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Land Use–Land Cover Change and Implication to Biodiversity in Kihansi Catchment

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Abstract

Land cover-land use (LC-LU) change has significant impact on wetland ecosystem. This study examined the impacts of LC-LU change on spray wetland ecology at Kihansi Gorge and implications to conservation of fragile biodiversity. Remote sensing methods were used to asses land cover changes from 1990 to 2015 and to forecast change in 2035. It was revealed that forests decreased from 28,454 to 10,897 ha and woodland from 26,903 to 19,914 ha. In 1990, woody cover dominated with a total cover of 38% of the entire catchment. The cropland that included grassland and bushland with scattered crops has been on the increase and it expanded to 51% of the total catchment area by 2015. The expansion of crop land and bushland are expected to continue increasing at the expense of other land cover types. It has been forecasted that by 2035 the grassland and natural woody cover will be occupied by seasonal mono-crops. Currently, exotic plantations are replacing natural vegetation cover and this has negative impacts on catchment biodiversity and riverine species. Alteration of terrestrial vegetation cover results into changes in river flow regimes, that impact species that depend on specific water flow characteristics. Land use practices introduce sediments, fertilizers, manure and pesticides in rivers that impair water quality and this is detrimental to aquatic biodiversity. The most important species significantly impacted by the LU-LC change in the Kihansi catchment is the extinct of Kihansi Spray Toad (KST).

Keywords: Kihansi, land cover change, biodiversity, prediction, remote sensing

Introduction

Kihansi Catchment is located in the Udzungwa mountains in the southern part of Tanzania. It is part of the Eastern Arc Mountains (EAM) ecosystem and a site of global significance for biodiversity conservation (Burgess et al. 2004). Kihansi ecosystem harbours the International Union for Conservation of Nature (IUCN) threatened and endemic flora and fauna species, including the Kihansi Spray Toads (KST). This area has been regarded as biodiversity hotspot due to extraordinary high level of endemism and extremely high degree of threat. At the same time, Kihansi Catchment is critical source of water for hydropower development, maintenance of peoples' livelihood and the protection of biodiversity. Kihansi River is a major source of national hydropower supply contributing 35% of the total hydropower generated national wide and about 15% of the total electricity generated from all sources (Makongoro et al. 2013). The upper catchment of River Kihansi supports about 14 villages with a total population of 35,177 (NBS 2002) of which their main livelihood activities are crop farming and a few animal keeping. While in the lower catchment particularly the natural forest contains high plant biodiversity (majority are endemic), fresh-water biodiversity, mammals and birds.

Biodiversity in the catchment is threatened by various human activities that impacts their natural habitat Threat includes the establishment of Lower Kihansi Hydo-Power project (LKHP) that altered approximately 95% of the habitat of KST. Since the commencement of the LKHP, river flow over the Kihansi fall was significantly reduced by over 91%. Before the LKHP an average flow regime was 16 m^3/s and was reduced to about 1.5 m^3/s at a flow of bypass (Makongoro et al. 2013). Reduced flow shrunk water spray area on Kihansi fall rocky face and led to drying of vegetation, which is the habitat of KST.

The major study objective was to assess the consequences of land use change on conservation of the Kihansi spray toad (KST) and maintenance of the local communities' livelihood. The trends of land cover and land use (LC-LU) need to be examined to uncover their impacts on the catchment biodiversity. LC-LU changes have significant impacts on river flow that in turn influence the river ecological habitat. Of the specific interest in this study is a spray wetland and vegetation of Kihansi Gorge. Land covers in the catchment were monitored for the past 25 years in order to identify changes that may impact river and terrestrial ecology within the catchment. This study covers entire Kihansi Catchment, which comprises the Lower Kihansi, a critical habitat and biodiversity hotspot zone, and the Upper Kihansi which is a peoples' livelihood support zone.

Characteristics of the study area

Kihansi Catchment covers the Udzungwa Mountains, south of the EAMs and partly the Kilombero River valley. The upper part of the catchment is in the eastern side of the Udzungwa Mountain–the block mountain separating Ruvu and Rufiji River Basins. The Upper Kihansi Catchment refers the area covered by Kihansi tributaries above the Kihansi Hydropower (KHP) dam. The Lower Kihansi Catchment often refers the areas drained by Kihansi River tributaries below the KHP dam; often excluding the Kilombero Valley zone (See Birhanu 2009, Mkongoro et al 2013). Since Kihansi is a tributary of Kilombero, the Kihansi catchment in this study includes the flood plain of Kilombero, up to the location where water from Kihansi Rivers enters Kilombero River.

The total area of the catchment studied is about 1,197 km^2 which includes about 355 km^2 in the flood plain of which the Kihansi River runs for about 37 km before joining the Kilombero River. The Kihansi catchment that has an influence on the gorge is about 650 km^2 only. The topography in the catchment is highly rugged and incised with narrow valleys. Slopes on the faces of valleys are steep, up to 74°. Such slopes are prone to landslides when disturbed and easy sediment delivery to the river channel. The catchment falls from 2,200 m on the north western side of the catchment to 100 m above sea level where Kihansi enters Kilombero River. The uplifted parts of the catchment rise from about 600 m to the 2,200 a.s.l. on the apex of the catchment. The upper catchment is North-South oriented and falling to 1,200 m at the KHP dam. The lower catchment contains the uplifted part and the graben (down warped block of the Eastern Africa Rift System - EARS) that form the Kilombero flood plain. The graben is SW-NE oriented.

The natural land covers in the Kihansi Catchment is influenced by altitude. The lowland in the flood plains is dominantly covered by seasonally inundated grass. In few places, this grassland contains scattered wood and often interrupted by swamps (the permanently inundated wetlands). The elevated zones in the flood plain are covered by open woodland. The flood plain is usually hot and dominated by elephant grasses. The plain and the upland are demarcated by escapement that runs from NE to SW, diagonal to the catchment. Natural cover on the escapement is the closed forest, particularly in the eastern border of the catchment. This forest is a forest reserve. It contains tall trees and undergrowth forming impassable vegetation. The zone, outside the forest reserve, in the south-west of the catchment, is characterized by an open forest, which contains tall trees and the undergrowth is dominantly tall grasses. The land that spread north-west from the closed forest with elevation above 1,700 m a.s.l. is largely bushland, mostly containing short trees. The northern part of the bushland is interrupted by cultivation and the southern part is uncultivated. Where the bushland have been cultivated the landscape exists as a mosaic of bushland and ferns as the second growth. Wood growth in this zone appears stunted. Further up in the catchment, above the 1,900 m a.s.l. the dominant natural vegetation is open grass. This grassland is intensively cultivated, and is interrupted with, pine forests and seasonal crops.

Land use in the Kihansi catchment is mainly cultivation and animal keeping. In the lowland the seasonally inundated grassland and wetland are converted to paddy farms throughout the floodplain. Production of rice in the lowland is a main activity. Addition crops grown in the low land are both perennial and annual crops. None inundated land are grown maize, sorghum, sesame and herbaceous crop such as cassava, sweet potatoes, pumpkins, pigeon-peas, groundnuts. Vegetables such as beans, cabbages, onions, okra and tomatoes are also growing in this area. These crops are not produced in large scale compared to rice, the staple food in the area. Perennial crops in the area include coconuts, cocoa, palm-oil, sugar cane, bananas, oranges, mangoes, pawpaws, sweet melons, lime fruits and guavas. The crop vegetation occurs in small patches of farms, and often mixed cropped and the vegetation exists as a mixture of grassland, cropland and trees, natural and planted. Cattle are grazed in expansive grasses existing in the lowland.

In the upland the main land use are cultivation, animal keeping and logging. Logging was mainly on pine plantations grown in the upland. Cultivation in the upland mainly involves maize, wheat, finger millet, round potatoes, sweet potatoes and pyrethrum. Tree crops including bananas, pears, peaches, avocado, oranges and guavas exist in cool upland environment and are grown for fruits. Pines are grown in the upland for timber, and small animals which occur in the upland are either zero grazed or tethered on farm fallows with grass and herbaceous vegetation.

Materials and Methods

The methods used in this study were largely remote sensing techniques coupled with field observations of existing land covers. Past remotely sensed digital images were processed and analyzed using Geographical Information Systems (GIS).

Aster Digital Elevation Model (DEM) with 30 m spatial resolution was downloaded from Aster-DEM website for Kihansi Catchment. The DEM was used to produce slopes and 3-D maps which were employed to identify the ecological sensitivity over areas of various land cover. The DEM was used also to identify zonation of vegetation and to delimit the Kihansi catchment. Landsat image with a resolution of 30 m, at interval of 5 years were used to detect land cover changes. The TM and ETM+ Landsat images from NASA Program (2003), for the years 1990, 1995, 2000, 2005, 2010, and 2015 were downloaded and used to determine the land cover for the respective years and land cover change detected by taking land cover coverage difference between respective years.

The fieldworks involved tracking points on the ground using Garmin 60 Hand held Global Position System (GPS) Receiver. Location of the sample points were used to verify land cover classes delimited from the current satellite images. The coordinates in the major land cover classes were picked on the classified recent land cover map, loaded in the GPS, and these points tracked in the field using GPS navigation tools. The easily accessible land cover classes, particularly along the roads and paths were used. The accessibility was determined from the high resolution satellite images from Google Earth and a topographic map.

Data analysis

The initial data processing involved extracting useful information from topographic maps. Hard copy topo-sheets were scanned, imported into GIS software, georeferenced and digitizing Kihansi river system to extract digital shape file of Kihansi River. Extraction of a drainage system was followed by analyzing the DEM to create the topography of the Kihansi catchment using the hill shades and orthographic display using IDRISI 17.0-The Selva Edition (GIS-Software). The Kihansi draining system and topography map were used to delineate the boundary of the catchment. Within the catchment boundary the land covers for years from 1990 to 2015 were produced from Landsat images.

Landsat images were classified for those years of interest to create land cover maps. The pixel based remote sensing classification method, particularly; cluster analysis technique was employed (Ball and Hall 1965). This technique groups pixels of the remote sensed images in classes using statistical algorithms. Each class represents reflectance characteristics of a specific land cover category. The theory behind this method is provided by Lillesand et al. (2015). Broad classification was performed and the maximum number of classes required was obtained from the high-resolution Google-Map. In a high resolution image, various land cover categories are discernible. The class produced by the analysis was verified based on field observations.

The changes were computed by calculating size differences of each land cover and/or percentage of size change. The area changes of land covers at an interval of 5 years were compared to examine the coverage changes. Moreover, cross-classification was performed to compare land transformation (change of land category at a given location) at 5 year interval. The cross-tabulation analysis for the pair wise intervals was created to examine proportions of change for each pair. Significance of change for each category and overall change was also evaluated.

Results

Land cover change in Kihansi catchment

It was observed that, the land cover in Kihansi catchment had been altered before the year 1990, the benchmark year of this study. The current natural land covers are remnants of natural vegetation still existing in the area. Except in the forest reserve, the rest of vegetation in the catchment is a secondary growth, since the natural vegetation has been cleared as the result of cultivation.

The major categories of land covers observed in Kihansi catchment since 1990 are forest, woodland, bushland, cultivated land, open grassland, seasonally inundated grassland, grassland with scattered crop, and bushland with scattered crops (Figure 1). The land cover categories in hectares for the years 1990, 1995, 2000, 2005, 2010 and 2015 are shown in Table 1. The bushland with scattered crops is the mixture of bushes and bushy crops. This cover contains crops and bushes that cannot be distinguished on satellite images with the medium spatial resolutions. The bushland with scattered crops also represents areas with mixed cropping. The open grassland mostly occurs on upland in the catchment. Some grassland areas are mixed with crops that cannot be distinguished from grasses based on classification method employed.

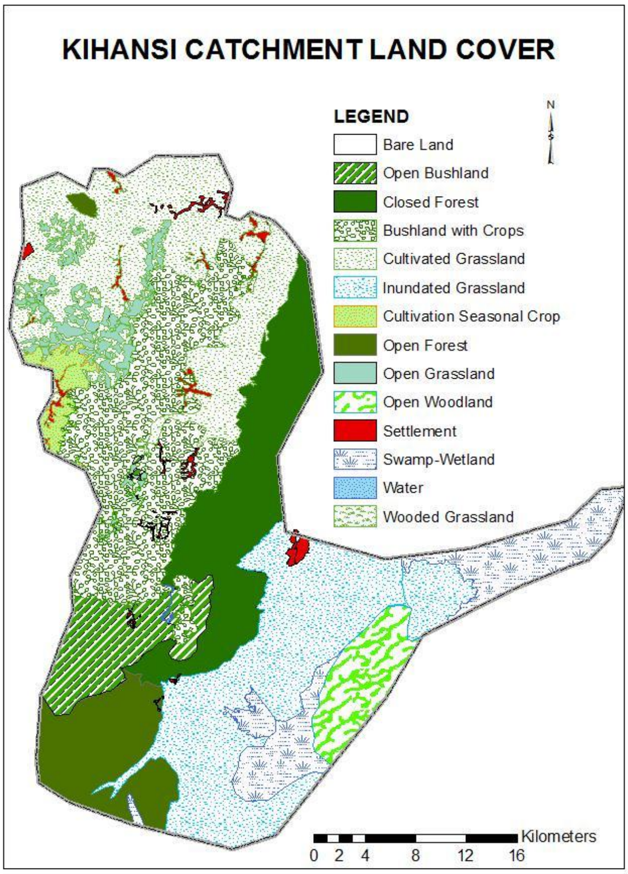

Figure 1: Kihansi catchment land covers.

Table 1: Land cover classes detected in Kihansi catchment from 1990 to 2015

Year	1990	1995	2000	2005	2010	2015
Land cover types	**Area (Hactres)**					
Forest	28,454	20,456	19,318	18,583	12,057	10,897
Bushland	17,246	19,107	22,528	10,768	6,530	20,655
Woodland	26,903	25,443	23,876	23,925	20,129	19,914
Open Grassland	13,012	9,833	4,206	3,871	2,446	5,894
Cultivated Land	6,308	5,954	16,118	16,715	28,083	32,487
Bushland with Scattered Crops	11,042	18,946	11,247	15,543	16,191	14,767
Grassland with Scattered Crops	9,286	12,926	13,001	19,213	29,316	11,882
Seasonally inundated Grassland	7,328	7,118	9,497	11,33	5,025	3,277
Water	232	28	20	60	34	38
Total	**119,811**	**119,811**	**119,811**	**119,811**	**119,811**	**119,811**

The general trend of land covers in Kihansi Catchment is that forest, woodland and open grassland are decreasing, while cultivated land, grassland with scattered crops and bushland with scattered crops are increasing. The forest decreased from 28,454 to 10,897 ha and woodland from 26,903 to 19,914 ha in 25 years. The forest was wider and thicker in the 1990s, extending further south-west and scattered in the north-west of the current forest reserve.

The forest was decreasing at the fastest rate, more than half of forest existed in 1990 had been depleted in 25 years. The mixed cropping was largely practiced in the catchment, often mixed with grassland and bushland. This type of cultivation was dominant in the upland and accounted for 17.6% of the catchment. The cultivated land, on which the seasonal crops are grown, was restricted on the smallest areas on the tip of the catchment and on lowlands in 1990. By the year 2015 the entire area of the catchment was cultivated. In the upland cultivation was absent only in the forest reserve and on the lowland permanently inundated wetlands and woodlands were spared (Figure 2)

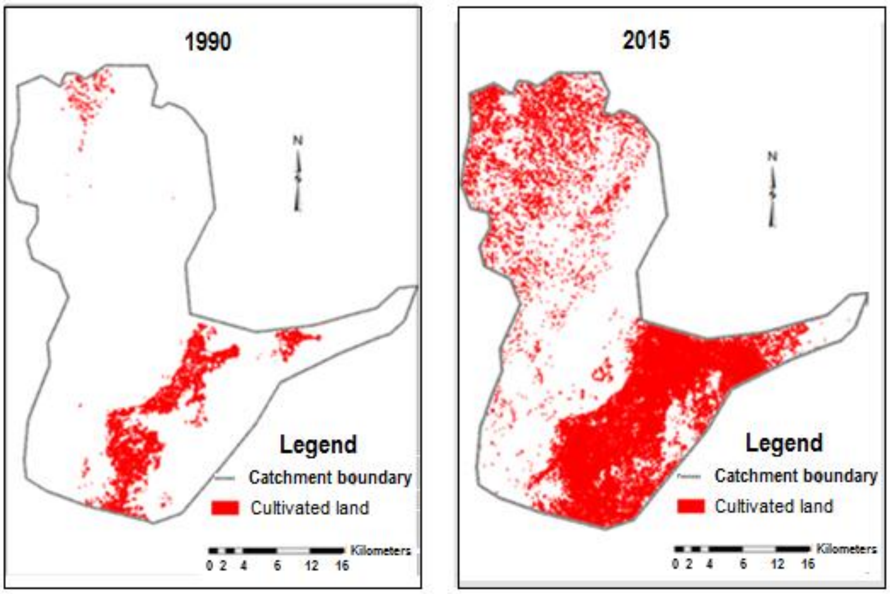

Figure 2: Cultivated land for the year 1990 and 2015.

In the year 1990 the largest vegetation cover was wooded cover, that is, forest and woodland (Figure 3). Both accounted for about 46.2% of the entire catchment. By 2015 the dominant land cover was the cultivated and crop land that claimed about 48.9% of the total catchment area. The forest was reduced to 9.1% of the entire catchment from 23.7% that existed in 1990. Bushland has increased slightly. However, the bushland trend had been fluctuating between increase and decrease at short intervals. This variation indicates the occurrence of secondary growth that existed as fallows. Fallows existed between successive cultivations, when the farms were put to rest. Open grassland had been shrinking on the expense of cropland. It was reduced from 10.9% to 4.7% of the entire catchment. Seasonally inundated grassland is regulated by the occurrences of flood events of the Kilombero River flood plain. Seasonally inundated grassland trend also shows short cycle fluctuations that are related to cycles of large flow events of the Kilombero River.

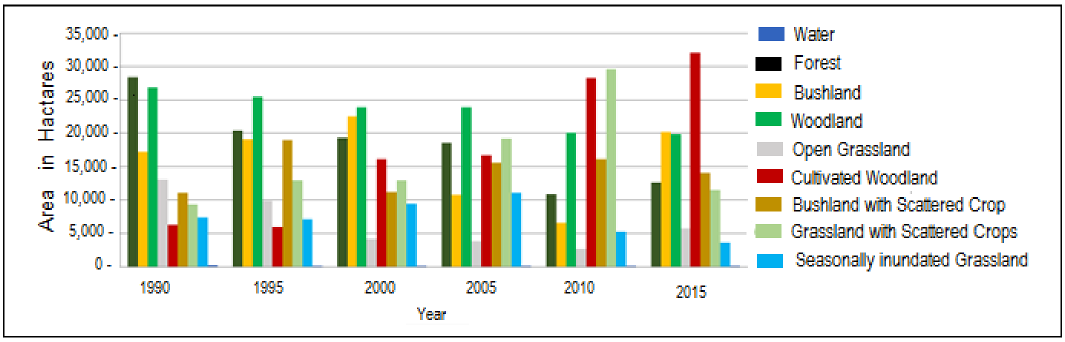

Figure 3: Land covers variation in Kihansi Catchment for the period 1990 to 2015.

Land cover transformation in Kihansi Catchment

Cross tabulation analysis shows that about 5.7% of the forest was converted into open woodland, 3.8% into bushland and 0.5% into bushland with scattered crops in 10 years from 1990 to 2000 (Table 2).

Table 2: Proportion of land cover type converted into another type for the period between the year 1990 to 2000

Year	**2000**											
	Land Cover Type		**Bo**	**BSc**	**Cm**	**Fn**	**Go**	**Gos**	**GSc**	**Wo**	**IW**	**Total (%)**
	Name	Code	**Proportional cover (%)**									
1990	**Open bushland**	Bo	5.7	3.9	0.5	0.5	0.9	0.1	1.1	1.8	0.0	**14.4**
	Bushland with scattered crop	BSc	1.6	1.6	1.5	0.2	1.1	0.9	1.5	0.7	0.0	**9.2**
	Cultivated land	Cm	0.3	0.0	3.5	0.0	0.0	1.0	0.3	0.1	0.0	**5.3**
	Natural Forest	Fn	3.8	0.5	0.4	13.0	0.0	0.0	0.3	5.7	0.0	**23.7**
	Open grassland	Go	0.6	0.2	1.6	0.0	0.3	1.7	1.4	0.5	0.0	**6.5**
	Seasonally inundated grassland	Gos	0.1	0.0	2.5	0.0	0.0	2.8	0.6	0.0	0.0	**6.1**
	Grassland with scattered crops	GSc	0.6	0.5	2.1	0.1	0.5	0.8	2.9	0.3	0.0	**7.7**
	Wooded grassland	Gw	1.0	1.1	0.1	0.1	0.3	0.0	1.4	0.3	0.0	**4.3**
	Open woodland	Wo	5.1	1.5	1.2	2.0	0.4	0.4	1.3	10.5	0.0	**22.5**
	Inland water	IW	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	**0.2**
Total (%)			**18.8**	**9.4**	**13.4**	**16.1**	**3.5**	**7.9**	**10.9**	**19.9**	**0.0**	**100.0**

Key: *Bo - Open bush land; BSc - Bush land with scattered crop; Cm - Cultivated land; Fn-Natural Forest; Go - Open grassland; Gos - Seasonally inundated grassland; GSc - Grassland with scattered crops; Gw - Wooded grassland; Wo - Open woodland; IW- Inland water.*

In 2010, after 20 years the forest had been reduced from 16.1%, which had remained in 2000, to 9.1% (Table 3). Cultivated land increased from 13.4 to 23.7%. Cultivation expanded and replaced 4.1% of grassland, 0.5% of the bushland, 0.7% of the woodland. The new land opened up for cultivation from the year 2000 to 2010 was 15.6%. The woodland also decreased slightly from 19% to 16% on the expense of the bushland (3.2%) on which new farms were opened. Changes occurred differently in upland and plains. Cultivation replaced 4.3% of the seasonally inundated grassland in the plain; in the upland it replaced 3.1% of the bushland and 2.4% of the woodland. Not much cultivation occurred on the open woodland because these areas are depleted of nutrients and not suitable for crop production. Once forest transforms to woodland (the sparsely populated trees) in the tropics, nutrients are fast leached because of the rapid oxidation and precipitation. Litter is not fast replenished under woodland to replace the lost nutrients due to fewer leaves on woodland canopy and shallower roots for nutrients syphoning compared to the closed forest bigger trees.

Table 3: Proportional of land cover type converted into another type for the period between the years 2000 to 2010

Year	**2010**											
	Land cover type		**Bo**	**BSc**	**Cm**	**Fn**	**Go**	**Gos**	**GSc**	**Wo**	**IW**	**Total (%)**
	Name	**Code**	**Proportional Cover (%)**									
	Open bushlaland	**Bo**	2.7	3.7	3.1	0.4	0.3	0.0	5.4	3.2	0.0	**18.8**
	Bushland with scattered crop	**BSc**	0.7	2.6	1.4	0.1	0.0	0.0	4.1	0.4	0.0	**9.4**
	Cultivated land	**Cm**	0.2	0.3	8.1	0.0	0.9	1.3	1.9	0.7	0.0	**13.4**
	Natural Forest	**Fn**	0.6	1.5	0.4	7.7	0.0	0.0	3.4	2.4	0.0	**16.1**
2000	**Open grassland**	**Go**	0.1	0.9	0.7	0.0	0.0	0.0	1.6	0.1	0.0	**3.5**
	Seasonally inundated grassland	**Gos**	0.0	0.0	4.3	0.0	0.5	2.5	0.3	0.3	0.0	**7.9**
	Grassland with scattered crops	**GSc**	0.2	2.5	3.2	0.1	0.2	0.5	3.6	0.5	0.0	**10.9**
	Open woodland	**Wo**	0.9	1.9	2.4	0.7	0.3	0.0	4.3	9.4	0.0	**19.9**
	Inland water	**IW**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Total (%)			**5.5**	**13.5**	**23.7**	**9.1**	**2.2**	**4.4**	**24.7**	**16.8**	**0.0**	**100.0**

Key: *Bo - Open bush land; BSc - Bush land with scattered crop; Cm - Cultivated land; Fn Natural Forest; Go - Open grassland; Gos -Seasonally inundated grassland; GSc - Grassland with scattered crops; Gw - Wooded grassland; Wo - Open woodland; IW- Inland water.*

The bushland with scattered crop and grassland with scattered crop continued to increase by replacing the bushland and open grassland, respectively. Grassland with scattered crop had increased from 10.9 to 24.7% in 10 year from 2000 to 2010, but much of increase occurred in the plain. While the bushland with scattered crop increased from 9.4 to 13.5% and largest increase occurred in the upland.

Raking the land cover based on the acreage transformation, conversion of forest to woodland ranked high in the first 10 years where 6,864 ha of forest were converted to woodland, followed by 6,125 ha of woodland which was converted to bushland and 4,621 ha of bushland were converted to bushland with scattered crops. In the second turn of the second decade 2000 to 2010, transformation of the forest had been complete. The land cover that was highly transformed was the bushland. About of 6,417 ha of bushland were converted to grassland with scattered crops, 5,209 ha of woodland were converted to grassland with scattered crops and 5,117 ha of open grassland were converted to cultivated land. With these changes, the trajectory of land cover changes in the Kihansi catchment were from forest to woodland to bushland to bushland with scattered crops to grassland with scattered crop and finally to annual crop cultivation.

The Kappa Index of Agreement (KIA) indicates that land cover changes for the period of 2000 to 2010 were slightly higher compared to the 1990 to 2000 period. The land covers that showed significant changes were the seasonally inundated grassland, bushland with scattered crop and the open bushland for both periods. Changes were less significant for the two periods for the bushland with scattered crops, forest and the open woodland. Less changes on bushland with scattered crop, the category that contains bushy perennial crops is due to the fact that once the land is converted into a perennial crop, it remains in that use for a long time. The forest change is less significant because much of the forest cover is a forest reserve. Once the natural forest on none-forest reserve is depleted no further decrease of forest is possible, as the rest of natural forest is under forest reserve, on which human activities are prohibited. Small changes of open woodland are due to limited nutrients under this cover, due to factors explained above.

Projected land cover in Kihansi catchment

In the previous sections, it was observed the transformations of land covers in time and space that have been occurring from the year 1990. It is obvious that these trends of changes will continue beyond the present states since Kihansi Catchment is still farmed as in the past. Up to the present, no regulations have been imposed on land uses except the maintenance of the current Kihansi Forest Reserve.

With business as usual considerations in mind, the dynamic modelling was performed to predict the future land cover. First the projection of land cover for ten years in the future from the present state was performed based on the present rates of change. Secondly, twenty years projection, that is, projection to the year 2035 is performed by examining the rate of changes that existed from the year 1995. The acreage of land covers existing in the year 2015 and the projected covers by the year 2025 and 2035 are shown in Figure 4.

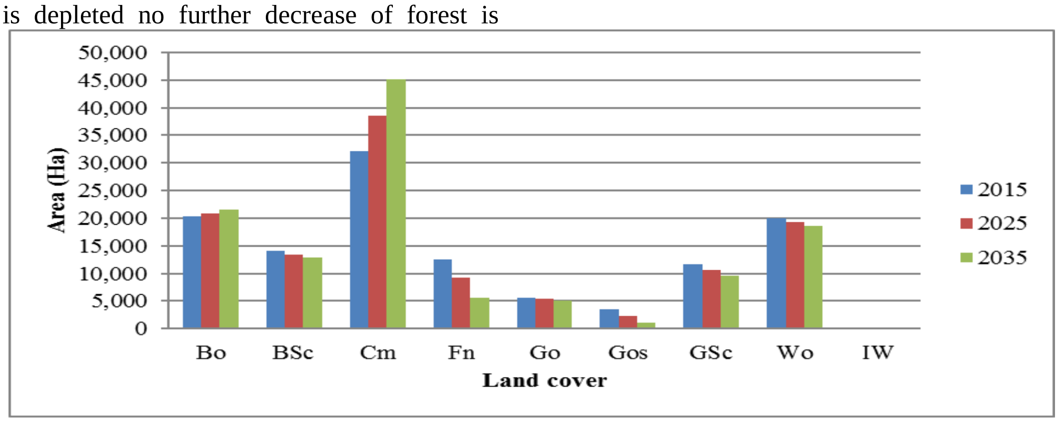

Figure 4: Quantitative variation of all land covers for the years 2015 (measured), 2025 and 2035 (estimated) (Key: *Bo-Open Bushland, BSc-Bushland with scattered crop, Cm-Seasonal Crop Cultivation (Cultivation); Fn-Natural Forest; Go- Open Grassland; Gos-Seasonally inundated Grassland; Wo-Open Woodland; IW- Inland water).*

The projections of land cover indicate that open bushland and cultivated land will increase in the Kihansi Catchment. The rest of land covers will decrease but at different rates (Figure 4). Open cultivation is predicted to increase by 20% for the first 10 years from the present and by 16% in the subsequent 10 years to the year 2035. Open cultivation is largest in the plain where it replaces seasonally inundated grassland, but significant changes also occur in the highest altitudes in catchment, replacing the open grassland and the open bushland. In the plain, the open cultivation of pad and seasonal crops such as maize replaces the seasonally inundated grasslands. The rate of decrease of the seasonally inundated grassland is high, in the order of 34% to 51%. The seasonally inundated grassland in the plain is projected to decrease from 3,569 ha of existing to 1,150 ha, about one third decrease in 20 years to come.

The forest is projected to decrease by 27% in the first ten years and the rate will increase if the natural forest reserve is not protected to 39% by the year 2035. Almost half of the current forest reserve will remain at business as usual scenario. The forest is projected to be replaced largely by the open woodland; however, such rates of forest decrease will not continue since in the forest reserve no human activities are allowed at the moment.

The woodland is projected to decrease at a very slow rate of the order of 3% on average in 10 years followed by the bushland with scattered crops with an average of change of 4% in 10 years. The slow rate of bushland with scattered crop is that, bushland with scattered crops is occupied with perennial crops that remain un-uprooted for a long time.

The grassland with scattered crop will also decrease at the appreciably low rate of 9 to 10% in 10 years. The rate of decrease increases with time. The grassland with scattered crop is projected to be replaced by seasonal mono-crop cultivation in both the plain and upland. However, bushland with perennial scattered crop will dominate the uplands as opposed to seasonal crop cultivation in the plains.

By the year 2035, about 45,171 ha in the catchment will be occupied by seasonal cultivation crops. Much of the land to open up a new land for cultivation would have been exhausted remaining the woodland in the elevated areas in the plain, swamps and dry open grassland that cannot undergo flood irrigation. In the upland, the potential land for cultivation will have been occupied by perennial crops in the bushland with scattered crops category, and in the open grassland that exists as prairie, seasonal tropical crops will be limited since they grow in these areas with difficult. Much of the open bushland which appears in the projected land cover map (Figure 5) would have occurred if the forest was not a forest reserve. Therefore, much of bushland is projected to occur on the forest reserve in the year 2035, but actually this condition will not be reached since the forest reserve is not available for cultivation.

Discussion

The trajectory of land cover changes in the Kihansi Catchment has implications to the natural resources and biodiversity. The obvious implication is the depletion of natural wood cover in the catchment and existence of seasonal mono-crops on cultivated land. Some of the upland vegetative cover is replaced by the pine plantations as a strategy to replenish the lost natural wood. As much new land covers are emerging in the Kihansi Catchment, negative impacts may arise on the resources and biodiversity.

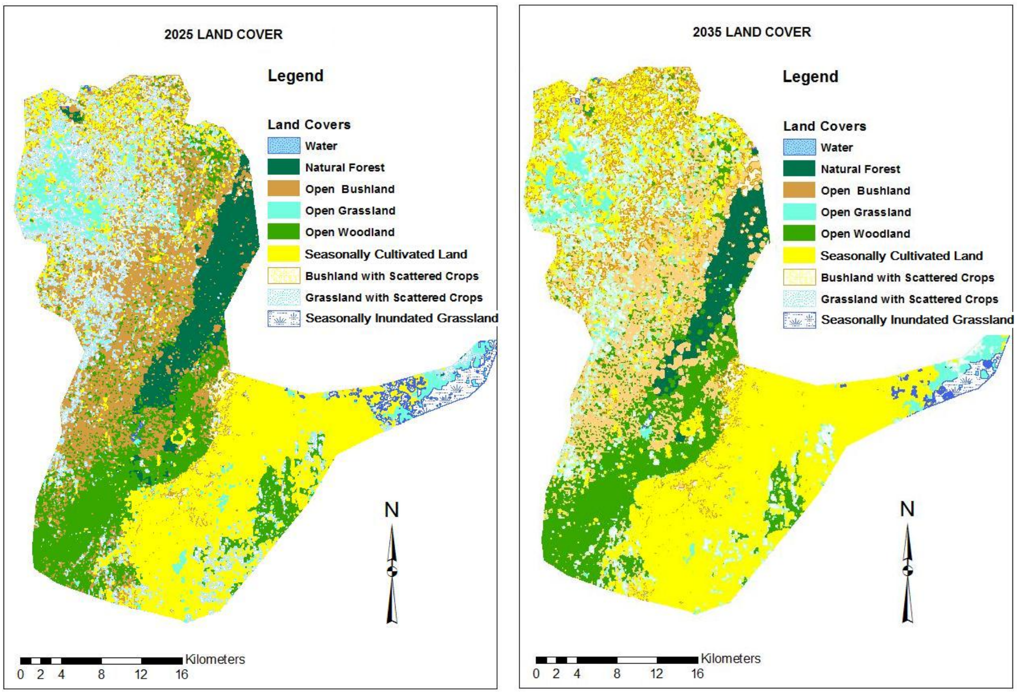

Figure 5: Variation of the projected land covers for the year 2025 and 2035.

Land cover change impacts of on water resources

River Kihansi annual minimum discharge has been declining from 9 m^3/s in the early 1980s to 7 m^3/s in the mid-1990s to below 6 m^3/s in the 2000s with the lowest value of 4.97 m^3/s in December 2005 and January 2006 (NEMC 2013). This change of water in the Kihansi River system is attributed to change of rainfall (Makongoro et. al. 2013). Other plausible reason that could explain the decreasing trend of water flow is a change in land cover. Sources of water for Kihansi River and streams are the cultivated areas and the trajectory of land cover changes in these areas is from wooded cover to open cultivation. Such trajectory favors the increase of quick runoff and reduction of delayed runoff. Much of the sources of the Kihansi Catchment streams which is currently occupied by bushland with scattered crop and cultivated land were woodlands. Woody plants have deep roots that allow deep percolation of water and improved delayed runoff. While bushlands with scattered crops and seasonally cultivated crops have limited deep rooted vegetation on steep slopes the dominant runoff is the overland flow. Therefore, even without changes of the amount of rainfall, the flow in the river will decrease due to the current trajectory of land cover changes as much of water in the catchment will increasingly flow in the river as surface runoff that causes flash floods and lack of delayed flow to supply water in the river, long ago after rains have stopped. Since seasonal cultivation is projected to increase, the notable impact of this effect is to decrease a constant supply of water in the river.

As much as a constant flow of water in the river will be altered, but also the quality of water supplied to the river. As seasonally cultivated land increases, surface runoff increases and the amount of sediments in the river supplied by sheet wash from bare soils will also increase. Sediments also could increase in the river due to removal of wooded vegetation in the steep slopes. Wooded vegetation that has deep roots holds together thick layers of soil. Without deep-rooted vegetation, landslides on steeply inclined slopes will increase. Landslides will supply large quantities of soil in the river. Moreover landslide scars are the constant supplies of sediments to the river until the scar of exposed soils is colonized by vegetation, which may take a long time the vegetation to colonize and stabilize it.

Quality of water would likely be altered by intensified cultivation. As note in this study, by the year 2035 there will be no land to open up for cultivation. All the land will be occupied by crops either perennial or seasonal crop, except the woodland areas. The viable optional to continue to support the livelihood of increasing population in the Kihansi catchment will be an intensive cultivation. Under intensive farming production will need to be supported by farm implements, such as fertilizers, organic manure and pesticides. These farm implements in the catchment will find their ways into the river, adding to deterioration of quality of water in Kihansi Rivers.

Land cover change impacts of on biodiversity

Kihansi forest, a remnant natural vegetation cover of the Kihansi catchment, is a site of high biodiversity and endemism. Studies of biodiversity in the Kihansi forests have reported occurrence of rare plants in the Kihansi and Udagaji Gorge (NORPLAN 1999); varieties of mammals of specific importance are the Uhehe Red Colobus and Sanje Mangabey which are rare and therefore are of high conservation importance (Rodgers and Homewood 1982); sixteen bird species of conservation concern including 12 threatened and near-threatened species; high biodiversity of fish including 13 species of fish from 13 different families; herptiles endemic to Eastern Arc (NORPLAN 1995) and of particular importance the *Nectophrynoides*, named the Kihansi Spray Toad (*Nectophrynoides asperginis*, Poynton et al. 1998).

The direct impact of land cover changes on Kihansi catchment on biodiversity is the changing vegetation assemblage which leads to change of habitat characteristics due to change in assemblage of both terrestrial and aquatic plants. As the natural land cover of the Kihansi Catchment has been shrinking only to remain on the conserved area of the Kihansi Catchment so does the catchment's natural biodiversity for both flora and fauna.

In addition to the impact on biodiversity resulting from changing land cover, there are indirect impacts resulting from alterations of water resources, in terms of flow quantity, patterns of flows and water quality. Decrease of water quantity will have direct impacts on herptiles and fish in the Kihansi River streams, including the river reaches that are under conservation. Consequently, fish biodiversity is threatened and rare species such as the KST could extinct because of decrease of water in the streams that support the fish and amphibian species.

Changing of patterns of flows as the result of land cover changes is also a threat to the biodiversity of Kihansi species. Various river flows play important roles in maintaining habitats of various species in the river. High flows maintain habitats by flushing out undesirable substances in the river such as deposition resulting from excessive sediments and algae blooms that may result due to excessive nutrients. Normal flows (maintenance flow) maintain the optimum conditions for species to thrive and breed and low flows are required to balance the habitat population, while some of the population disappears, nutrients and foods for species are accumulated. Frequent excessive flows due to reduced delayed flows will strip out the required nutrients to maintain aquatic vegetation and foods for specials thus threaten the aquatic biodiversity in rivers.

Changing water quality due to sediments, fertilizers, manure and pesticides also have detrimental effects to the species as the materials in water may lead to increase of algae, and aerophytes that may have detrimental effects to the existing species, production of toxins by certain algae, increase of water turbidity, alkalinity or acidity and heavy metals, all these will favour the most tolerant species and rare species could extinct.

Biodiversity is also impacted by introduction of exotic plant species such as pine in the catchment. The pine species have multiple impacts to the biodiversity that include acidifying the soils (Bautista-Cruz, and Del Castillo 2005). The soil acidity eliminates humus forming bacteria and fungi and prevents further decay of litter. Consequently, no other vegetation thrives under the canopy of pine forest. Replacing the natural vegetation with pines directly curtails the native biodiversity in the catchment. Moreover, increasing the pine plantation in the Kihansi Catchment will not only affect soils, but also changing the pH of water in the Kihansi River beyond the survival of fresh water biodiversity.

Another impact of pine growth is the reduction of water resources. Pine thrives well in the humid environments with no scarce rainfall reference (Duangsathaporn, and Palakit 2013). However, under limited amount of rainfall, pines are not the appropriate plantations to protect river water sources. The soils under pine plantations are drier and less organic (Hofstede et al. 2002) that signifies that pines have low water retention capacity and reduces delayed flows that are the sources of a constant river flow. Therefore, impacts of pines in the tropics where rainfall is scarce will likely reduce the regular flows in rivers, and contribute to impact native biodiversity.

Conclusion

This study examined land cover and land use change and its implication to Kihansi catchment biodiversity and water resources. Vegetation cover in the catchment was greatly transformed. Most of the natural vegetation was replaced by seasonal crops and pine trees in the upland, and rice pads in the lowland. The general trend of land cover change was that natural forests, woodland and open grassland were decreasing while the cropland and bushland usually mixed with scattered crops were increasing. Forests decreased from 28,454 ha to 10,897 ha and woodland from 26,903 to 19,914 ha in 25 years from 1990. The largest vegetative cover in 1990 was wooded cover which occupied 46%; by 2015 the wooded cover was reduced to 26% of the entire catchment. Cropland increased to cover about 51% of the total catchment. The projected vegetative cover to the year 2035 shows 39% decrease of forests under business as usual scenario. About half of the natural forest existing in 2015 will remain in 2035, and about 66,250 ha out of 119,811 ha will be under variety of crops. Arable land will be exhausted in upland by 2035 and the bush land with scattered crops will be mainly occupied by perennial crops.

The obvious implication of land cover change in Kihansi Catchment is depletion of natural vegetation cover in the catchment and increase in cropland. Some of the upland cover was replaced by pine plantations as a strategy to replenish the lost natural wood resources. As new vegetation is introduced in the Kihansi Catchment negative impacts on water resources and biodiversity arose. The notable impact on water resources was the decrease of constant supply of water in the streams**.** Implication of land cover change on biodiversity includes change of Kihansi terrestrial and aquatic habitats and consequently the impacted native biodiversity including the KST that was extinct in the wild to warrant the re-introduction.

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Conflict of Interest

The author declares that there is no conflict of interest.

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