THE USE OF SATELLITE IMAGES TO MONITOR THE EFFECT OF SAND DAMS ON STREAM BANK LAND COVER CHANGES IN KITUI DISTRICT

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Abstract

A study was carried out to investigate the effect of sand dam construction on land cover changes along the stream bank during the dry season using satellite images. Two water catchments namely Kiindu and Mbusyani in Kitui district that have similarities in topographical features were chosen for the study. Land cover change detection analysis was done by use of Landsat ETM+ 2001 and Landsat TM 1986 satellite images for Kiindu and Mbusyani catchment for the period 1995- 2001 (after sand dam construction) and 1986 (before sand construction) respectively. Based on the reference data collected from the field two land cover types were of significance importance for the research study i.e. vegetation and bare land.

The classification involved identifying areas of vegetation existence and non-existence during the dry season along the stream banks. Following the classification a change detection analysis was carried out between 2001 and 1986 whose results indicated an increase in vegetation as result of sand dam construction. Kiindu catchment vegetation increased by 52% whilst Mbusyani increased by 43% in 2001 i.e. The relative change in area (ha) from bare land to vegetation was 1356.5 ha and 1218.8 ha compared to vegetation in 1986 which was 229.7 ha and 264.3 ha respectively. The overall accuracies of the classification maps for the two catchments were; Kiindu 90% in 2001 and 87% in 1986 with Kappa Statistics of 0.74 in 2001 and 0.67 in1986. Mbusyani on the other hand had 89% in 2001 and 87% in 1986 with Kappa Statistics of 0.78 in 2001 and 0.66 in 1986. The results from the analysis therefore indicated that sand dam did have a significant influence on land cover changes along stream bank channels during the dry period.

Key words: Sand dam, land cover, remote sensing, GIS, water catchment, landsat ETM+

1.0 Introduction

Over the years the arid and semi-arid areas in Kenya have experienced land degradation largely due to multiplicity of interacting environmental and socio economic factors. The degradation process has been aggravated by deforestation, overgrazing, increased demand for agricultural land with poor agricultural practices, increased evapotranspiration and reduced annual rainfall. It is projected according to studies that annual rainfall is about (450-900) mm on average (FAO, 1987) leading to poor land cover especially in the dry season. The result of this is increased rates of runoff, decreased infiltration rates and increased wind and water erosion.

Land cover along stream channels is a prerequisite to high water infiltration and aquifer recharge in the dry season. It enhances the stream capacity to accumulate and store water underground that is useful to the people and the environment during the dry spell. It averts high levels of sediment accumulation which are as a result of extreme levels of soil erosion during the rain period.

Sand dams are concrete structures, whose location in ephemeral sand-river beds demands detailed surveys, preferably with thorough ground truth (Munyao J.N. *et al.* 2004). The potential of sand dams in an area is a function of the availability of sand on streams, topography that allows construction of weirs, geology to suit storage structures and the presence of a population to make use of the water. (Nissen-Petersen, 1997), Sand dams effectively increase the volume of groundwater available for abstraction as well as prolonging the period in which groundwater is available for abstraction (Nissen-Perterson E**.,** 1982). Sand dam construction is associated with land cover change due to the lateral movement of water as result of aquifer water recharge. The amount of extractable water from a river stretch in between two sand dams is 8372 m^3 per year, (Borst L., De Haas S**,** 2006). Changes in land cover alter both runoff behavior and the balance that exists between evaporation, groundwater recharge and stream discharge in specific areas and in entire watersheds, with considerable consequence for all water users (Sahin, V., and Hall, M. J., 1996), (Defries, R. and Eshleman, K. N., 2004). Sand dams are fully functional within a period of 5-8 years after construction. The research draws inferences through comparing land cover before and after sand dam construction during the dry month.

Remote sensing technology has enhanced land cover assessment through the increased availability and improved quality of multi-spatial and multi-temporal remote sensing data as well as new analytical techniques. (Rogan, J. and Chen. D.M, 2004), Land cover assessment involves change detection which is defined as a process of “identifying differences in the state of an object or phenomenon by observing it at different times” (Rogan, J. and Chen. D.M, 2004). A change-detection technique such as Post-classification comparison method used in this research determines the difference between independently classified images from each of the dates in question (Deer P., 1995). The assessment provides essential requirements for the sustainable management of natural resources, environmental protection and food security.

1.1 Study Area

The study area consists of two catchments, namely Kiindu and Mbusyani in Kitui District as shown in figure 1. The District in the Eastern Province of Kenya is a semi-arid region under agro-ecological zone iv and v situated 150 km East of Nairobi. The total land area is approximately 20,402 km^2 and is characterized by hilly ridges, separated by low lying areas between 600 and 900 meters above sea level, about 1^o 22' south and 38^o1'East. The rainfall amount is (450-900) mm on average. Soils in these areas are sandy, dry and therefore prone to soil erosion by wind and sporadic torrential rains.

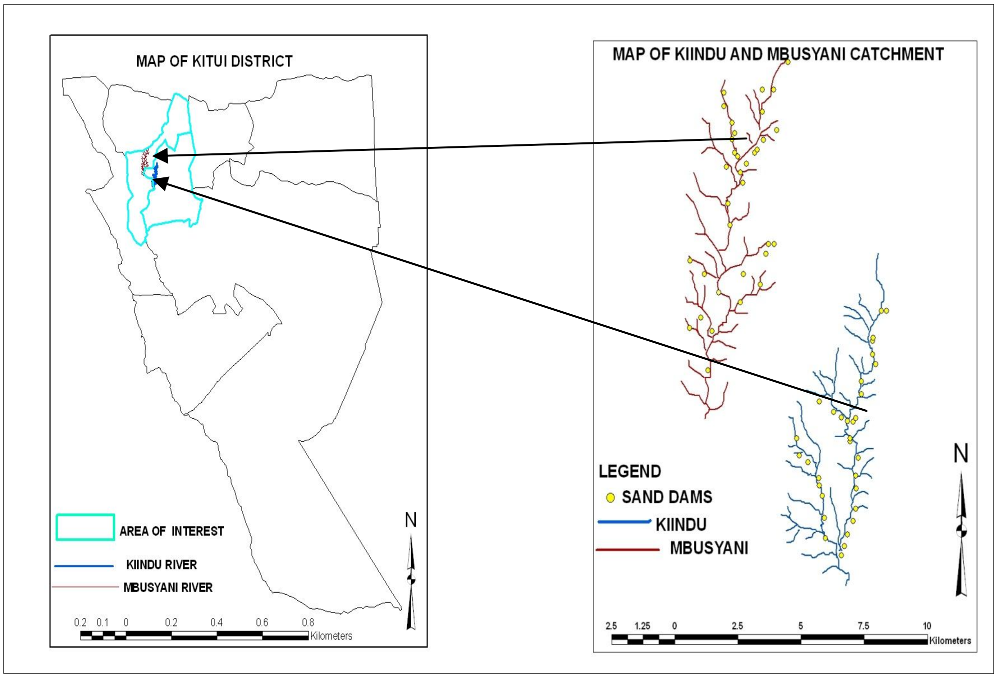

Figure 1: map of study area

Notable vegetation in the area includes deciduous woodlands such as *Acacia tortillis, Hpaenae ventricosa, Salvadora persica, Acacia Nubica* and *Acacia commiphora*. (Gooding J.R, and Northington J.K, 1985). Ephemeral rivers in Kitui District experience high flow in April-May and November-December rains while becoming dry immediately after one month. The water catchments are characterised by metamorphic and igneous basement covered with weathered rocks.

1.2 Rainfall Data

The rainfall data shown in Figure 2 was significant in establishing the rainfall trends and fluctuations between the two periods; before sand dam construction (1986) and after sand dam construction (1995 to 2001). Rainfall has a great influence on the vegetation and similar rainfall trends were significant for the study.

The other importance of rainfall data was to serve as an aid in the selection of the most appropriate month for the research study, a dry month in the year.

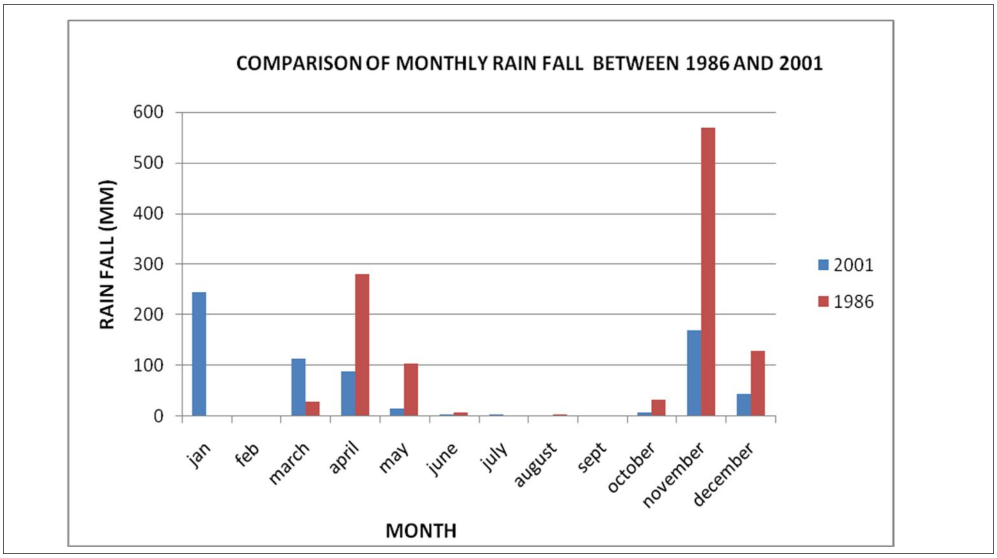

Figure 2: Monthly rainfall data

Vegetation in the semi arid areas is characteristics of tall shrubs and other thorny Bushes, e.g. *Acacia clavigera, Acacia nilotica, Acacia seyal, Terminalia combretum* and *Commiphora* sp. (Katumo V., 2001) succumbs to drought after 3 months dry period. The vegetation sheds off its leaves as drought escaping mechanism and hence would appear as bare land on a satellite image, (Bunn S. E., and Arthington A. H., 2002).

2.0 Methodology

2.1 Data Sources and Specification

There are various data sources used in the research, the GPS location of sand dams and training areas for the vegetation type obtained from the field, digital topographical map at a scale of 1:50,000 for Kitui area from the department of Geomatic Engineering and Geospatial Information Systems of Jomo Kenyatta University of Agriculture and Technology. Finally satellite imageries from the Landsat TM for 26th August 1986 and Landsat ETM+ for 14th October 2001 were acquired from the Regional Centre for Mapping of Resources for Development at Kasarani, Nairobi.

2.2 Tools Used for Data Capture

The reference/ field data was collected from the field through a GPS survey of the water catchment area. The reference data was significant in validating the classification results of the satellite images, with GPS survey used to establish the location of sand dams. During the survey the various land cover types prevalent in the area were identified namely, bare land, grassland, short and tall shrubs, tall trees and irrigated agricultural land. For the purpose of the research study the grassland, short, tall shrubs, tall trees and irrigated land were merged as one land cover type i.e. vegetation. Other tools involved in data capture and its storage and analysis included computer software ArcGIS 9.3 and ERDAS IMAGINE 8.6.

2.3 Data Preparation/Geo-Referencing

Scanned topographical map at a scale of 1:50,000 were georeferenced to Clarke 1880 UTM zone 37 South, and subsequently used for digitizing the catchments used for the study. The satellite images obtained for the study were also georeferenced using ERDAS IMAGINE 8.6 to the same projection system.

2.4 Data Processing

Digitisation of the field data using ArcGIS 9.3 was done in order to enable the classification of the satellite images. Water catchments i.e. Kiindu and Mbusyani were extracted from digitized topographical map of Kitui using ArcGIS 9.3 and a buffer of 400m created. Buffering was for identification of the stream bank area of interest. Overlaying of the water catchments onto the satellite images was done using ERDAS IMAGINE and a subset of the region of interest for the study created. The subset images for Kiindu and Mbusyani catchments were 2631.2ha and 2812 ha respectively. Cloud cover effect in the Landsat ETM+ 2001 image was evident and hence a shape file was created using ArcGIS 9.3 which was used in masking out clouds on the all the images (coinciding areas on all images) using ERDAS IMAGINE.

2.5 Image Classification

A supervised land cover classification was carried out based on the ground truthing data/field data using ERDAS IMAGINE. The classification was performed, using a maximum likelihood classifier. Figure 3 shows, the land cover classifications for the year 1986 and 2001 respectively. The classification of the two Landsat images was geared towards separating two prominent classes with reference to the field data obtained and with relevance to the research study.

2.6 Change Detection Analysis

This encompasses the quantification of temporal phenomena from multi-date imagery that is most commonly acquired by satellite-based multi-spectral sensors (Coppin, P.I *et. al.*, 2004).

The method used in the change detection analysis was post classification that produces spectral classification results from each end of the time interval of interest, followed by a pixel by pixel or segment by segment comparison to detect changes in land cover types (Bunn S. E., and Arthington A. H., 2002). The two land cover maps were compared pixel by pixel with the final results showing both change and no-change information as well as 'from to' land cover change information.

3.0 Results

3.1 Results of Supervised Classification

The objective of the research study was to use satellite image to deduce the significance influence of sand dams on land cover types along stream banks. The study hence narrowed down to two land cover types based on the reference data collected from the field. The two land cover types were vegetation (tall and short shrubs, irrigated agricultural land, grasses and trees) and bare land (roads, dry vegetation and fallow land).The results indicated a visible land cover change between the two periods. Vegetation and bare land did exist in both periods with a difference in the area covered. Concentration of vegetation is evident closer to the stream channel but expand gradually for the period after dam construction. Bare land is sparsely distributed along the stream channel as captured in Figure 3.

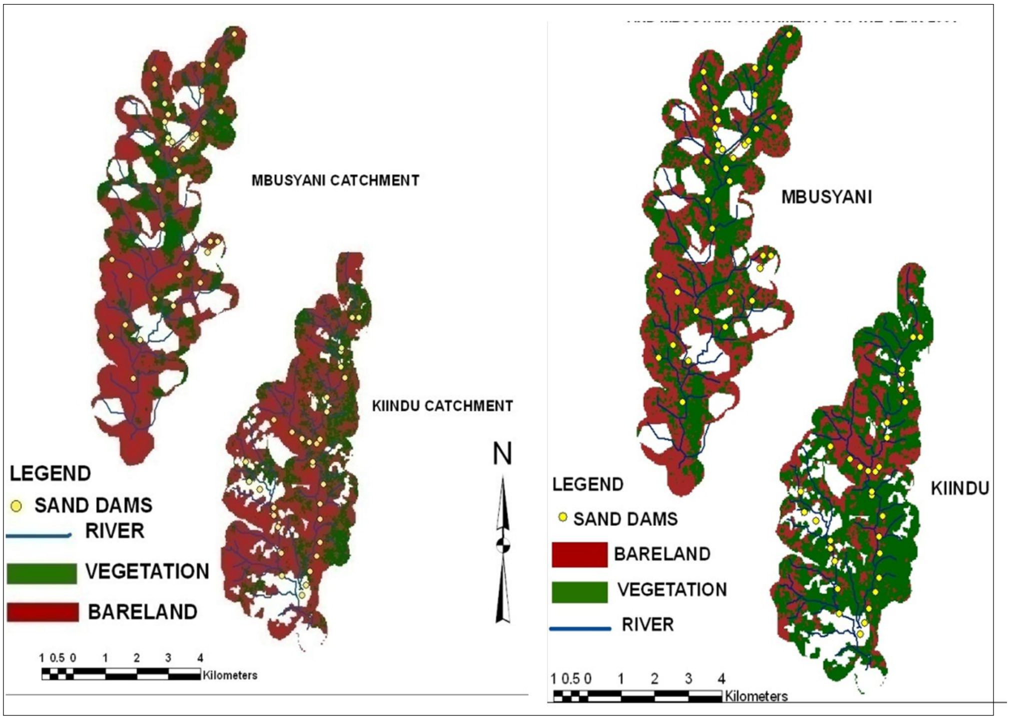

Figure 3: Map of land cover types for Kiindu and Mbusyani catchment for the year 1986 and 2001

Studies carried out by (Vogelmann J.E. *et al*. 2001) have indicated a higher similarity of occurrence in the ability of Landsat TM and Landsat ETM+ to measure land cover changes accurately. An increase in vegetation in the 2001 satellite image can be associated with inter-annual fluctuations in vegetation occurrence as well as vegetation productivity (Wezel, A., and Schlecht, E., 2004). Such fluctuations in vegetation occur with changes in soil moisture. (Rogan, J., *et. al*. 2008) chose a supervised land cover classification method and the resulting classification averaged an overall accuracy assessment of 84% and hence considered an indicative of the potential for Landsat TM data in land cover assessment over a diverse area. Comparing the findings of the above studies to the results of the supervised classification of Landsat images used in this study together with the accuracies therein it is evident that the accuracy results for the classification are comparable and hence reliable. The prior knowledge of the research area and reference data used during the classification enhanced confidence in the accuracy of the classification results.

Supervised classification works best when it involves the identification of relatively few classes, when the training sites can be verified with ground-truthed data, and/or when the user can identify distinct, homogeneous regions that represent each desired class (Lillesand T. M., and Kiefer R. W., 1994). This is the reason for merging various vegetation classes into one class in order to improve on the classification.

3.2 Results of Accuracy Tests for Land Cover Classification for 1986 and 2001

The overall accuracy of the land cover classification in 2001 for Kiindu and Mbusyani catchment was 90% and 89% respectively with kappa statistics being 74% and78% as shown in tables 1 and 3. In the 1986 overall accuracy test were 87% for both catchment and a kappa statistics of 67% and 66% respectively as shown in tables 2 and 4. These slight differences in the accuracy results from the two Landsat sensors (TM and ETM+) while not very significant can be attributed to the differences in the sensor characteristics, especially their radiometric ranges with ETM+ being able to allow finer radiometric resolution in contrast to that by TM.

Table 1: Error matrix accuracy statistics for Landsat ETM+ 2001 for Kiindu catchment

Classified data	**Reference data**				
	Vegetation	Bare land	Total possible	**Producers accuracy %**	**Users accuracy %**
Vegetation	257	12	269	91.79	95.54
Bare land	23	70	93	85.37	75.27
Totals	280	82	362		

overall accuracy %	**90.33**
Kappa Statistics	**0.7366**

Table 2: Error matrix and accuracy statistics for Landsat TM 1986 for Kiindu catchment

Classified data	**Reference data**				
	Vegetation	Bare land	Total possible	**Producers accuracy %**	**Users accuracy %**
Vegetation	38	9	47	71.7	80.85
Bare land	15	136	151	93.79	89.47
Total	53	145	198		
Overall Accuracy	**87.44**				
Kappa Statistics	**0.6699**				

Table 3: Error Matrix and accuracy assessment for Landsat ETM+ 2001 for Mbusyani catchment

Classified data	**Reference data**				
	vegetatio n	Bare land	Total possible	**Producers accuracy %**	**Users accuracy %**
Vegetation	90	13	103	89.11	87.38
Bare land	11	109	120	89.34	90.83
Total	101	122	223		
Overall Accuracy %	**89.24**				
Kappa Statistics	**0.7832**				

Table 4: Error Matrix and accuracy statistics for Landsat TM 1986 for Mbusyani catchment

Classified data	**Reference data**				
	vegeta tion	Bare land	Total possible	**Producers accuracy %**	**Users accuracy %**
Vegetation	51	10	61	94.65	87.62
Bare land	25	177	202	68.92	83.61
Total	76	187	263		
Overall Accuracy	**86.69**				

%	
Kappa Statistics	**0.6576**

A standard overall accuracy for land-cover mapping studies has been set between 85 percent (Anderson, J.R., 1976) and 90 percent (Lins, K. S.,1996) The accuracy results therefore fall within the acceptable ranges that define quality in classification.

3.3 Results of Change Detection Accuracy Assessment for Kiindu and Mbusyani Catchment Respectively

The accuracies of the change detection were computed based on visual interpretation of the image data. The reference visual random points were generated using ERDAS IMAGINE and used for the accuracy assessment.

Table 5: Change detection accuracy assessment for Kiindu catchment

Classified data	**Reference data**				
	To bare land	To vegetation	Total possible	**Producers accuracy %**	**Users accuracy %**
To bare land	7	2	**9**	**77.78**	**70**
To vegetation	3	115	**118**	**97.46**	**98.29**
Classified Totals	**10**	**117**	**261**		
Overall accuracy %	**96.06**				
Kappa statistics %	**71.56**				

Table 6: Change detection accuracy assessment for Mbusyani catchment

Classified data	**Reference data**				
	vegetation	Bare land	Total possible	**Producers accuracy %**	**Users accuracy %**
Vegetation	90	13	103	89.11	87.38
Bare land	11	109	120	89.34	90.83
Total	101	122	223		
Overall Accuracy %	**89.24**				
Kappa Statistics	**0.7832**				

The classification had only two land cover types therefore the visual analysis was not as intensive hence an appropriate tool for the interpretation as shown in tables 5 and 6. [11] Examined the use of different accuracy indices, including overall, average and combined accuracies and the Kappa coefficient of agreement to determine an optimal threshold level for change detection images. They recommended the Kappa coefficient because it considers all elements of the confusion matrix. The accuracy of a post classification method depends on the accuracy of the independent satellite images (9).

3.4 Results of Change Detection Analysis

Changes in land cover were established through the changes in pixel counts in both 1986 and 2001 respectively and computed into percentage and total area in ha as shown in table 7. A relative change of 60% and 57% for Kiindu and Mbusyani respectively was evident. This covered an area of 1581ha and 1622ha for the two catchments respectively. Therefore a significant land cover change between vegetation and bare land occurred for the period (before) and (after) sand dam construction. To further deduce this, a change detection analysis was carried out.

Table 7: Showing change in land cover classes from 1986 to 2001

Land cover types	**Kiindu catchment land cover change**						**Mbusyani catchment land cover change**					
	1986		**2001**		**Relative change**		**1986**		**2001**		**Relative change**	
	Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)	**Area (Ha)**	**Proportion (%)**	Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)
Vegetation	229.7	9	1810.5	69	**1580.8**	**60**	264.3	26	1357.7	48	**1622**	**57**
Bare land	2401.5	91	820.4	31	**-1581.1**	**-60**	2549.7	74	1456.3	52	**-1622**	**-57**

A change detection analysis for all land cover types was computed using ERDAS IMAGINE as shown in table 8 and figure 4 on change detection analysis. The results obtained were compared to percentage pixel counts and area (ha) for each land cover type. The percentage change for each land cover type i.e. increases; decreases and area that remained unchanged were deduced. The focus for the research study was on the increases and decreases on the land cover types. The land cover changes were compared to the presence of the sand dams along the catchment.

Table 8 shows that bare land decreased by 52 %(1357ha) and 43 %(1219ha) to vegetation for Kiindu and Mbusyani respectively. The vegetation decreased by 8 %(224ha) and 14 %(403ha) for Kindu and Mbusyani catchment to bare land. This can be associated with area of land cleared for cultivation (fallow land). About 40% and 43% of the area for Kiindu and Mbusyani remained unchanged respectively.

Figure 4 shows the increase in vegetation associated with the decrease in bare land, (see the decrease in green color). There is also a decrease in vegetation which leads to an increase in bare land, (see the red color). The areas in white are those where there was no significant change.

In north China, (Xiao, J., *et. al*, 2006) evaluated urban expansion and land use change with 1987 Landsat TM and 2001 Landsat ETM+ data. Successful land use and land cover classification allowed (Xiao, J., *et. al*, 2006) to identify a relationship between land use and land cover change and urban expansion using post classification change detection technique.

The accuracy test in the research are indicative of accurate results obtained from the change detection analysis i.e. Overall accuracy of 96.06% and Kappa Statistic of 71.56% for Kiindu catchment and overall accuracy of 94.44% and kappa statistics of 85.78% for Mbusyani catchment. It is evident that there is a positive change in vegetation for the two catchments.

Table 9: change detection analysis between 1986 and 2001 for Kiindu and Mbusyani Catchment

	Kiindu catchment change analysis						**Mbusyani catchment change analysis**					
land cover type	**bare land**		**Vegetation**		**Relative change**		**bare land**		**Vegetation**		**Relative change**	
	Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)	**Area (Ha)**	**Proportion (%)**	Area (Ha)	Proportion (%)	Area (Ha)	Proportion (%)	**Area (Ha)**	**Proportion (%)**
Bare land			1356.5	52	**1356.5**	**52**			**1218.8**	**43**	**1218.8**	**43**
Vegetation	224.3	8			**224.3**	**8**	**403.2**	**14**			**403.2**	**14**
Total	**224.3**	**8**	**1356.5**	**52**	**1580.8**	**60**	**403.2**	**14**	**1218.8**	**43**	**1622**	**57**

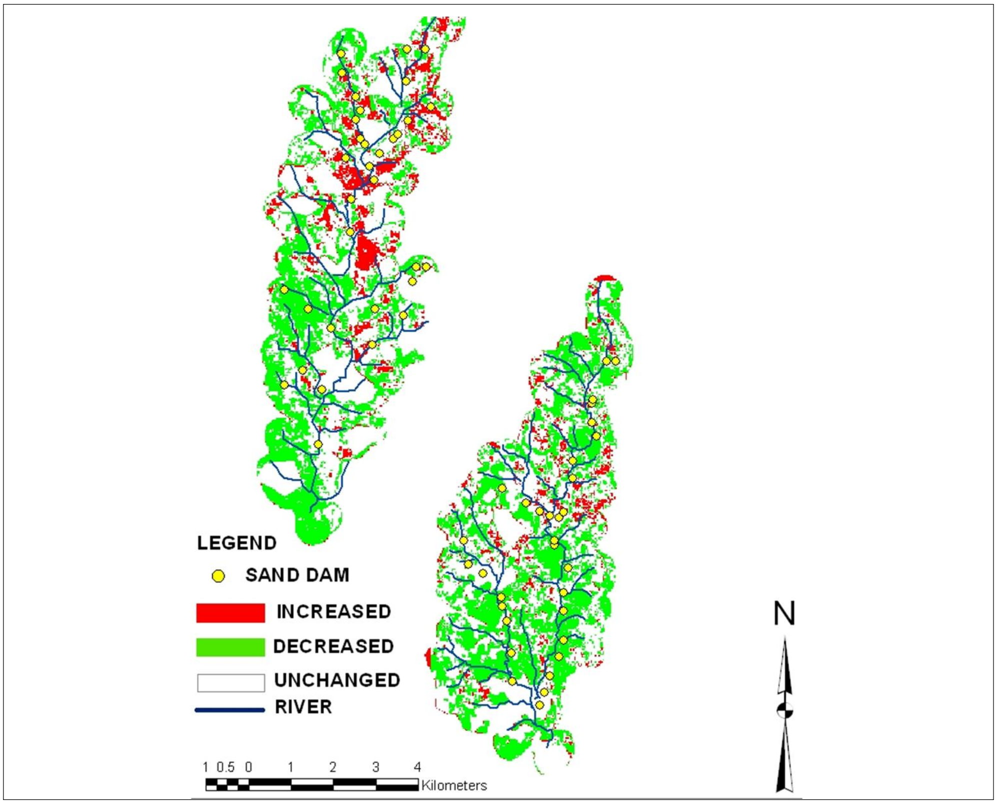

Figure 4.0: Change detection analysis for Kiindu and Mbusyani

4.0 Discussion

The change is evident in 28 out of the 32 sand dams on Kiindu catchment. 4 sand dam did not show any change in land cover type. This could be associated with the lateral abstraction of water due to rocks on the banks of the river. In Mbusyani catchment 34 sand dams were featured in the research study and 2 out of these did not show any change in land cover type whilst 4 were affected by clouds since these areas were masked out. In total 28 sand dams showed a significant change in land cover.

The research was conducted during the dry period in the month of August and October respectively when the relative vegetation present is very low in the semi-arid areas. The increase in vegetation in the dry period with respect to the presence of sand dams in the two water catchment is explained by (Borst L., De Haas S**,** 2006) through a hydrological study that quantified the ability of a sand dam to increase underground water recharge.

This can be interpreted as the reason for the vegetation to remain green through the dry period and also the upsurge of vegetation that normally would be non-existence during the same period e.g. short shrubs such as lantana camara and grassland characteristic of couch grass. (Jacobson, P. J., *et al.* 1995) describes sand

dams as being able to create artificial aquifers which are responsible for vegetation change along river banks. Looking at (3) summary of dam's ecological impacts, he mentions the modification of river systems through a change in existing species and the manner in which they may occur. Alterations in soil moisture regimes which under natural factors would be due to rainfall (3) usually cause plants to respond in terms of germination, growth, and reproduction. Similarly then according to this study sand dams cause a shift in soil moisture regimes(increases) and therefore would sustain vegetation during the dry period in the catchments where they have been constructed.
(Bunn S. E., and Arthington A. H., 2002) The green vegetation response to change in soil moisture may not have been primary in this study but include such response as;

(i) Increase in green vegetation matter (leaves).
(ii) New species of vegetation that do not occur during dry period up surging.
(iii) Increase in extent of vegetation i.e. area covered.

The unique response of the vegetation towards change in soil moisture regimes can be established through NDVI and soil moisture studies for these catchments where sand dams have been constructed.

The use of remote sensing satellite imagery of medium resolution plays a significant role in trend analysis of land cover change. The period before sand dam construction 1986 and after sand dam construction 2001 has been significantly compared using the Landsat ETM+ and Landsat TM. 1986. Studies by (Vogelmann J.E., et al., 2001) as discussed earlier have shown similarity in the measurements of land cover changes by use of Landsat TM and Landsat ETM+ without any major effects.

A shorter period for comparison i.e. before and after sand dam construction would have been preferred for the study but the use of satellite imagery for 1995 was not possible due to cloud cover effect of above 50% for the specific dry months in the area of interest. A series of epochs before and after sand dams could also have been preferred but the cloud cover effect of above 50% in the area of interest for most of the years before and after sand dam construction made it difficult. These epochs would have been able to establish the land cover change trend with the maturity of a sand dam since as earlier indicated a sand dam becomes fully functional after 5-8 years of construction.

Other years namely (1994 to 1987) were also affected by cloud cover effect of above 50%. Evidently research study was still able to show that a significant relationship did in fact exist between sand dam construction and land cover change along the stream channels.

5.0 Conclusion

Accurate land cover assessment and monitoring of its dynamics is possible using remote sensing medium resolution satellite imagery. Land cover alters evaporation, ground water recharge and stream discharge and therefore prerequisite for sustainable management of natural resources, environmental protection and food security. The effect of sand dam on land cover along stream banks shows the significance of spatial scale data in the development of regional estimates of land cover changes and hence improving the ability to estimate land use and ecosystem interactions with global climate change. The resulting spatial data yielded from these study shows, a significant presence of vegetation during the dry period due to sand dam construction.

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