). To be able to control and manage land use change, systematic monitoring and mapping of change over spatial and temporal spaces is required to provide an understanding of the factors contributing to land use change together with the role and significance of each of these factors.

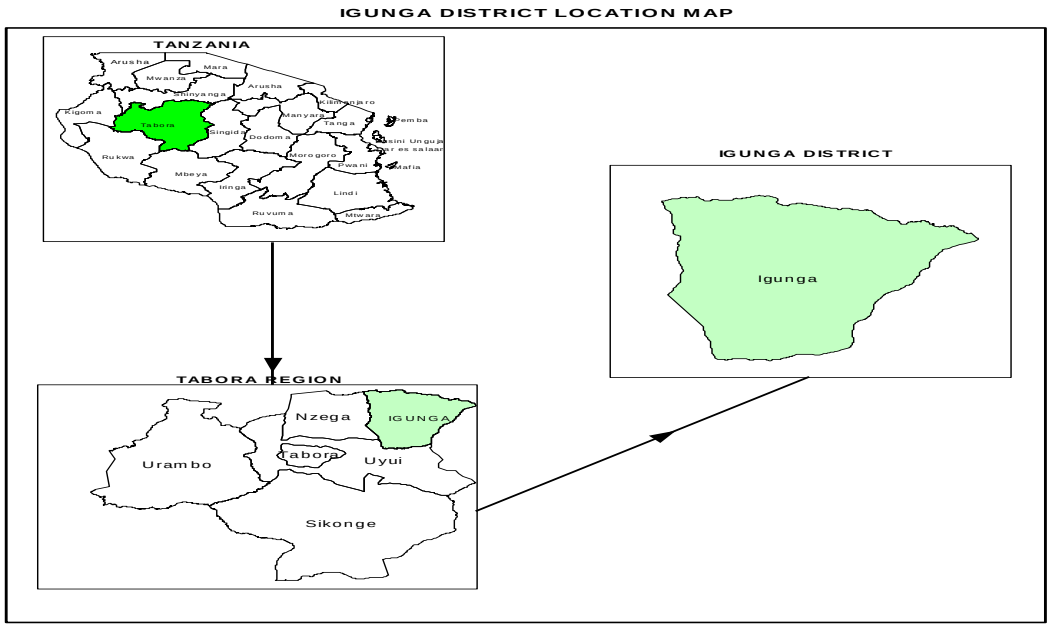
To monitor and control land use and land use changes at any spatial scale, an understanding of the trend in the use of land in a specified spatial extent over a given temporal range is required. The main objective of this research is, therefore, to study changes of vegetation cover and water resources in Igunga District in order to get the magnitude and trend of changes of vegetation cover so as to influence policy reform which help to control the continued depletion of these resources.

Description of the study area

Tabora Region is the largest region of Tanzania in terms of areal coverage, covering about 76,151 square kilometers which is approximately 9% of Tanzania.. The region was originally subdivided into four districts namely Tabora, Urambo, Nzega and Igunga, later two other districts namely Uyui and Sikonge were established. The location of the present six districts in the region is shown in Figure 1.

Igunga District is situated within the lowland area in the North-Eastern part of Tabora Region. The district is semi-arid in nature and its vegetation cover consists of woodland in the South-Western areas, swamps and bush land thickest in the Northern and Eastern parts (Tabora Socio-Economic profile, 1996). Because of the aridity condition, the district has insufficient rainfall to support vegetation growth and to make land retain water throughout the year for livelihood of people.

As a result, degradation of vegetation cover and water resources in Igunga District is of major concern and needs to be redressed as it might lead to the loss of biodiversity and loss of natural ecosystems which is vital for serving the current and future sustainable development.



METHODOLOGY

Sources of satellite data

The primary data used in this research were the remotely sensed Landsat satellite imageries. The data were selected because it has a long history of coverage in the area and therefore, offers the possibility of comparison across different epochs. All the images were taken during the peak of the rainy seasons. Six scenes of five year intervals were selected for the study as shown in Table 1.

Table 1: Choice of Remote Sensing Data

S/NO	Image acquisition date	Sensor
1.	05 March 1985	Landsat MSS
2.	23 April 1990	Landsat TM
3.	02 April 1995	Landsat TM
4.	18 Jan 2000	Landsat ETM+
5.	21 April 2005	Landsat ETM+
6.	11 April 2010	Landsat TM

Sources of secondary data

In addition to the satellite images, the secondary data that were used in the study are the 1:50 000 Scale base maps i.e. standard sheets No. 80/1, 80/3, 80/4, 81/1, 81/2, 81/3, 81/4, 90/1, 90/2, 90/3, 90/4, 99/2, 100/1 and 100/2, and aerial photos covering Igunga District. These maps were obtained from the Survey and Mapping Division (SMD) in the Ministry of Lands, Housing and Human Settlement Development (MLHHSD) in Dar es Salaam. The maps were used in the preparation of the Accuracy Assessment report of the classified image data, and the aerial photos were used for data validation.

Ground truthing data

A field trip was carried out with the aim of gathering ground truth information for purposes of image classification. Ground truthing refers to the process of collecting field information to be used for training in supervised classification

and for checking the results classification. The instruments used were Garmin EMTAC S3 BTGPS hand held GPS receiver. Data resulting from this field work included GPS position of points representing land use and cover classes of interest and routes of interest that were traversed. An average of 15 points for each class were picked for classification accuracy assessment.

Unstructured interviews

Some useful information was acquired through unstructured interviews with local Government leaders. The interviews were done based on unstructured questionnaires prepared prior to the field visit as guidelines to the interviews. Villagers and the following officers namely the District Forestry officer, the Agricultural and Veterinary Officers, were interviewed.

Data Validation

Data validation for the topographical maps consisted of the examination of features present in the paper maps and the paper prints aerial photos or the area, using distance measurements and by visual inspection. Both the topographical maps and aerial photographs were found to be in good order for the purpose of this study. The information present in topographical maps tallied with the corresponding information in aerial photographs; assuring consistency. Prominent features present on the ground were confirmed by visual observation to be in place in the topographical maps and aerial photographs implying that topographical maps used in this study form a reliable source of information.

The quality of satellite images from both IRS and Landsat was checked by examining consistency with topographical maps and aerial photographs and found to conform to the requirements of this study. All satellite image data were 100% cloud free within the study area.

Classification procedures

Images classification was performed by using Hybrid classification method. Hydbrid method was found to be useful because both supervised and unsupervised classifications features are utilized. Hybrid classification method is particularly useful to apply where there is complex variability in the spectral response patterns for individual land cover types present (Lillesand et al, 2004). This condition was found in Igunga district where there is distinct variability in land use cover and vegetation patterns from highland to lowland areas including the wetlands.

Class editing

The results of classification showed a high spectral overlap between some of the classes resulting into mixed classes. For example houses, bare soil and roads were classified as one land category as they all posses similar spectral values. This is because majority of the houses in the area of study are thatched with dry grass, and a good number of others has a layer of soil itself as their roofing. The roads are not paved and on the satellite imagery they resemble bare soil spectrally making the two indistinguishable. Another reason for the mixed classes is that the settlements are intermixed with agricultural land i.e. mixed farming. Most of the houses are surrounded by cultivated land, planted with food crops. This made it difficult to distinguish spectrally between houses and cultivated land or grassland using the conventional multispectral image classification algorithms. Mixed classes were rectified through class editing, where each pixel in the mixed classes is visited and labeled by its true class.

Classification Accuracy Assessment

Classification accuracy assessment was carried out using the error matrix. This is the most common way to assess classification accuracy (Card, 1982; Congalton, 1991). The assessment was done by comparing the classified map derived from remotely sensed data and data collected in the field.

Land cover change detection

The change detection was performed to assess how vegetation and land use cover in Igunga have changed from 1985 to 2010. Change detection was carried out using the GIS

Analysis tool of ERDAS Imagine software which allows two thematic image files of different years to be compared. The assessment of vegetation cover change was done for consecutive epochs of five years each (i.e. 1985-1990, 1990-1995, 1995-2000, 2000-2005, and 2005-2010). Change detection results are presented using change matrices showing the area covered by a change from one land use category to another land use category

RESULTS AND ANALYSIS

Image Classification results

Results include the classified images and accuracy analysis. Figure 2 shows one of the original image of Igunga (2000) which was used in the analysis. A total of five satellite images were classified. Here in figure 3 one of the classified images of (1995) along with its accuracy assessment results is presented. Overall, the Error Matrices of the classified images showed accuracies achieved were above 80% which were sufficient for the purpose of change detection.

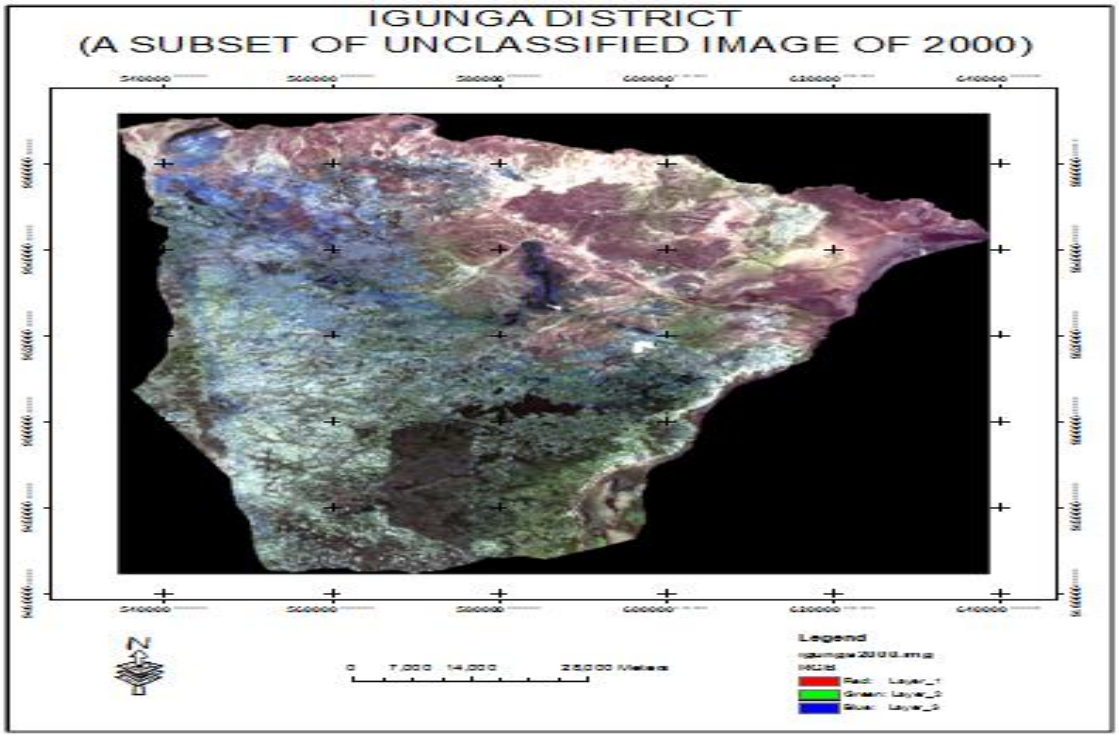
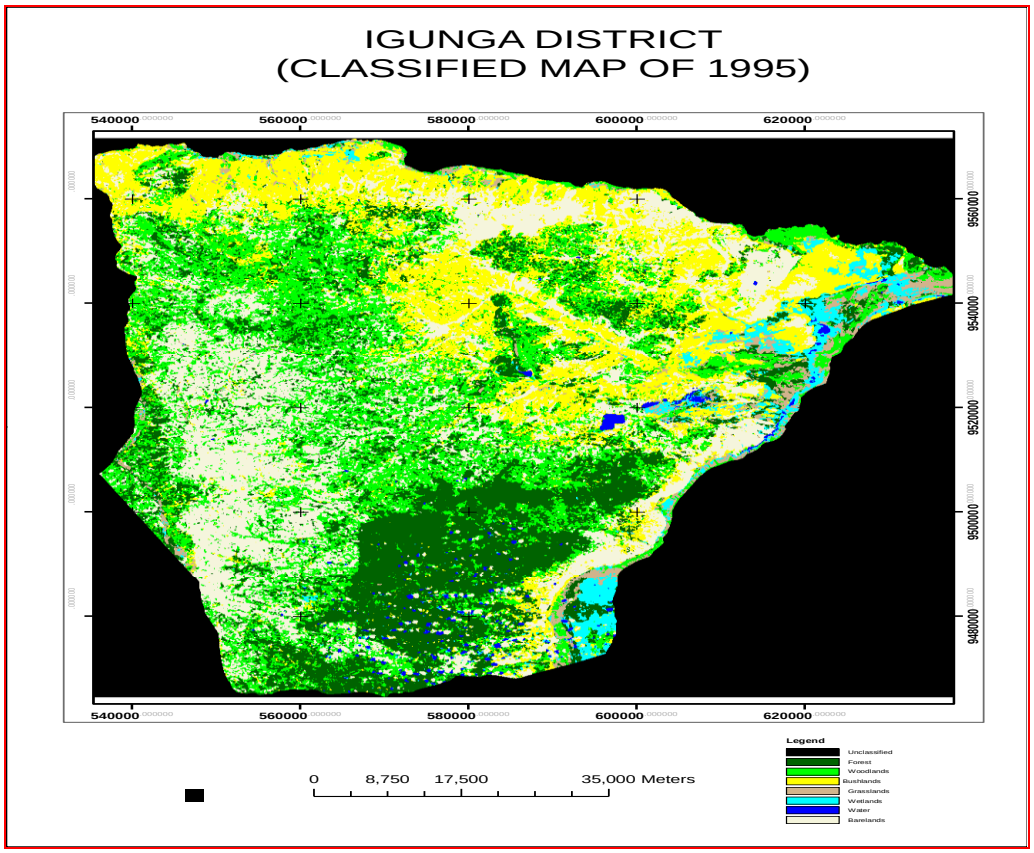


Figure 2: One of the original images of Igunga



Accuracy Assessment Report (1995)

Reference Data for the Image of 1995							
Classified Data	**Forest**	**Woodland**	**Bushland**	**Grassland**	**Wetland**	**Water**	**Bareland**
Forest	13	3	2	0	1	0	0
Woodland	0	30	2	0	0	0	1
Bushland	0	1	25	2	0	0	0
Grassland	0	0	0	2	3	0	0
Wetland	1	0	0	0	4	0	0
Water	0	0	0	0	0	1	0
Bareland	0	0	1	0	2	0	35
Column Total	**14**	**34**	**30**	**4**	**10**	**1**	**36**

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Forest	14	19	13	92.86%	68.42%
Woodland	34	33	30	88.24%	90.91%
Bushland	30	28	25	83.33%	89.29%
Grassland	4	5	2	50.00%	40.00%
Wetland	10	5	4	40.00%	80.00%
Water	1	1	1	100.00%	100.00%
Bareland	36	38	35	97.22%	92.11%
Totals	129	129	110		

Change Detection Results

The change detection was intended to identify the fundamental process of transition of vegetation cover and water resources of Igunga District. This was important because, in order to curb the vegetation cover and water resources depletion problem there is a need to understand the fundamental process of land cover transition effective conservation and management strategies.

The fundamental processes of transition in this study were constructed in matrices to show the magnitude of transitions, and the amount of gained or lost in each category.

Table 3 shows the areal coverage of each land cover category at the beginning and end of each epoch. In the assessment of each category, the amount of gain or loss was assessed relative to the distribution of the other categories. The following subsections discuss the change detection results of each category.

Change of Forest cover

In 1985 the forest cover dominated in the most part of Igunga District especial in the South western part, the forest lands covered an area of about 257,661 ha which was the biggest area compared to other categories. But the forest land was continually diminishing from one epoch to another between 1985 and 2005. From 2005 up to 2010 the trend changed and started to increase. The area increased from 22,798 (ha) of 2005 which was very minimal, and reached 49,458 (ha) in 2010. From the interviews it is confirmed that disappearance of forest cover during the period resulted mostly of forestry product harvesting including harvesting for timber and firewood reducing most of it to woodlands (Table 5).

Table 3: Land Cover of Igunga district at the beginning and end of each epoch between 1985 and 2010

	AREAL COVERAGE (HECTARES)					
	1985	**1990**	**1995**	**2000**	**2005**	**2010**
Forest	257,661	204,103	151,156	85,973	22,798	49,458
Woodland	37,668	156,155	183,266	128,187	117,755	74,100
Bushland	53,449	74,272	145,814	58,271	126,231	178,768
Grassland	93,066	82,872	18,937	14,755	16,824	12,382
Wetland	28,147	20,026	21,578	40,299	19,084	35,826
Water	15,578	13,963	5,126	14,233	11,382	9,478
Bareland	220,106	153,926	179,583	363,634	391,695	345,438

Table 4: Change of Vegetation Cover between 1985 and 2010

Vegetation	Changes 1985-1990	Changes 1990-1995	Changes 1995-2000	Changes 2000-2005	Changes 2005-2010
Forest	(53,558.37)	(52,947.45)	(65,182.32)	(63,174.96)	26,660.10
Woodland	118,487.25	27,110.97	(55,078.38)	(10,432.89)	(43,654.54)
Bushland	20,822.13	71,541.90	(87,542.46)	67,959.90	52,537.18
Grassland	(10,194.39)	(63,935.10)	(4,181.94)	2,069.28	(4,442.15)
Wetland	(8,121.69)	1,552.23	18,721.35	(21,214.89)	16,741.48
Water	(1,615.05)	(8,836.20)	9,106.29	(2,850.57)	(1,903.63)
Bareland	(66,180.15)	25,657.47	184,050.81	28,061.28	(46,256.78)

Note: The brackets stand for negative changes

In the summary of gain and loss of forest cover, Table 5, from 1985 to 2010 most of the forest (142,208 ha) cover was lost to woodland, bushland and grassland. However, forest cover gained 971,426 ha from woodland. The overall transition change shows there was a net loss of 122,258 ha for the 25 years period, beteen1985 and 2010.

Table 5: Forest gain and loss (1985-2010)

	Total Loss to(ha)	Total Gain from (ha)
Woodland	142,208	71,426
Bushland	44,690	23,564
Grassland	33,539	10,910
Wetland	3,731	603
Water	18	1
Bareland	55,299	50,724
Total (ha)	**279,485**	**157,227**

Change of Woodland

In 1985 woodland cover dominated most of the South-Eastern parts of Igunga district, (37,668 ha) which was small compared to forest cover and bushland. But the trend of change of woodland was alternating from one epoch to another when compared to the trend of forest cover change which was systematically decreasing. Woodland increased from 37, 66.61 ha in 1985 to 156,155 ha in 1990 and reached the maximum of 183,266 ha in 1995. Then it decreased to 128,187 ha in 2000, to 117,755 ha in 2005 and lastly to 74,100 ha in 2010. This was mostly the result of conversion of woodland to agricultural area and human settlement (bareland), thereby converting it to bushland. However, during the same period some regeneration occurred to turn woodland into forest.

Table 6: Woodland cover gain and loss (1985-2010)

	Total Loss to (ha)	Total Gain from (ha)
Forest	52,217	161,417
Bushland	104,926	67,286
Grassland	10,348	41,958
Wetlands	2,378	426
Water	68	4
Bareland	261,601	33,041
Total (ha)	**431,539**	**304,132**

Transitions of gain and loss of woodland show that, from 1985 up to 2010 the woodland cover lost most to bareland 261,601 ha, 104,926 to bushland, and 10,348 ha to grassland. However it gained 161,417 ha from the forest land. The overall transition change shows the net loss of woodlands cover was about 127,407 ha between 1985 and 2010.

Transitional Change of bushland

In 1985 bushland cover dominated mostly in the central part and in the Northern parts of Igunga district (53,449 ha). But the trend of change of bushland was generally increasing between 1985 and 1995, and decreased in 2000 only. Then there was an increase between 2005 and 2010. When compared to the trend of change of forest cover and woodlands cover, the trend of change of Bush land was generally an increasing one.

Table 7: Bushland gain and loss (1985-2010)

	Total Loss to (ha)	Total Gain from (ha)
Forest	19,106	49,149
Woodland	67,286	104,926
Grassland	16,929	42,480
Wetland	7,600	8,088
Water	428	1,211
Bareland	211,070	244,333
Total (ha)	**322,419**	**450,187**

The trends of transition of gain and loss for bushland reveals that, between 1985 and 2010 it lost most (211,070 ha) to bareland; and gained 244,333.16 ha also from bareland. The overall transition change shows the gross gain of bushland was 127,768 ha during the period.

Change of grassland

In 1985 grassland dominated the western and the Northern parts of the district. The grasslands areal coverage decreased drastically between 1985 and 1995. It dropped from 93,066 ha to 18,936 ha, most of it lost to bareland, and little gain from forest.

Table 8: Grassland cover gain and loss (1985-2010)

	Total Loss to (ha)	Total Gain from (ha)
Forest	10,236	34,213
Woodland	41,958	10,348
Bushland	42,480	16,929
Wetland	7,236	13,883
Water	4,471	15,566
Bareland	84,535	25,511
Total (ha)	**190,916**	**116,451**

However, from 2000 there were very little changes in grassland vegetation cover. It remained almost unchanged to 2010. The overall transition change shows the net loss of grassland covers was about 74,465(ha) from 1985 to 2010.

Transitional change of wetlands

The wetland covers dominated mostly in the south-western part especially in the Wembele plain, and the areal coverage of 28,147 ha was small compared to areas covered by forest, woodland, bushland and grassland. Findings from this research show that there was an increase in Wetland in 2000 which was due to high rainfall from El Nino, (1,359 mm in 1997, 782mm in 1998, 685mm in 1999 and 735mm in 2000) while the average rainfall in Igunga is 709.333mm. So, in the four consecutive years the amount of rainfall exceeded the average amount.

Table 9: Wetlands cover gain and loss (1985-2010)

	Total Loss to (ha)	Total Gain from (ha)
Forest	32	4,301
Woodland	426	2,378
Bushland	8,088	7,600
Grassland	13,883	7,236
Water	11,544	12,702
Bareland	46,500	63,686
Total (ha)	**80,473**	**97,905**

The trend of gain and loss of wetlands between 1985 and 2010 shows that most of the lost (46,500 ha) was to bareland. But it gained 63,686 ha also from the bareland. There was a net gain of about 17,432 (ha) between 1985 and 2010.

Transitional change of water resources

The main water sources in the study area are the Mwampuli and Bulenya reservoirs. Water sources of Igunga District did not change much. However, the water levels of the reservoirs did depending on the amount of rainfall in each epoch. The large change of water level in 2000 was due to the high amount of rainfall in 1997, 1998, 1999 and 2000.

Looking at the trend of gain and loss of water resources, it is seen that, from 1985 to 2010 the water resources lost 15,566 ha to the grassland; and gained much 11,936 ha from bareland. The overall transition change shows the net loss of

water resources by about 6, 115 ha between 1985 and 2010.

Transitional change of bareland

Between 1985 and 2010, bare land dominated the Northern part the District, and generally, the trend of change is an increasing trend. In 1985 the area of bareland was 220,105 ha, briefly dropped to 153,926 ha in 1990, and in 1995 was 179, 583 ha. But in 2000 the area of bareland increased to 363,634 ha. In 2005 increased to 391,695 ha and in 2010 dropped again to 345,438ha.

Table 10: Bareland gain and loss (1985-2010)

	Total Loss to (ha)	Total Gain from (ha)
Forest	13,332	92,690
Woodland	33,041	261,601
Bushland	244,333	211,070
Grassland	25,511	84,535
Wetland	63,686	46,500
Water	11,936	5,096
Total (ha)	**391,840**	**701,492**

The overall trends of gain and loss of bareland show that between 1985 and 2010 there was a loss of 244,333 ha to bushland; but there was a gain of 261,601 ha from woodland. This resulted in the net gain of about 309,652 ha in the period. This net gain is the indication of increase in human settlement and agricultural activities which clear bushland and woodland leaving behind the land bare

CONCLUSION AND RECOMMDATION

CONCLUSION

This study was undertaken for the purpose of detecting, mapping and analyzing the conversion of land cover from one category into another that has taken place in Igunga district, Tabora Region for a period of 25 years since 1985. To characterize land cover changes for the period Landsat TM and Landsat ETM+ satellite images dated 1985, 1990, 1995, 2000, 2005 and 2010 were used.

The land use classes of particular interest to this study namely bareland (which includes agricultural and human settlement areas), forests, forest, woodland, bushland, grassland and wetlands were adequately compiled from all the data sets.

The results show that a total of 122 258 ha of forests were converted into other land cover types during the period i.e. 1985 – 2010 while total of 137,407 ha of woodland were converted to other land covers in the same period. Bushland gained 127,768 ha from other land covers in the study period, while grassland lost 74,465 ha to other land covers, and wetlands gained 17,432 ha. During the study period bareland gained the most 317,652 ha mostly from woodland and bushland.

RECOMMENDATION

The research findings have revealed that the natural ecosystems provided by land cover are greatly influenced by human socio-economic activities. In order to reverse the situation, interventions must involve issues that control human activities; which are bylaws, policies and regulations, in particular those involved in forestry, wetlands management, and land use planning.

Policy Reform Strategies.

From the findings, wetlands were degraded by overgrazing. Now that there is no National Policy on Wetlands Management, wetlands issues are being addressed through wetlands programmes. As a result, wetlands issues are just discussed in some other national Policies

and Legislations like Land act No. 4 and Village Land Act No 5 (1999), the Environment Policy, (1997) and others. However these Policies and Legislations do not adequately address sustainable management of wetland and therefore, wetlands are not protected from degradation. There is a need of having a wetland policy to specifically protect and address wetlands issues.

Introduction of Alternative Energy Sources

The government should take the responsibility of introducing an affordable energy production technology that can be used by most rural people to replace the extensive use of wood and charcoal as energy sources. These alternative energy sources may include the use of solar energy and biogas.

Introduction of community based forest management practices

Community based forest management practices are already in place in other parts of the country. It is a strategy to achieve sustainable forest management by encouraging the management or co-management of forest and woodland resources by the communities living closest to the resources. Residents of Igunga district to be encouraged to such practices for the purpose of participatory approach towards forestry conservation.

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