IMPACT OF 2003-2015 FOREST COVER CHANGES ON TREES DIVERSITY IN GISHWATI LANDSCAPES

By

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IMPACT OF 2003-2015 FOREST COVER CHANGES ON TREES DIVERSITY IN GISHWATI LANDSCAPES

Thesis submitted in partial fulfillment of the award of MSc degree in Biodiversity Conservation and Natural Resources Management

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Declaration

I declare that this Dissertation contains my own work except where specifically acknowledged

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Signed………………………………………..
Date…………………………………………..

Certification

This is to certify that the Project Work entitled "**IMPACT OF 2003-2015 FOREST COVER CHANGES ON TREES DIVERSITY IN GISHWATI LANDSCAPES"** is a record of the original bonafide work done by:

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in partial fulfilment of the requirement for the Degree of MASTER OF SCIENCE IN BIODIVERSITY CONSERVATION AND NATURAL RESOURCES MANAGEMENT in College of Science and Technology, University of Rwanda during the Academic Year 2017-2018.

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Abstract

The deforestation of tropical forests has been considered as the major driver of the forest cover change and loss of about 50,000 plant and animal species is attributed to it. Two main interventions to be adopted to tackle the issue, are (i) the protection of the current forests, (ii) rehabilitate and restore of degraded forests. This study was carried out in Gishwati Landscapes located in North–West of Rwanda which include the former Gishwati Forest Reserve. The main objective of this study was to quantify forest cover change from 2003 to 2015 and compare current tree species diversity and their distribution in different forest structures (restored and remnant forests. Supervised classification was done in Erdas Imagine and Arc Map software in analysing L7-ETM+(2003) and L8 OLI/TIRS (2015) images to quantify land uses and forest cover changes. From land cover change detection results, two different types of forested areas were found: (i) undestroyed natural forest areas and (ii) regenerated forest from converted cropland and pasture in which 120 samplings plots were established and tree species were recorded. Further analysis was done using PAST for tree species diversity. Supervised classification gave three main land uses which are cropland, forest, and pasture. Change detection showed that cropland reduced in size by 25%, forest increased by 5.2 % and pasture by 20%. For tree diversity and species richness, the forest derived from cropland has high species richness (21), followed equally by forest to forest and pasture to forest (20). Species dominance index of the remnant forest is higher (0.1998), followed by pasture converted (0.1891) while the cropland converted to forest come at the last position (0.145). Simpson's index of forest derived from cropland was higher (0.855), followed by pasture derived (0.8109) and finally by the remnant forest (0.8002) while the Species evenness is higher in the forest from cropland (0.4457) followed by forest converted from pasture (0.3995) and then remnant forest (0.3585). There has been a positive forest cover from 2003 to 2015 which is beneficial for the sustainability of biodiversity. Good news is that it has been observed that conversion from cropland to forest can increase up forest cover than converting pasture to forest. Remnant forest is more abundant in trees than restored forest which still emphasize role of forest protection before rehabilitation and restoration.

Key words

Key words: Gishwati, land use, forest cover change, species richness, tree diversity.

List of symbols and acronyms

GACP: Gishwati Area Conservation Program

UNEP: United Nations Environment Programme

GIS: Geographical Information System and

RS: Remote Sensing

PAs: Protected Areas

OLI: Operational Land Imager

TIRS: Thermal Infrared Sensors

ETM +: The Enhanced Thematic Mapper Plus

PAFOR: Projet d’Appui a l’Aménagement Forestier au Rwanda

NGOs: Non-Government Organizations

Table of Contents

List of Tables

List of Figures

1. Introduction

The deforestation of tropical forests has been considered as the major driver of the forest cover change (Kayiranga et al., 2016), and loss of about 50,000 plant and animal species (Count and Change, 2013). The deforestation is a result of many factors mainly the population growth (Kissinger et al. 2012), population's development projects (Said & Balakeristanan 2000) in and around protected areas which accelerates deforestation and in return impacts negatively on biodiversity (Duran et al., 2003). One can distinguish two types of land cover changes; rapid which may be characterized by clearing the forest for agriculture extension and other development projects and slow like tree damage and death due to acidic rain. Knowledge of forest cover principles is a tool for decision making when dealing with biodiversity conservation, climate change, people livelihoods and natural resources (Adedeji et al., 2014).

The United Nations for Environment Protections (2010) stated that Protected areas (PAs) play a role of the cornerstone of forest conservation policy in developing countries with the main objective of conserving the forests and its ecological processes including carbon sequestration, hydrological services, and biodiversity habitat. The disturbance of functionality of PAs, projected to be increased in future, caused by surrounding matrix remain one of the big issues which developing countries are facing nowadays and most of the biodiversity hotspots are located in within these regions (Bailey et al. 2015). The disturbance of those PAs reduces their ability to preserve and protect their species richness and related ecological processes (Bond et al., 2012).

Geographical Information System (GIS) and Remote Sensing (RS) tools are well known as an appropriate way to study forest cover and its changes because it has a capacity to cover a large-scale area and it provides the time-series information (Kayiranga et al. 2016). Mapping of forest cover and its change gives a valuable information for management of natural resources and for projection of the future interventions of land productivity (Adedeji and Adeofun, 2014). Forest cover change-detection and mapping is important for a range of environmental applications, including land use planning, landscape monitoring, natural resources management, habitat assessment and finally for biodiversity conservation of any landscape (Sakthivel et al. 2010). One of the major topic of the natural resources management is to know how the forest cover change is affecting the biodiversity (Orsi 2010). Forest restoration indirectly inducing the forest cover is one of the major pillar of global biodiversity conservation focus nowadays (Adams 2015) with aim of bringing back former species and installing new ones for increase of the vegetation over the world (Baatuuwie et al.,, 2011). Vegetation diversity depends greatly on the forest cover of a particular landscape (Omoro et al., 2010). Vegetation Species composition may change due to a conversion of a land cover to another. Any change of land cover type to forest cover results in increased trees and vegetation diversity (Uwimana 2007).

Gishwati Landscape is a montane rainforest fragment located just south of Volcanoes National Park in western Rwanda (Kisioh 2015). It was the largest rainforest in Rwanda and was 28 000 ha in 1970 reduced to 600 ha in 2005, this is a very high reduction that resulted from rapid degradation and change due to forest conversion to settlement, farming, and pastoralism (Mvunabandi, et al., 2002; Rebecca et al., 2015; Kayiranga et al., 2016). It is one of the most densely populated areas of Rwanda characterized by unsustainable agricultural practices with less productivity of surrounding communities. This pushed the incumbent population to look for alternative livelihoods in form of increasing encroachment, poaching and other types of illegal resource extraction (Kisioh 2015). Many actors, government and NGOs, started thinking on its restoration with the aim of ensuring that benefits to global climate, biodiversity in its all aspects and ecosystems services to Rwandan people (Hope 2015). Some interventions were to stop people from encroaching into the patches of forest left in south west of the Gishwati area and to restore them for water catchments by the government of Rwanda (Uwimana 2007); in 2005 PAFOR (Projet d'Appui a l'Aménagement Forestier au Rwanda) started restoring one part of Kayove Forest Reserve and also Gishwati Area Conservation Project (GACP)'s conservation and restoration activities from 2008 to 2012, increase the size of the forest and made a big contribution in the reduction of illegal activities (Hope 2015).

The present study specifically aims to understand the magnitude of forest cover change in Gishwati landscapes from 2003 to 2015 and its impact on trees diversity as a contribution for its future management.

1.1 Problem Statement

The forest degradation has been considered for many years worldwide as big driver of biodiversity diminution to even loss (Aborisade 2012) which was the case for Rwandan context as stated by Kayiranga et al. (2016). Most of protected areas in Rwanda are facing the same problem due to habitat loss because of the increasing human population, with the density reaching up to 800 habitants/sq. km which are striving to get farmland, firewood for cooking, housing development, legal and illegal timber harvesting, etc. (Rift & Series, 2013; Kayiranga et al., 2016). With a big focus on the area conservation and restoration, there is a need of assessing the forest cover change over time (12 years) and to find the impact of converted land cover to forest on trees diversity which will ignite a change in affronting Gishwati conservation and restoration efforts currently and in its future management.

1.2 Research objective

The main objective of this study is to quantify forest cover change from 2003 to 2015 and compare tree species diversity in relation to different forest structure (restored and remnant forests). Specifically: (1) To quantify the forest cover and its changes between 2003 and 2015; (2) To analyse the dynamics of other land covers changes in comparison to forest from 2003 to 2015; (3) To assess tree species diversity of restored forest based on the land use source; and (4) To compare tree species diversity in restored and remnant forest.

2. Materials and Methods

2.1 Research Design

The figure (1) below shows the general framework and chain starting by the acquisition of data which are processed to give a meaningful information to respond to our research objective.

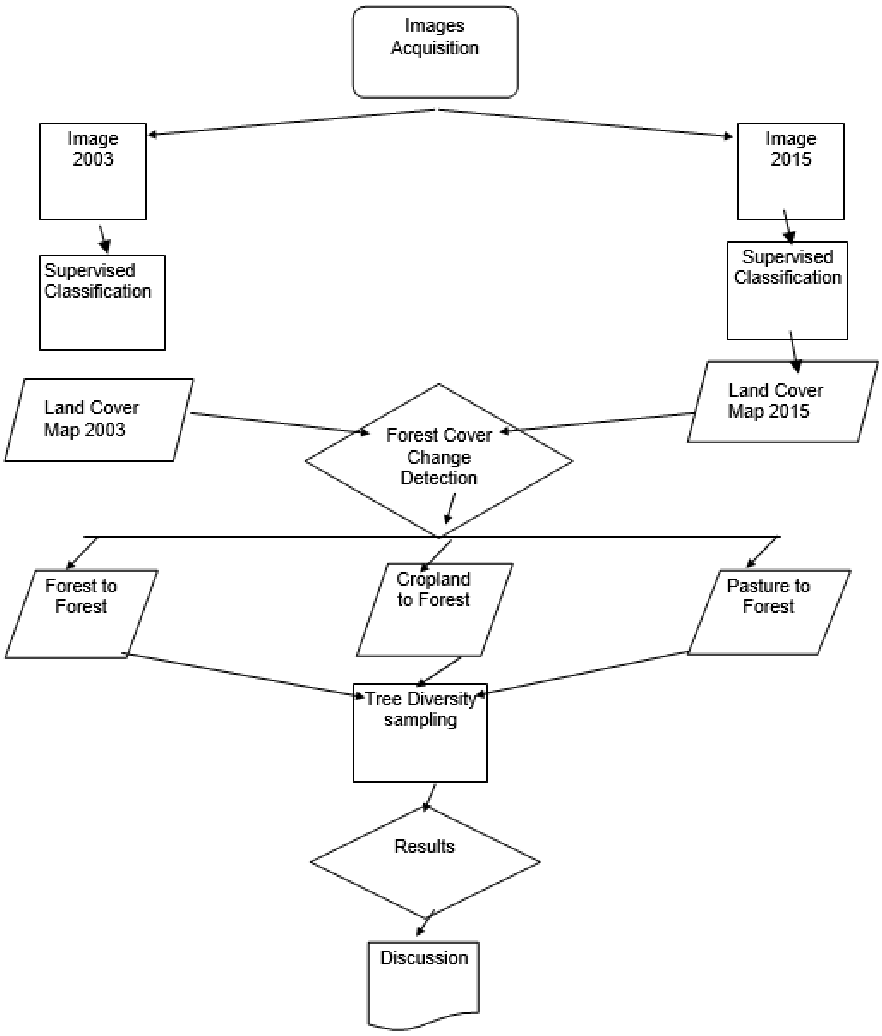

Figure 1: Research design flowchart

2.2 Study Area

As illustrated in Figure 2, Gishwati Landscape is a mountainous rainforest comprising Congo–Nile watershed divide and is in Northwestern of Rwandan territory with an elevation ranging from 2000 to 3000 m above sea level with 35% slope gradient. Geographically, it is from 29°22'0" E to 29°32'0" E and 1°34'0" to 1°54'0" S. Temperatures are generally cool with an average of 10°C and mean annual rainfall of 1800 mm is typical for an African rainforest (Nyandwi and Mukashema, 2011).

Gishwati Landscape has more than 84 species of trees and shrubs, including numerous indigenous hardwoods and bamboo and a wide range of fauna can be found within the forest (Nsabagasani and Nsengimana,. 2009).

Gishwati rainforest landscape has witnessed dramatic deforestation over the last century from conversion to agricultural lands, and pasture, and as well as for timber and energy usage. Natural regeneration and extension of the core forest through the Gishwati Area Conservation Program (GACP) increased the area from 600 ha in 2008 to 1,484 ha in 2012 (Kisioh 2015).

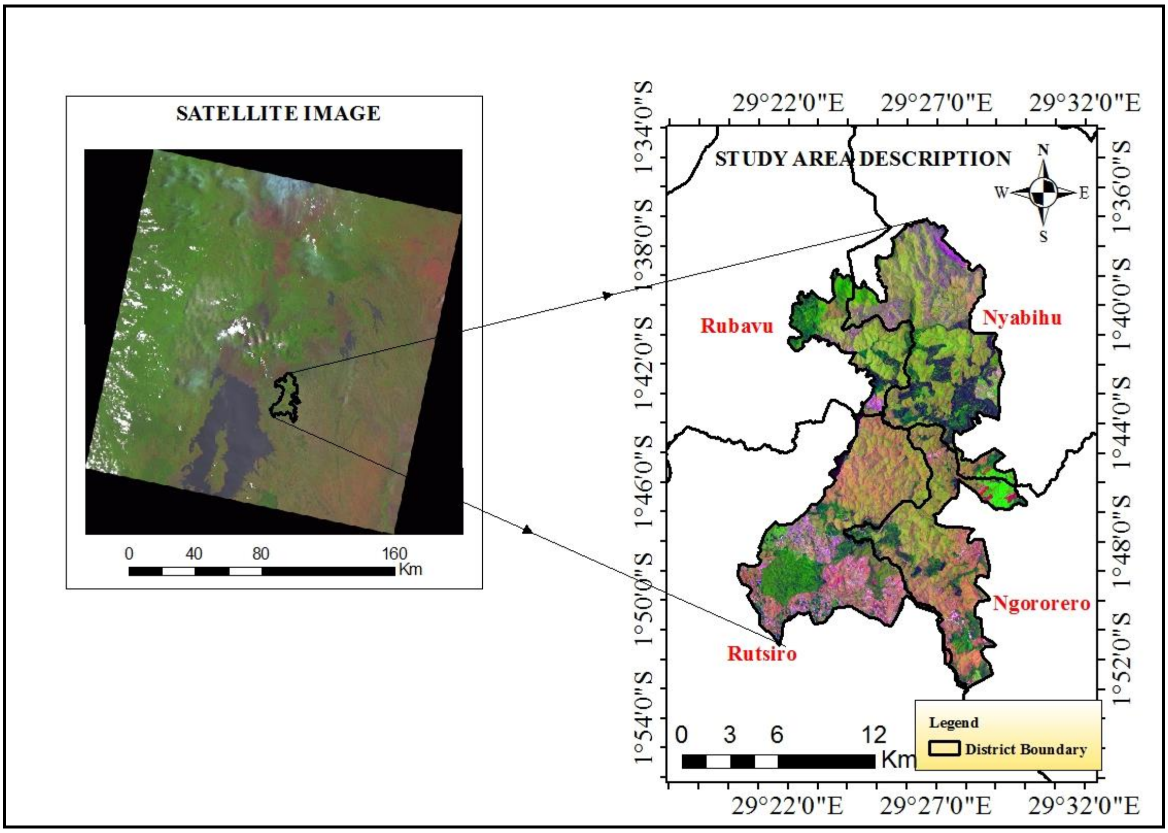

Figure 2: Location of the study area image.

2.2 Data Acquisition

2.2.1 Satellites Images

Two clouds free images have been downloaded from U.S Geological Survey (USGS) https://earthexplorer.usgs.gov/ being L7-ETM+(2003) and L8 OLI/TIRS (2015) to evaluate Gishwati Landscape and other land covers in two different time scales. In two different spectral forms which are 30m resolution (multispectral bands) and 15m (panchromatic bands), those images were downloaded to merge the two spectra for strong resolution images. An area of interest was digitized and taken from google Earth images to be used in the downloaded images, which was corresponding with the former Gishwati Forest Reserve (Kisioh 2015).

2.2.2 Trees sampling

According to the main objective, physical features, allocated time and financial resources, random sampling was used within generated forest clusters/cover types by the outputs of our first objective.

From land cover change detection results, we managed to get two different types of forested areas: (i) undestroyed natural forest areas and (ii) regenerated forest from converted cropland and pasture area to forest. Both forested area types have been used to reach our objective of trees diversity assessment. Based on the proportion of the forested area, we sampled 54.1% for the undestroyed natural forest (forest to forest conversion), 32.6% cropland to forest and 13.3% pasture converted to forest.

Taking into consideration the area, we decided to take 120 sample points and distributed proportionally to correspond to 64 plots for forest to forest, 39 for cropland to forest and 17 for pasture to forest cover. The specific location of these sample points within each forest cluster/type was determined randomly in ArcGIS 10.5 and corresponding coordinates have been used to go on the field for tree diversity sampling plots.

For trees diversity, a plot of 20m x 20 m quadrant (Kent 2012) was used. Location of the plot was found by using a GPS through waypoint navigation. In each plot, geographic parameters were recorded on forms and trees species, number and types were recorded (Khaine et al. 2017) with no distinction of native and exotic. For the sake of this research, every tree is considered when it is equal or more than 15 cm high. The sampling has been done in May 2018.

2.3 Data Processing

2.3.1 Images processing

Two main software Erdas Imagine 9.2 and ArcMap 10.5 were used in data preparation for a final meaningful information (Tempfli et al. 2009). Layer stacking and pan sharpening have been performed, followed by images sub-setting upon Area of Interest (AOI) (Forkuo and Frimpong, 2012). Then, followed images supervised classification by Maximum Likelihood classifier (MAXLIKE) scheme and land cover changes on two Landsat's images 2003 L7 ETM+ and 2015 L8 OL/TRS in order to quantify change happened for three main land cover being natural forest, pasture and cropland within the study area (Kayiranga et al. 2016). Land cover change detection have been compiled in Erdas Imagine 9.2. and then transferred into Arc Map 10.5 for data exports and maps generation.

2.3.2 Accuracy assessment

For a meaningful information on Gishwati land cover change, the performance of accuracy assessment is of high importance for understanding, estimating the changes occurred from 2003 to 2015. It gave us correspondence certainty on classification and ground reality. Random samplings sites were generated and plotted on google earth images of 2003 and 2015 respectively (Tempfli et al., 2009; Cheruto et al., 2016).

The Kappa coefficient also has been calculated in order to see degree of agreement between the classification reality with the reality on ground (Forkuo and Frimpong, 2012). The Kappa coefficient ranges from 0 (no reduction in error) to 1 (complete reduction of error) and can also be represented in percentages for a better understanding. Three categories are known for analysis: a value greater than 80% represents a strong correlation, between 40 to 80% represents moderate correlation and finally below 40% shows poor correlation (Congalton 1991).

2.3.3 Trees diversity analysis

Data collected from the three categories of forested areas were analyzed using Microsoft Office Excel, Past 3.14 software. Data analysis focused on species occurrences, species richness, species abundance and species diversity. Species richness is the number of species per unit area (Sagar et al., 2003). High diversity shows an area containing large number of species. To reach one of our objectives of this study, we have calculated species richness, dominance, Simpson 1-D, Shannon_H and Evenness_e^H/S indices attributed to species diversity (Zilliox and Gosselin, 2014). High value of index represents high diversity (Khaine et al. 2017).

3. Results

3.1 Forest Covers and Change

3.1.1 Gishwati Land cover types in 2003 and 2015

The analysis of L7 ETM+ image supervised classification generated three main land cover types for the Gishwati landscapes in 2003 which are dominated by cropland, followed by pasture and forest (Table 1). The analysis of L8 OL/TRS image supervised classification generated three main land cover types which are dominated by pasture followed by forest and cropland (Table 2) for Gishwati landscapes in 2015.

Table 1: Gishwati Land cover types in 2003

Classes	Pixels	Area (Ha)	Area (%)
Forest	317781	7150.0725	25.1065
Crop Land	582216	13099.86	45.99836
Pasture	365735	8229.0375	28.89514
Total	1265732	28478.97	100

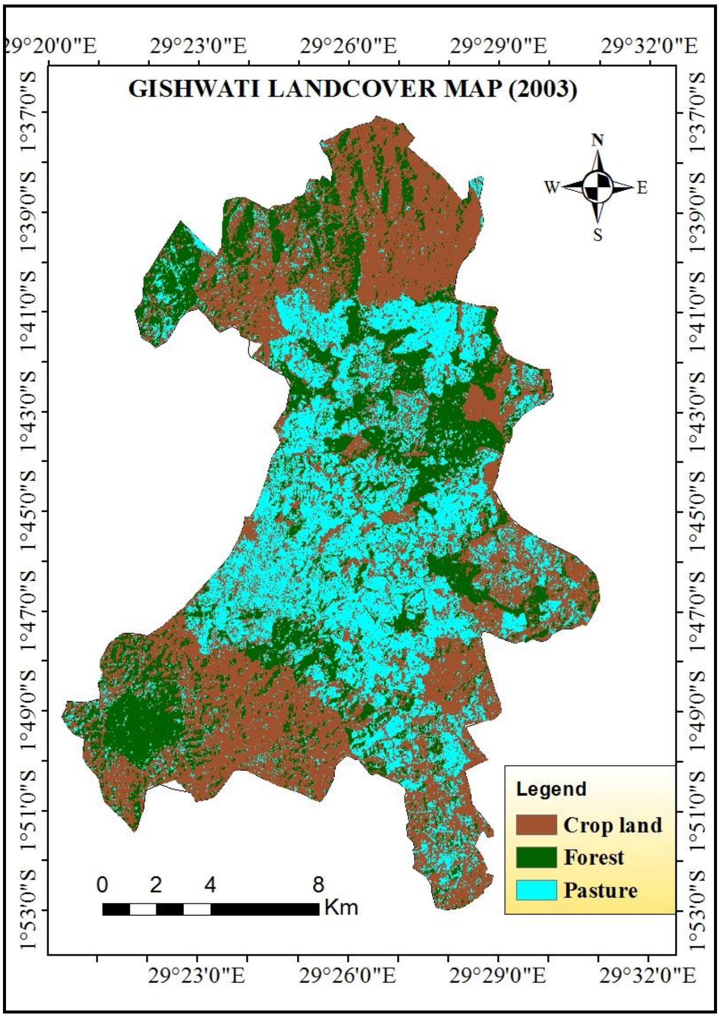

Figure 3: Gishwati Landcover map 2003

Table 2: Gishwati Land cover types in 2015

Classes	Pixels	Area (Ha)	Area (%)
Forest	383237	8622.833	30.278
Crop Land	267518	6019.155	21.135
Pasture	614977	13836.983	48.587
TOTAL	1265732	28478.970	100

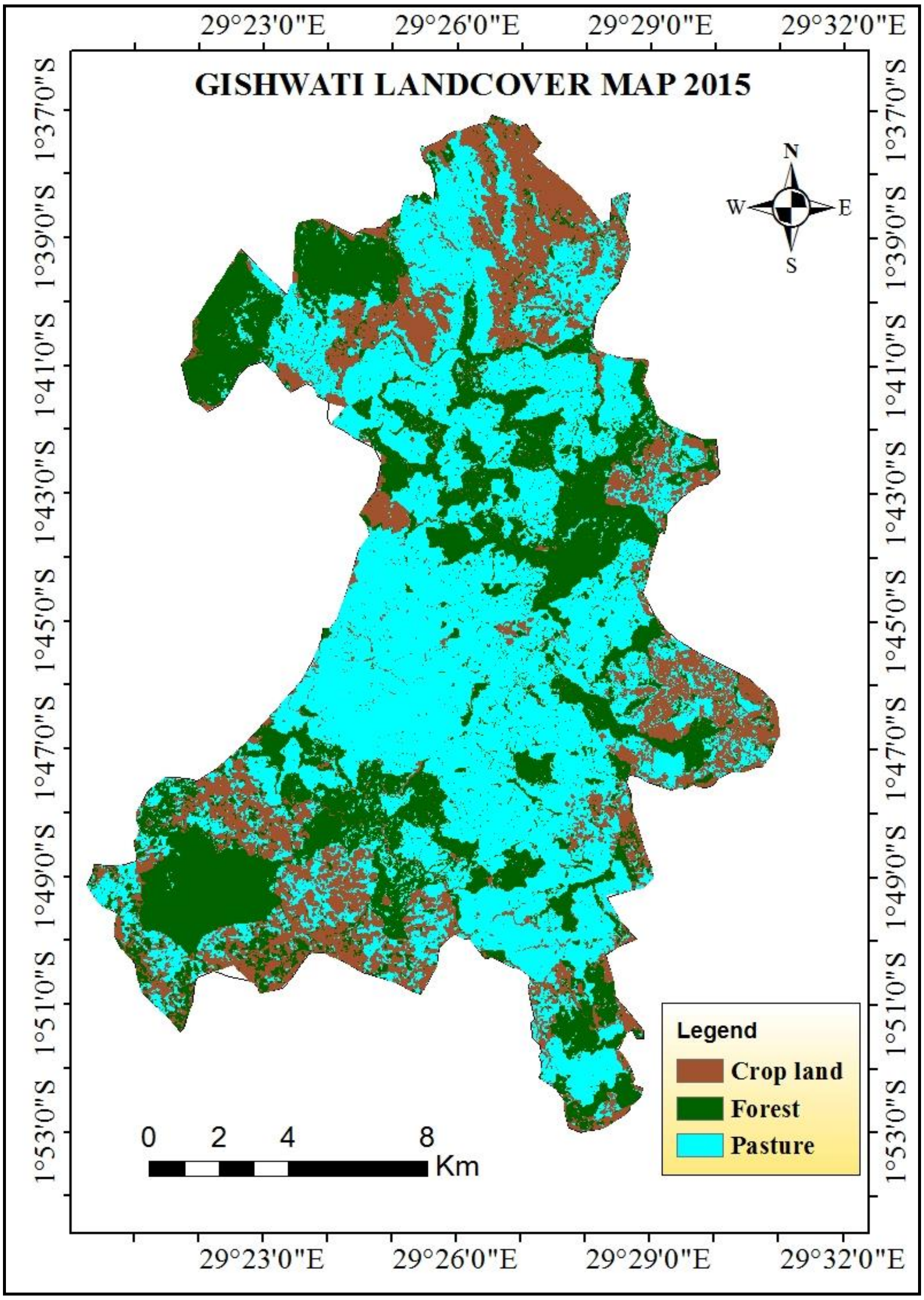

Figure 4: Gishwati Landcover map 2015

3.1.2 Gishwati Land Cover Changes (2003 – 2015)

Table 3 shows that there have been changes on the Gishwati land cover from 2003 to 2015 for every type.

Table 3: Gishwati Land cover changes between 2003 and 2015

Landcover ><	Forest (Ha)	Crop Land (Ha)	Pasture (Ha)
Forest	4623.28	794.183	1732.61
Crop Land	2827.19	4623.17	5649.5
Pasture	1172.36	601.808	6454.87

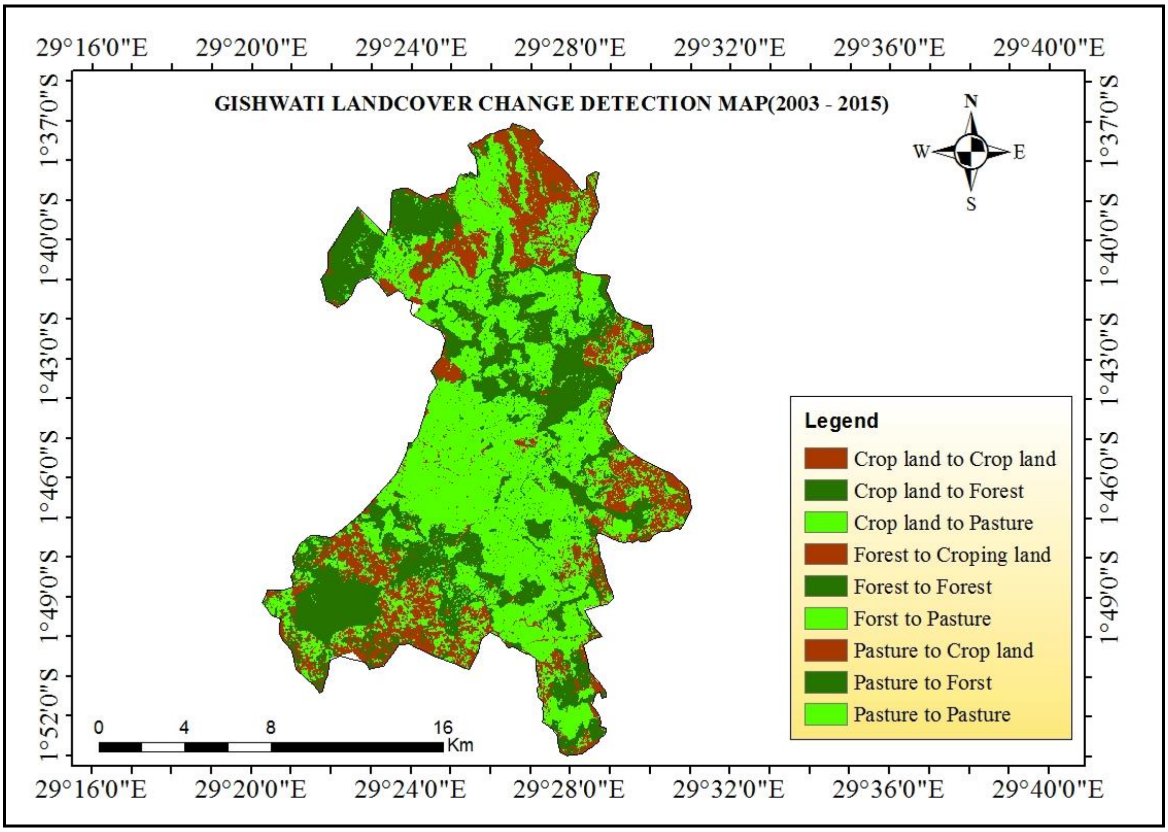

Figure 5: Gishwati landcover change detection map (2003 – 2015)

3.1.3 Forest Landcover Change from 2003 to 2015

Table 4: Forest land cover change between 2003 to 2015

Year	# Pixels	Area (Ha)	%
2015	383237	8622.8	30.3
2003	317781	7150.1	25.1
Variance		1472.8	5.2

The table 4 shows the area occupied by the forest in Gishwati has increased by 5.2 % from 2003 to 2015.

3.1.4 Accuracy measurements for 2003 and 2015 classified images

3.1.4.1 Accuracy assessment image classification 2003

Table 5: Accuracy statistics of image classification 2003

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Forest	8	8	7	87.50%	87.50%
Crop land	14	13	12	85.71%	92.31%
Pasture	8	9	7	87.50%	77.78%
Totals	30	30	26		

Overall Classification Accuracy = 86.67%

Overall Kappa Statistics = 0.7938

3.1.4.2 Accuracy assessment image classification 2015

Table 6: Accuracy statistics of image classification 2015

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Forest	7	7	6	85.71%	85.71%
Crop land	10	9	9	90.00%	100.00%
Pasture	13	14	12	92.31%	85.71%
Totals	30	30	27		

Overall Classification Accuracy = 90.00%

Overall Kappa Statistics = 0.8446

3.2 Tree Diversity

Analysis of trees diversity sampled in remnant forest and forest converted from cropland and pasture land covers showed below results.

3.2.1 Species identified

Table 7: Trees descriptive statistics per forest derived type

Summary Statics	Forest to forest	Cropland to forest	Pasture to Forest
No of species	20	21	20
Max	768.0	378.0	257.0
Sum	2555.0	1458.0	736.0
Mean	106.5	60.8	30.7
Std. error	43.3	20.0	12.0
Variance	44893.8	9553.6	3472.5
Stand. Dev	211.9	97.7	58.9

A total of 4749 individuals were found in the three converted land uses to forest represented in 24 species. The most abundant specie is *Alnus acuminata* with 1273 occurrences, followed by *Eucalyptus maidenii* 1095 and *Pinus patula* 676 (Figure 6).

3.2.1.1 Species per converted to forest land use

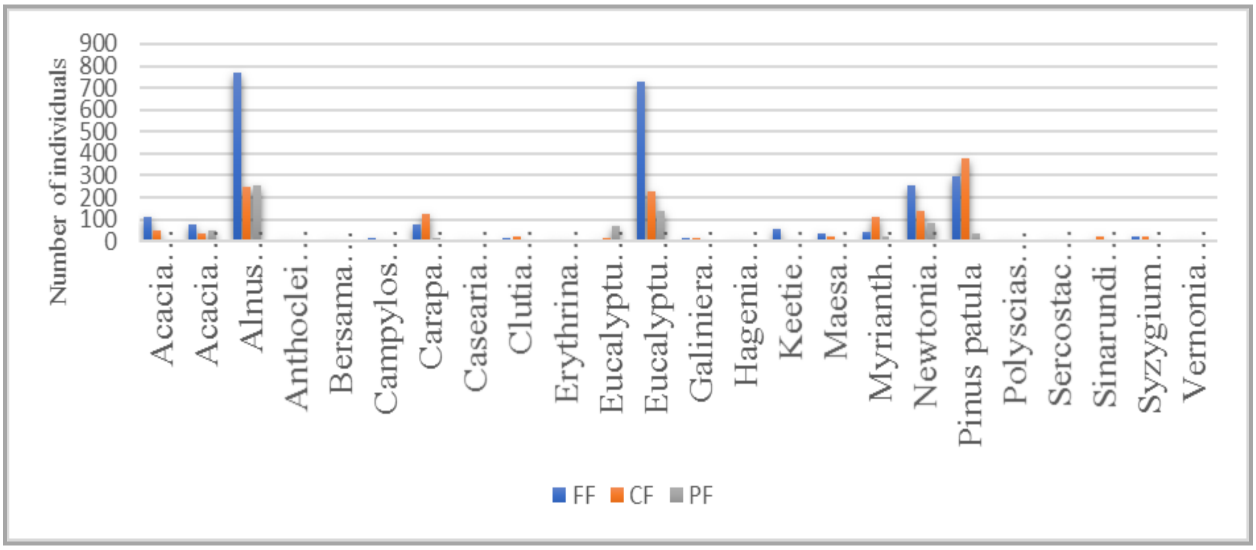

Figure 6: Trees species abundance per land use conversion

Per land use, *Alnus acuminata* broke the record of being abundant in two converted to forest land uses being respectively forest to forest with 768 individuals and pasture to forest with 257 individuals while *Pinus patula* culminated cropland to forest with 378 individuals.

3.2.2 Species diversity indexes

Table 7: Species diversity indexes

Index	Forest to Forest	Cropland to Forest	Pasture to Forest
Taxa_S	20	21	20
Dominance_D	0.1998	0.145	0.1891
Simpson_1-D	0.8002	0.855	0.8109
Shannon_H	1.97	2.236	2.078
Evenness_e^H/S	0.3585	0.4457	0.3995

Considering (Table 7) Species richness, forest derived from Cropland has high species richness (21), followed equally by forest to forest and pasture to forest (20). Species dominance index of the remnant forest is higher (0.1998), followed by pasture converted (0.1891) while the cropland converted to forest come at the last position (0.145). Simpson's index of the the forest derived from cropland is higher (0.855), followed by pasture delivered (0.8109) and finally by the remnant forest (0.8002) while the Species evenness) is higher in the forest from cropland (0.4457) followed by forest converted from pasture and then remnant forest respectively (0.3995) and (0.3585).

4. Discussion

4.1 Land cover types mapping and land cover change detection

Analysis of the two landsat images of Gishwati Landscape in 2003 and 2015 showed a change in its land covers. Table 1 showed that the area of the Gishwati Landscapes was higher 28000 ha as documented by other researchers (Nsabagasani & Nsengimana, 2009; Kisioh, 2015). One of the major drivers of its change was deforestation as most of other rainforest landscapes around the world (Number et al. 2013) for agriculture, grazing and rural settlement which is the case also for the mains land uses who made Gishwati Landscape area diminishing (Mvunabandi et al. 2002). The cropland occupies a big part with a percentage of 45.99 % in comparison to pasture (28.8%) and forest (25.1%) (Table 1). This has been stated in other documentation which highlighted agriculture extension as one major factor to forest degradation (Nyandwi and Mukashema, 2011;; UNEP and GEF, 2014). On other side, Table 2 shows that the pasture was occupying a big area (48.5 %), followed by forest (30.2%) and the cropland (21.1%) respectively which also has been found in another research done by Humphrey (2015) stating that the grazing was the dominant usage of the forest reserve.

Basing on Figure 5 emphasize the increasing trend of the forest cover during 12 years' time of our study. The forest cover was 25.1% in 2003 and reached 30.3% area. This is explained by effort put in Gishwati to conserve it to be nominated as a National Park (Hope 2015; Kisioh 2015). Many literatures attach the biodiversity sustainability to forest landscape integrity. Turner (1996) found that the more forest fragmentation, the more extermination or extinction to the biological diversity of the biosphere which implies a forest restoration as an important tool for biodiversity conservation (Turner 1996).

The pasture area increased by 19.7%. According to Forest of Hope (2015), cattle grazing was the most frequent of illegal activities (Kisioh 2015) which explain the increased area of the grazing The decrease of the crop land has compensated all the increase of forest and pasture. This is more beneficial for the biodiversity because among the three studied land cover types, cropland play a big role in fauna and flora disturbance more than others by clearing the above ground vegetation and exposing the soil to the sun and prey to predators (Bennett and Saunders, 2010).

The Tables 5 and 6 show the accuracy on which the classification of the satellite image into three main land cover types match with the ground truth (Congalton 1991). All the accuracy assessment results are in the acceptable ranges. This shows that the accuracy was performed with high certitude and imagery is reflecting the reality on the ground (Congalton et al.,1996).

For 2015 classified image, the overall accuracy calculated is 90.00% and a kappa coefficient 0.8446 which is ranked for a strong correlation (Forkuo & Frimpong 2012) which guarantee a big reflection of the images data with the reality on the field which is higher that some researches done. The reason is the good image downloaded as said by Knippers and Wei (2004).

4.2 Tree Species dominance, richness, and diversity in Gishwati Landscapes

4.2.1 The species richness

The species of the sampled area were represented by 24 different species which is a sign of a good vegetative future as it is a result of only 12 years change status for restored forest and there is expectation of more other tree species to come. Most of species found in our study are exactly recalling the ones which were a focus to PAFOR as stated by Kisioh (2015). Top five species are *Alnus acuminata, Eucalyptus maidenii, Pinus patula, Newtonia macrocalyx and Acacia meansii* respectively. Most of exotic trees were planted in order to encompass native ones which were not regenerating for the sake of keeping a strong forest cover (MWE, 2016).

Forest derived from cropland has a high species richness than other which have the equally the same number. The capability of the soil to allow a good regeneration as it has mixture of both organic and inorganic fertilizers can explain this. Second, it may also be attributed to the efforts which were taken in agroforestry development as another source of tree starting point (Jacob et al., 2016).

The remnant forest change has the highest mean tree density followed by restored forest from cropland and while restored forest from pasture showed the lowest value. This can be attributed to the protection of the forest against encroachment and to bio physiochemistry of the forest.

4.2.2 Species dominance

The remnant forest land use has a high species dominance than other derived land uses. This is because the forest is not disturbed by anthropogenic activities like in other land uses which hence is related to the heritage given to the current situation (Ifo et al. 2016).

4.2.3 Species diversity

According to Table 7, the restored forest from cropland showed high values of Simpson, Shannon, and Evenness indices, followed by pasture converted to forest and finally by remnant to forest. No studies found on trees composition of forest resulted from cropland and pasture land uses.

Our study showed that the forest derived from cropland has more different species than others. This can be attributed to soil productivity of the farming area where there is application of both organic and mineral fertilizers which is in favour to trees adaptability (Longworth and

Williamson, 2018) and also to the absence of higher canopy which might be coming from old and tall trees with the advantage of leaving openings and good phototropism resulting in facilitation of tree species regeneration by both seeded and non-seeded multiplication (Khaine et al. 2017).

4.2.3.1 Species evenness,

The results in Table 7 revealed that forest derived from cropland has a higher relative abundance of each species that other forest derived land uses. This can be attributed to the nature of the previous land use which was disturbed to the same extent along the entire area (Omoro et al. 2010) and also to the openness of the area (Xu et al. 2016) which is in favorless for pasture and forest respectively.

4.2.3.2 Shannon and Simpson's indices

As stated by Beauchamp (2016), Shannon's and Simpson indices describe a measure of diversity and combine both species richness and evenness. High value of index represents high diversity. High diversity relates to an area containing large number of different species (Omoro et al. 2010) which means that forest derived from cropland also excels the tree diversity than other deriving land uses. The reason resides in the openness of the area for tree seeds and non-seeds regeneration coupled with less competition on different tropisms (Xu et al. 2016) in comparison secondary to forest derived to pasture and thirdly to forest This is not the same as results found by Uwimana (2007) in the same area as due to the fact that she was comparing three land use covers.

5. Conclusion

The study of Gishwati landscapes cover change from 2003 to 2015 and showed that there has been a domination of three main land cover types which are forest, crop land and pasture. Contrary to other researchers, the forest cover increased in 12 years' time which favorize biodiversity sustainability in the area. Another promising trend was that the cropland area is the one who decreased a lot to increase the pasture and forest covers. We found also that restoration of degraded forests or landscapes is possible and is beneficial to biodiversity conservation and a big emphasis can change a lot in the protection and preservation of world flora and fauna. Secondly, the study revealed that land uses impacted on the status of tree diversity in detected changes to forest cover. Like in other studies, the forest derived from forest had a higher species richness than others respectively cropland and pasture forest derived.

The results of our study showed also that forest derived from cropland are subjected to give a higher tree species diversity than forest derived from pasture and forest conversion respectively. The trend is due to continued supply of organic and inorganic supply of fertilizers to the cropland and to the openness of the area for easy nutrient uptake, easy seeded and non-seeded germination, and reduced impact of tropisms in comparison to pasture and forest.

This study appreciated the role of remote sensing in land cover change detection for a biodiversity conservation decision making. Land sat data are good sources of imagery for analysis of land cover. The values of the accuracy got do well show a good correlation of the photos quality versus the truth on ground as no sampling plot taken randomly was out of the scope of our research. All have fallen in one of the three land uses and there was a presence of trees.

Some recommendations risen from this study: Increased and diversified efforts are to be encouraged in the restoration and regeneration of the degraded landscapes as we are confident of the good results. A further study need to be conducted to assess trees development and other biodiversity species over time in comparison to remnant and restored forests. The results of this study showed that much efforts are needed in pasture when restoring forest cover, which can be adopted in further restorations agenda. Increased effort to restore degraded landscape needed to be adopted to achieve future conservation targets. Usage of remoted sensing in land cover change analysis need to be encouraged to timely monitor and tackle forests degradation and landscape desertification.

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Appendices

Appendix 1: Accuracy reports

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : d:/msc bio cons & nat res man/thesis/landcover change gishwati/gishwati/classified images/classified images/recodser_2003.img
User Name : theogenen
Date : Fri Nov 17 15:20:27 2017

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
	0	0	0	---	---
Forest	8	8	7	87.50%	87.50%
Crop land	14	13	12	85.71%	92.31%
Pasture	8	9	7	87.50%	77.78%
	0	0	0	---	---
Totals	30	30	26		

Overall Classification Accuracy = 86.67%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.7938

Conditional Kappa for each Category.

Class Name	Kappa
	0.0000
Forest	0.8295
Crop land	0.8558
Pasture	0.6970

----- End of Kappa Statistics -----

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : d:/msc bio cons & nat res man/thesis/landcover change gishwati/gishwati/classified images/classified images/recorder_2015.img
User Name : theogenen
Date : Fri Nov 17 15:25:24 2017

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
	0	0	0	---	---
Forest	7	7	6	85.71%	85.71%
Crop land	10	9	9	90.00%	100.00%
Pasture	13	14	12	92.31%	85.71%
	0	0	0	---	
Totals	30	30	27		

Overall Classification Accuracy = 90.00%

----- End of Accuracy Totals -----

KAPPA (K^) STATISTICS

Overall Kappa Statistics = 0.8446

Conditional Kappa for each Category.

Class Name	Kappa
	0.0000
Forest	0.8137
Crop land	1.0000
Pasture	0.7479

----- End of Kappa Statistics -----

Appendix 2: Sampling points for forest to forest conversion (remnant forest)

OID	X Coordinates	Y Coordinates
1	29.453944	-1.730268195
2	29.37103859	-1.811218358
3	29.46831007	-1.775529353
4	29.4816619	-1.684341096
5	29.43588813	-1.68835859
6	29.49434799	-1.780777305
7	29.37346043	-1.825898825
8	29.35771893	-1.820249739
9	29.47784632	-1.699099618
10	29.38623802	-1.780563592
11	29.45200328	-1.811471303
12	29.37547291	-1.665211194
13	29.3785511	-1.824170731
14	29.37668588	-1.683893022
15	29.43377495	-1.665446874
16	29.35845742	-1.794060477
17	29.39965491	-1.788285441
18	29.47025578	-1.77054667
19	29.4816683	-1.723801055
20	29.46192533	-1.736681183
21	29.36367591	-1.682548671
22	29.36198194	-1.818958802
23	29.43223766	-1.682719536
24	29.41876093	-1.800588931
25	29.4462326	-1.731944825
26	29.43208255	-1.683524466
27	29.4757133	-1.720652284
28	29.47018622	-1.722981408
29	29.45342126	-1.743532315
30	29.43807137	-1.711359306
31	29.41123102	-1.801377158
32	29.44792646	-1.693257343
33	29.3981173	-1.796195914
34	29.47176427	-1.699463238
35	29.46622429	-1.717121839
36	29.46329986	-1.739226472
37	29.49393237	-1.781299356
38	29.38412907	-1.674872727
39	29.42680413	-1.791093783
40	29.48424718	-1.700555506
41	29.35689485	-1.829233048
42	29.47142226	-1.773746578
43	29.43571967	-1.680658822
44	29.42221945	-1.639030732
45	29.48112789	-1.726320497
46	29.48992943	-1.782841741
47	29.46712172	-1.71424503
48	29.42989855	-1.698574502
49	29.49148357	-1.782359326
50	29.47290888	-1.758443417

51	29.44385409	-1.741195401
52	29.37865717	-1.826372244
53	29.4023034	-1.794841636
54	29.49555099	-1.780558066
55	29.40418408	-1.796544317
56	29.47499673	-1.731045455
57	29.36667272	-1.82453701
58	29.43183468	-1.724598679
59	29.39127375	-1.658380583
60	29.41456504	-1.830023459
61	29.4591968	-1.870553118
62	29.39821541	-1.65665503
63	29.4606935	-1.766717779
64	29.40714038	-1.655185187

Appendix 3: Sampling points for cropland to forest conversion

OID	X Coordinates	Y Coordinates
1	29.37210046	-1.840417194
2	29.37975096	-1.666330382
3	29.38504979	-1.778608487
4	29.45132451	-1.809742646
5	29.46125545	-1.828128228
6	29.41164623	-1.658670908
7	29.38419853	-1.821198978
8	29.36586624	-1.671612634
9	29.36664319	-1.807216743
10	29.39965059	-1.802697245
11	29.43590814	-1.70740961
12	29.43709332	-1.707365869
13	29.47658714	-1.738572987
14	29.38816353	-1.837971224
15	29.44468609	-1.81477719
16	29.46751968	-1.855622349
17	29.46167037	-1.85915204
18	29.48303694	-1.754547254
19	29.41234394	-1.659257789
20	29.42413233	-1.792164469
21	29.44320541	-1.817448409
22	29.41394953	-1.711819364
23	29.49266044	-1.781476368
24	29.47255271	-1.874749444
25	29.38726746	-1.836845353
26	29.40485056	-1.653290807
27	29.35989694	-1.845258778
28	29.41647426	-1.652503715
29	29.3592482	-1.809849093
30	29.427481	-1.682397881
31	29.4730234	-1.850666514
32	29.40392586	-1.64964036
33	29.44782783	-1.81652974
34	29.37884863	-1.824983632
35	29.39980652	-1.804681037

36	29.44532891	-1.786843758
37	29.34337755	-1.814647789
38	29.38370173	-1.676255756
39	29.43652452	-1.729059342

Appendix 4: Sampling points for cropland to forest conversion

OID	X Coordinates	Y Coordinates
1	29.46403916	-1.727066195
2	29.41516809	-1.716223228
3	29.44857668	-1.764910391
4	29.38996455	-1.794957167
5	29.41206118	-1.800914536
6	29.36768347	-1.68868857
7	29.36017251	-1.824253343
8	29.38983827	-1.792871803
9	29.43505162	-1.702789423
10	29.47472208	-1.811828695
11	29.47064813	-1.825069858
12	29.37025378	-1.677754674
13	29.43538013	-1.788040805
14	29.43638096	-1.673503101
15	29.36510646	-1.81182855
16	29.45152379	-1.700561903
17	29.39641888	-1.781912627

Appendix 5: Data entry form

	Trees	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6		Plot 7		Plot 8		Comment
	Date							2/06/2018										
	Plots Number	P74		P67		P95		P59		P75		P89		P84		P58		
		Slop	Alt	Slop	Alt	Slop	Alt	Slop	Alt	Slop	Alt	Slop	Alt	Slop	Alt	Slop	Alt	
		9.06	2713	10.46	2475	19.95	2414	2779	2571	22.47	2501	24.89	2720	23.75	2489	22.14	2440	
Species		Sap	Trees	Sap	Trees	Sap	Trees	Sap	Trees	Sap	Trees	Sap	Trees	Sap	Trees	Sap	Trees	
1	Pinus Patula	11	49									3	32			6	7	
2	Alnus acuminata			3	25					1	27						11	
3	Eucalyptus maiden			1	8					1						3		
4	Newtonia macrocalyx			4				3	14			1	1	3	17			
5	Clutia abyssinica					5								1	4			
6	Carapa grandiflora					6	14	5	1									
7	Myrianthus holstii					1	3					1						
8	polyscias fulva					1		1										
9																		
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		

Appendix 6: List of tree species sampled in forest converted from different land uses

No	Species	FF	CF	PF
1	Acacia meansii	113	52	8
2	Acacia melanoxylon	79	36	52
3	Alnus acuminata	768	248	257
4	Bersama abyssinica	10	0	1
5	Campylospermum vogelli	16	0	0
6	Carapa grandiflora	80	124	14
7	Clutia abyssinica	14	21	1
8	Eucalyptus grandis	0	14	67
9	Eucalyptus maiden	727	226	142
10	Galiniera saxifraga	15	14	1
11	Hagenia abyssinica	0	3	0
12	Keetie gueinzii	59	9	3
13	Maesa lanceolata	39	23	7
14	Myrianthus holstii	45	109	19
15	Newtonia macrocalyx	252	138	81
16	Pinus patula	298	378	38
17	Polyscias fulva	1	12	5
18	Syzygium parvifolium	25	22	8
19	Anthocleista	2	1	8

	grandiflora			
20	Erythrina abyssinica	3	3	8
21	Vernonia amygdarina	3	3	8
22	Casearia runssorica	0	1	8
23	Sercostachys scandens	6	0	0
24	Sinarundinaria alpina	0	21	0

Appendix 7: Past Output for Trees Diversity Indices

Alpha diversity indices

Numbers | Plot

	A	Lower	Upper	B	Lower	Upper	C	Lower	Upper
Taxa_S	20	20	20	21	21	21	20	20	20
Individuals	2555	2555	2555	1458	1458	1458	736	736	736
Dominance_D	0.1998	0.1915	0.2093	0.145	0.1373	0.1547	0.1891	0.1722	0.2094
Simpson_1-D	0.8002	0.7907	0.8085	0.855	0.8453	0.8627	0.8109	0.7905	0.8278
Shannon_H	1.97	1.924	2.008	2.236	2.181	2.281	2.078	1.993	2.154
Evenness_e^H/S	0.3585	0.3424	0.3727	0.4457	0.4215	0.4662	0.3995	0.367	0.4307
Brillouin	1.951	1.905	1.989	2.204	2.149	2.248	2.025	1.942	2.099
Menhinick	0.3957	0.3957	0.3957	0.55	0.55	0.55	0.7372	0.7372	0.7372
Margalef	2.422	2.422	2.422	2.745	2.745	2.745	2.878	2.878	2.878
Equitability_J	0.6576	0.6422	0.6703	0.7346	0.7162	0.7493	0.6938	0.6654	0.7189
Fisher_alpha	2.957	2.957	2.957	3.476	3.476	3.476	3.793	3.793	3.793
Berger-Parker	0.3006	0.2877	0.319	0.2593	0.2366	0.2826	0.3492	0.3152	0.3845
Chao-1	20	20	23	22	21	24	23	20	26

Bootstrap N: 9999 Bootstrap type: Percentiles Unbiased Recompute

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