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REMOTE SENSING OPPORTUNITIES FOR BIODIVERSITY MONITORING IN REDD+ MRV

Kalkidan Mulatu

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REMOTE SENSING OPPORTUNITIES

FOR BIODIVERSITY MONITORING IN REDD+ MRV

Kalkidan Ayele Mulatu

Registration number: 88 05 04 586130

Supervisors:

Dr. Brice Mora
Benjamin DeVries

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To my late father, *Ayele Mulatu*.

Abstract

Forest related climate change mitigation programs such as Reduction of Emission from Deforestation and Degradation (REDD+), are expected to generate additional benefits towards local communities and biodiversity of implementation areas. Therefore, each project needs to design a reliable Measuring, Reporting, and Verification (MRV) system so that the impact of REDD+ activities can be evaluated. This study is focused on the MRV of biodiversity in REDD+ projects. The study investigated the international experiences of REDD+ projects towards biodiversity monitoring and identify existing gaps. Another aim was to find out the applicability of remote sensing tools to fill in gaps in biodiversity monitoring which is further expected to be adaptable to different tiers of International Panel on Climate Change (IPCC). Thus, the research aimed to provide a framework that can contribute to a more effective and comprehensive REDD+ MRV system. The study examined projects submitted to the Climate, community and Biodiversity Alliance (CCBA) to identify international experiences towards biodiversity monitoring. The results revealed the under-utilized status of remote sensing technology in the monitoring of biodiversity indicators. Therefore, based on literature review, forest fragmentation was proposed as a remote sensing based proxy indicator of biodiversity status. Hence, a case study was conducted to identify remote sensing capability for monitoring forest fragmentation and to further estimate biodiversity change in the UNESCO Kafa Biosphere Reserve, a candidate REDD+ area in Ethiopia. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) satellite imagery of 2000, 2005, and 2010 were used to perform a supervised forest and non-forest classification. The classification results indicated a decline in forest cover from 51.8% in year 2000 to 49.8% in 2005, and 44.8% in 2010. These maps were later used to perform fragmentation analysis. The Landscape Fragmentation Tool (LFT), Graphical User Interface for the Description of image Objects and their Shapes (GUIDOS), and FRAGSTATS were used to compute the fragmentation status of the study area. The results implied an intensification of fragmentation especially in the core forests, resulting in decline of habitat coverage and connectivity of the forest. This was expected to result negative change in the biodiversity status of the study area. Therefore, this remote sensing based biodiversity monitoring method was considered suitable for integration in Ethiopia’s recently initiated REDD+ MRV process, which already considered the use of remote sensing technology as a tool for biodiversity monitoring.

Keywords: Biodiversity Monitoring, Reporting and Verification (MRV); Reduction of Emission from Deforestation and Degradation (REDD+); Forest Fragmentation Analysis

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List of acronyms

A/R	Afforestation/ reforestation
AOI	Area of interest
ARR	Afforestation, reforestation and re-vegetation
BDI	Biodiversity indices
BMS	Biodiversity management system
BR	Biodiversity reserve
CCBA	Climate, community and biodiversity alliance
CDM	Clean development mechanism
CMR	Community managed reforestation
CPM	Community participatory monitoring
ESA	European space agency
FMA	Forest management agreement
GEO BON	Group on earth observations Biodiversity observation network
GUIDOS	Graphical user interface for the description of image objects and their shapes
HCVs	High conservation value
IFM	Improved forest management
IPCC	Intergovernmental panel on climate change
JI	Joint implementation
LEM	Local expert monitoring
LFT	Landscape fragmentation tool
MRV	Measuring, reporting, and verification
MSPA	Morphological spatial pattern analysis
PDD	Project design document
REA	Random ecological assessment methodology
REDD	Reduction of emission from deforestation and degradation
REDD+	Reduction of emission from deforestation and degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
RS	Remote sensing
SBIA	Social and biodiversity impact assessment
SLC	Scan Line Corrector
TM	Thematic mapper
UNESCO	United nations educational, scientific and cultural organization
UNFCCC	United nation framework convention on climate change
USGS	United states geological survey
VR	Validation report

1. Introduction

1.1 Background

Forests cover around 30% of the Earth’s land surface (nearly 4 billion hectares) (UNFCCC 2011). These forests have a vital role in keeping ecosystems in balance as they provide valuable services and goods, and serve as a habitat for a wide range of flora and fauna species and hold a significant standing stock of global carbon (Karousakis 2009; UNFCCC 2011). However, the permanent conversion of these forests to non-forested areas brings a significant impact on the accumulation of greenhouse gases in the atmosphere, degrades flora and fauna habitats, and affects forest service sustainability to local populations. Forest degradation caused by high impact logging, over-exploitation for fuel wood, intense grazing that reduces regeneration, and fires are typical examples that contributes for this problem (GOFC-GOLD 2010). These actions are more prevalent in developing countries where the society relies more on forest related products. To reduce emissions in such cases, the United Nation Framework Convention on Climate Change (UNFCCC) has designed an ecosystem-based adaptation and mitigation mechanism called “REDD” (Reducing Emissions from Deforestation and Degradation). This mechanism compensates developing nations that succeed in reducing carbon emissions (Stickler, Nepstad et al. 2009). A widening of the scope of REDD was adopted by the parties to the UNFCCC during Conference Of Parties (COP) 13 in Bali. It was calling for: ‘Policy approaches and positive incentives on issues relating to REDD in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries’. Parties to the UNFCCC subsequently adopted the Cancun agreement (COP 16) with a list of safeguards for REDD+, that are designed to address both social and environmental aspects (Verchot and Petkova 2010; Epple, Dunning et al. 2011). During the global expert workshop on biodiversity benefits of REDD in Developing Countries (UNEP, CBD et al. 2010), it was indeed agreed that a well-designed REDD+ mechanism has the potential to deliver significant benefits to indigenous peoples and local communities, and bring unprecedented benefits for biodiversity.

Besides UNFCCC, various initiatives on REDD+ are being done by a number of institutions, such as the UN-REDD programme, the Global Observation for Forest and Land Cover Dynamics (GOFC-GOLD), and by other independent research institutions. These organizations work on setting guidance and standard safeguards for organizations involved in advising, verifying and funding of REDD+ activities. Today most of these frameworks are designed to implement REDD+ activities focusing on reducing greenhouse gas emissions from forest activities and do not fully address social and environmental aspects. The interest in these so-called REDD co-benefits still need to gain proper recognition. Initiatives such as the Climate, Community and Biodiversity Alliance (CCBA) and the Group on Earth Observations Biodiversity Observation Network (GEO BON) contribute to this targeting to achieve sustainable results out of REDD+ activities (Epple, Dunning et al. 2011; Gardner, Burgess et al. 2011).

Establishing a reliable system for Measuring, Reporting, and Verification (MRV) for REDD+ projects is a cornerstone in assessing implementation status and to ensure adequate compensation (Herold and Skutch 2009). Setting up of such a monitoring system is considered to be effective at assessing the impact of REDD+ projects on carbon and multiple co-benefits. The Convention on Biological Diversity (CBD) has proposed a framework and a series of indicators aimed at monitoring biodiversity at global scale (Butchart, Walpole et al. 2010). Some indicators have also been adapted for use at national and sub national level. Resources that are primarily set for carbon stock assessment can also be used to indicate change in co-benefits. For instance, data collected via remote sensing and ground measurements could also be used to provide direct and indirect data to measure biodiversity indicators as well (Teobaldelli 2010).

REDD+ MRV

Forest ecosystem based climate change mitigation projects are increasingly committed to the consideration of biodiversity issues beside their carbon emission reduction motives. The same is true when it comes to REDD+ activities. In 2008, the G8 environment ministers along with other concerned countries acknowledged the importance of addressing biodiversity as an essential part of their meeting dialogue. A decision was made to take action on developing synergistic policies that considers biodiversity and ecosystems contribution towards climate change issues. Their critical roles in regulating the climatic condition at the local, regional, and global scale were taken in to consideration. The meeting also emphasized that land-based climate change mitigation approaches, such as REDD should also promote biodiversity conservation, sustainable forest management and enhancement of forest carbon stocks. This is expected to be achieved by integrating the mitigation potential of forests and other land uses into future action to tackle climate change (SIRACUSA. and Dell'ambiente 2009). According to the international set of standards by the UNFCCC and the CCBA, these activities need to have an MRV system that indicates the project's contribution for change in carbon stock and associated safe guards. Therefore, countries are expected to create synergy between biodiversity monitoring and on-going MRV for carbon (UNEP, CBD et al. 2010). Monitoring the impacts of REDD+ activities on biodiversity is essential for determining the project's outcomes as well as implement adjustments when deemed necessary (Epple, Dunning et al. 2011). However, as there's a lack of coordinated data collection and management framework at a global level, this has restricted the identification of trends in biodiversity change and the analysis of drivers and pressures. As a result different stakeholders such as GEO-BON are operating to establish a coordinated, and globally integrated observation system that gathers and shares information on biodiversity (GEO-BON. 2012). Having a standard monitoring system is expected to enable compatible reporting at different levels (sub-national, national, global) and to aid in avoiding biased estimates. As for REDD, the challenges in monitoring biodiversity are choosing aspects to be monitored, attributing particular changes to REDD actions, and the likely scarcity of resources for biodiversity monitoring (Dickson and Kapos 2012).

Fortunately there are standards and guidelines available to help tackle these challenges, such as GOFC-GOLD sourcebook, CCB standards, factsheets and social and biodiversity impact assessment manuals (CCBA 2008; Pitman 2011; Richards and Panfil 2011; CCBA Undated). Climate, community and biodiversity alliance (CCBA) is a global partnership of leading companies and non-governmental organizations. It aims to enforce policies and markets to promote forest protection, restoration and agroforestry projects through high quality multiple-benefit land-based carbon projects. The CCB standards have become the most widely used and respected international standards for the multiple-benefits of land-based carbon projects with broad application across geographic areas and project types (CCBA 2008). Therefore, the project Design Documents (PDD) submitted are prepared according to the CCB project design standard. The general section of these documents provides a broad overview of the project's nature while the biodiversity monitoring section goes in detail and looks at the proposed methodologies to monitor project impact (Appendix 1).

1.2 Problem Definition

From the recognition of REDD as a formal activity during the UNFCCC 13th in Bali in 2007, to the current evolvement of becoming 'REDD+', several modifications on its scope and policy have been implemented (Karousakis 2009). Still some challenges exist to have REDD operational for meeting the goal set. Realizing co-benefits on REDD+ projects is one of the challenges that faces REDD+ projects (Laurance 2008). The main emphasis of adaptation and mitigation programs such as REDD has been focused in reducing approximately 1.5 Gt of annual carbon emission from clearing and degradation of forests in developing countries (Gullison, Frumhoff et al. 2007; Harvey, Dickson et al. 2010). However, such programs are expected to give a unique opportunity for advancement in conservation of tropical forests (Laurance 2008; Harvey, Dickson et al. 2010).

As the main objective of REDD activities are aimed at reducing carbon emission, co-benefits are not given adequate attention. Possible risks towards biodiversity, due to REDD projects include conversion of natural forests to plantation and other land use types that have low biodiversity value and resilience, the introduction of bio fuel crops, displacement of deforestation to lower carbon and high biodiversity areas, and afforestation activities in high biodiversity areas (UNEP, CBD et al. 2010). However, according to the UN-REDD program, there are several reasons for a broader than carbon approach to monitoring for REDD (UN-REDD 2010). It emphasizes the need for REDD+ efforts to be integrated with broader development goals, improved livelihoods, and poverty reduction. Yet, ensuring that the REDD projects will provide the desired benefits in both aspects of increasing carbon stocks, and still addressing the co-benefits will be a challenge (Brown, Seymour et al. 2008). Furthermore, integrating the co-benefit issues on the planning, design, implementation, monitoring, reporting, and evaluation of REDD+ activities will help to identify the impacts of such activities on multiple benefits (Secretariat of the Convention on Biological Diversity 2011).

The issue of biodiversity in REDD+ projects needs to be recognized by REDD+ stakeholders at the different level of implementation, since it is a defining element of forested ecosystems. The potential of carbon sequestration and storage are indeed expected to be high in biodiversity rich areas. Thus, it needs to be understood that investments in biodiversity and ecosystem services can in turn assure forest carbon stocks with long-term stability (UN-REDD 2010). Biodiversity monitoring is expected to be integrated in the REDD+ MRV to certify emission reduction projects results positive outcomes on biodiversity as well (Harrison, Boonman et al. 2012). Recently, justifiable concerns are being raised that the co-benefits must, like carbon, be real, additional and, as far as possible, measurable. The CCB standards for instance require REDD+ projects to describe their additional benefits towards the socio-economic and biodiversity conditions of project sites, and how this conditions will change with and without the influence of REDD+ projects. For arriving at some estimates, important questions related to identifying measurable indicators, finding a method of measurement, and demonstrating impact due to mitigation project activities (Figure 1) must be considered in the MRV (Richards 2011).

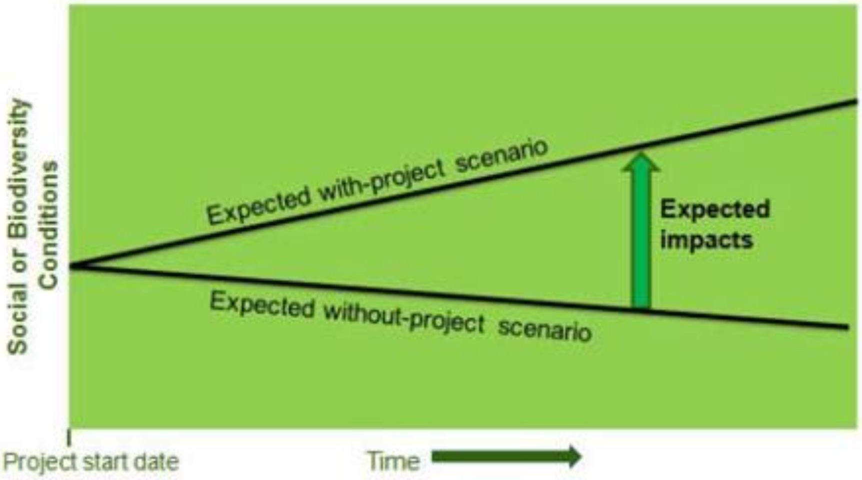

Figure 1: Graphical representation of expected net-positive benefits (source(Richards 2011))

The currently on-going REDD+ pilot projects can be used to identify gaps, obtain experience, and give a valuable opportunity for biodiversity policy makers to promote and support the inclusion of biodiversity in REDD+ MRV activities and assess their performance over time. International experiences from REDD+ demonstration activities can contribute in to policy making and system modification of international and national level activities (Karousakis 2009). However, due to the variety of forest conditions in the world (e.g., species composition, density, height, age, ecological interactions), associated ecosystem services, and diversity of drivers of deforestation and forest degradation, it is unlikely to establish a standard model of biodiversity monitoring protocol for all forest projects under REDD+ (Harrison, Boonman et al. 2012). Furthermore, gaps in coverage of already collected biodiversity data with uneven spatial, temporal and topical coverage and limited availability of long-term time series datasets is considered as an obstacle. Harmonisation of definitions, taxonomy, protocols and methods for making data exchangeable and comparable is essential in global reporting of biodiversity activities. The need for guidelines and manuals for REDD+ MRV reporting on biodiversity has been reported (Pandey 2012). Integration of biodiversity observations and data is strongly needed for sharing, assessing, predicting and modelling changes and species distributions. However, these observations on status and trend exist in an uncoordinated manner which hampers assessments on global and sub-global levels. Identifying common and region-specific indicators can enable the establishment of compatible system at the different observation levels. Hence, designing a monitoring plan for measuring impacts of REDD+ initiatives on biodiversity will demand certain capacities and resources. A minimum set of indicators and monitoring system can be used to address the changes (Epple, Dunning et al. 2011). Though in situ methods are commonly used for ecological and forest based monitoring in detailed studies, this study will investigate the applicability of remote sensing in biodiversity monitoring for REDD+ MRV. As been discussed by Roy et al., (2012), recent advancement in the fields of Remote Sensing (RS) and Geographic Information System (GIS) has enabled the acquisition and uniform documentation of biodiversity hotspots and gaps in biodiversity exploration. The applicability of remote sensing in monitoring biodiversity indicators was investigated in few research studies (Betts and Taylor 2002; Hadi, Wikantika et al. 2005; Munroe, Nagendra et al. 2007; Pacha, Luque et al. 2007). However, forest fragmentation potential for indicating change in biodiversity of forested areas could be seen as a possibility. Yet, as been argued by Tyrrell et al., (2011), it is indeed an open question as to what role MRV can play in monitoring the co-benefits of REDD+ activities.

1.3 Research objective

The general objective of this research is to provide a framework that can contribute to the establishment of an effective and comprehensive biodiversity assessment in REDD+ MRV. This study specifically aims to investigate:

- the current state of the art in biodiversity assessment of REDD+ MRV and identification of existing gaps
- the applicability of remote sensing to fill in gaps in monitoring of biodiversity indicators
- the relevance of using forest fragmentation as indicator of biodiversity change in forested areas
- the adoptability of the proposed method in to the different tiers of the International Panel on Climate Change (IPCC)

1.4 Research questions

To achieve the objective of this study, the following General Research Question (GRQ) and Specific Research Questions (SRQ) were identified.

GRQ: How can changes in biodiversity be monitored and gets further integrated in the existing capacity of REDD+ MRV?

SRQ 1: What are the international experiences on the biodiversity monitoring of REDD+ MRV? What is the state of the art, lessons learned and existing gaps?

SRQ2: What is the role of remote sensing in monitoring biodiversity, taking forest fragmentation as a single proxy?

SRQ 3: How can biodiversity change in UNESCO Kafa Biosphere Reserve be monitored using a remote sensing detectable proxy?

SRQ4: What is the potential for up-grading the proposed biodiversity monitoring system to the national level of Ethiopia’s REDD+ MRV?

1.5 Structure of the report

Chapter one of the thesis report presents the background, problem statement, research objectives and questions. Chapter two describes methodologies used to execute this study. Chapter three presents the results and discussions of the CCBA project review, literature review, and case study findings. The conclusion and recommendations are presented in chapter four. Appendices are included at the end of this report to provide detailed information on some points tackled in the four chapters.

2. Methods

2.1 Climate, Community and Biodiversity Alliance projects review

Project reports submitted to the CCBA were reviewed to extract international experiences in biodiversity monitoring of REDD+ MRV and identify existing gaps. As REDD+ is the main theme of this research, special interest was given to biodiversity monitoring exercised in these projects, while other climate change mitigation activities as Clean Development mechanism (CDM), Joint Implementation (JI), Afforestation and Reforestation (A/R), Improved Forest Management (IFM), and Community managed reforestation (CMR) were also taken to draw further experience. As the CCBA database has a large number of submitted documents of different project types from all over the world, selectivity has become a must. Therefore, certain criteria were set to consider only those projects that can be suitable for the research. Thus, project documents narrated in English were chosen for the analysis. In addition, REDD+ projects were given a priority, while other project types focusing on forest based mitigation activities were also taken to draw experiences. Global distribution of these projects was also put in to consideration.

The number of available documents per each project varied according to their CCB status. However, each project must have a Project Design Document (PDD) which is comprised of the General Section, Climate Section, Community Section, Biodiversity Section, and Gold level Section. In some cases the projects also provided an elaborated Monitoring Report (MR) along with the PDD. In such cases both of the documents were reviewed. Depending on the CCB status of the project (i.e. validated/undergoing validation), they can also have a Validation Report (VR) submitted by an external verifier. These documents were also used when found present, as they offer an inspective view over the proposed projects and also indicate gaps in the project design.

Primarily, a summary of these documents were made, and later it was fed to the summary matrix (Appendix 1). Two matrices were prepared for the analysis, where the first one presents the general aspect of the projects, while the second one specifically looks in to the proposed biodiversity monitoring techniques.

The general section matrix contained attributes that provides a border view of the projects. These attributes include type of the project, location of the project, vegetation type, area (ha), project proponent, funding, start year, crediting period (yr), CCB certifier, and CCB Status. These components have a potential to provide general information on the background of the projects, and their implementation status. For the biodiversity impact monitoring, variables extracted from the biodiversity section of the CCB standards were used. These variables are Initial plan for selecting biodiversity variables to be monitored and monitoring frequency, Initial plan for monitoring High Conservation Value (HCVs), and Commitment to developing a full monitoring plan. These biodiversity impact monitoring variables addresses the interest of this study as it provides information on the international experiences of biodiversity monitoring techniques.

The CCBA documents were further analysed by looking in depth to the ecosystem type of project areas, proposed biodiversity indicators, and specified monitoring methods. Special attention was given in to the use of forest fragmentation as indicator, and the applicability of remote sensing in biodiversity monitoring. The ecosystem types were analysed to indicate the operational regions of REDD+ projects. Biodiversity indicators used were further analysed by looking at their flora, fauna, and ecological footprint indicator combination. Emphasis was given during the report review whether forest fragmentation was monitored or not, to support the hypothesis that this indicator is a relevant proxy to monitor biodiversity in forested areas. Since the monitoring techniques were heterogeneous in character, they were assembled to generalized groups according to their nature of operation. These methods were separated into three categories: Field based, Geo-Information, and Other methods.

The Field based category contains approaches that comprise different types of ground based monitoring practices through agents of local experts and community members. The Geo-information class comprises of either remote sensing techniques or GIS based methods that are spatially oriented. For this purpose, the remote sensing definition by Bonn and Rochon (1992), “measurement of object properties on the earth’s surface using data acquired from aircrafts and satellites”, was adopted. This can be further simplified as an attempt to measure something at a distance than in-situ. The “other methods” group contains the use of existing data and interviews for biodiversity monitoring.

2.2 Forest fragmentation

A single biodiversity proxy, forest fragmentation was taken and dedicated literature were reviewed to identify fragmentation elements, its relation to biodiversity, and proposed monitoring techniques. The applicability of remote sensing in monitoring this indicator was given a priority. This review was found to be important to identify the link between forest fragmentation, habitat loss, and the likely resulting change in biodiversity.

2.3 Case study

This phase focuses on answering research question 3 using a case study area for quantifying forest fragmentation. Following the outcomes of the literature review, remote sensing potential for monitoring forest fragmentation, a proxy of biodiversity change, was investigated. A study site was chosen and further analysis on the forest fragmentation status and trend. Several geo-processing methods and approaches were used to acquire information and to make analysis on the fragmentation status of the study area. These methods were estimated to reflect on the ecological integrity and habitat connectivity of the forest.

The study site description, data types, methods and specific parameters employed are described below.

2.3.1 Study site description

This case study focuses on the UNESCO Kafa Biosphere Reserve (Kafa BR), located in the Southern Nations, Nationalities, and People’s Region, Ethiopia (Figure 2). This region has large tropical forest coverage in the country which is rich with flora and fauna biodiversity (Nune 2008). Most importantly, it is one of the last remaining montane cloud forest hosting the wild coffee arabica. It also has come to be Ethiopia’s first biosphere reserve and the first coffee biosphere reserve of the world (NABU 2011). It is currently taken as one of the local

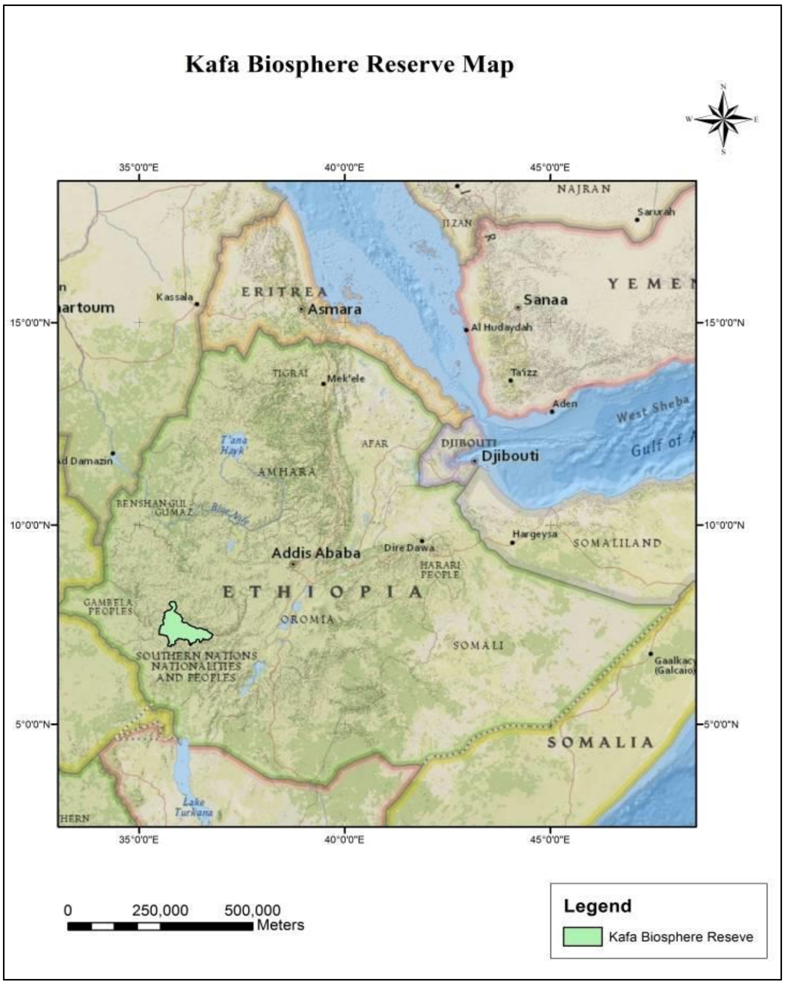

Figure 2: Location of the study area

REDD+ implementation area, comprising the Bonga, Boginda, and Mankira forests among other forests. Its altitude ranges from 500 to 3350 m.a.s.l. The Biosphere reserve covers a total area of 760.144.1 ha where 422.260.01 ha (55.55%) is covered by forest (BARD 2009).

Physical environment

Climate

Ethiopia is a tropical monsoon region with wide variation of climatic zones across the country due to topographic induced effects. The country has five (5) agro climatic zones due to altitude, rainfall, temperature variation, and agricultural production. Kafa BR is located in the Woina Dega zone which is characterised by highland areas of 1500 – 2400 m elevation, temperature of approximately 22^0C, and annual rainfall ranging between 510 and 1530mm. This zone also comprises other coffee growing, and natural forest areas of the country (BARD 2009).

The topography of Kafa BR is characterized by a varying elevation ranging from massive highlands and steep valleys, to plains and lowlands. The altitude of the area in this zone ranges from 500 m above sea level (asl) in the south, to the highest of 3,300m in the north east. This variation has influenced the climate, soil, vegetation and settlement patterns. It is also one of the wettest zones in the country receiving an average of more than 1500 mm per year. Summer (locally referred as Keremt) is time of the year where almost 40% of the rainfall is received in the region (BARD 2009).

Habitat type

The Institute Biodiversity Conservation (2009), classifies the country in to ten Ecosystem zones based on vegetation types. These zones are namely: *Afroalpine and Sub-Afroalpine*, *Montane Grassland Ecosystems*, *Dry Evergreen Montane Forest and Evergreen Scrub Ecosystems*, *Moist Montane Forest Ecosystems*, *Acacia-Commiphora Woodland Ecosystem*, *Combretum-Terminalia Woodland Ecosystem*, *Lowland Tropical Forest Ecosystem*, *Desert and Semi-desert Scrubland Ecosystems*, *Wetland Ecosystems*, and *Aquatic Ecosystems*. Within these diverse ecosystem groups various biological components of plants, animals, and microbial species exists (IBC 2005). The Kafa BR comprises Six of the above mentioned ecosystem types, which are:

- *Sub-Afroalpine* Habitat Type (altitudinal range > 3,200 m.a.s.l.)
- *Evergreen Montane Forest and Grassland Complex* (altitudinal range 1900 – 3.300 m.a.s.l.)
- *Moist Evergreen Montane Forest* Habitat Type (altitudinal range 1500 - 1900 m.a.s.l.)
- *Combretum-Terminalia Woodland* Habitat Type (altitudinal range 900 - 1900 m.a.s.l.)
- *Wetland* Habitat Type (altitudinal range 900 - 2600 m.a.s.l.)

Dresen (2011), described the percentage distribution of these habitat types in Kafa BR (Table 1), where the majority (52.1%) of the habitat type is dominated by *Evergreen Montane* Forest and *Grassland complex*.

These ecosystem types have their own unique composition of vegetation, settlement pattern; and they also serve as a host for various flora and fauna species. However, the pressure and threat on these natural habitats is pronounced due to deforestation, fire, human settlement, encroaching of agriculture and grazing, and mining (IBC 2009).

Table 1: Habitat types in Kafa BR (Source (Dresen 2011))

Habitat Type	**Area (ha)**	**Area (%)**
Evergreen Montane Forest and Grassland Complex	214986.55	52.1
Moist Evergreen Montane Forest Habitat Type	107393.28	26.1
Combretum-Terminalia Woodland Habitat Type	61307.48	14.9
Wetland Habitat Type	26832.69	6.6
Sub-Afroalpine Habitat Type	826.67	0.2
Sub-Afroalpine Habitat Type / Arundinaria alpina	492.67	0.1

The geographical distribution of these habitats were also mapped (Figure 3) by Dresen (2011)

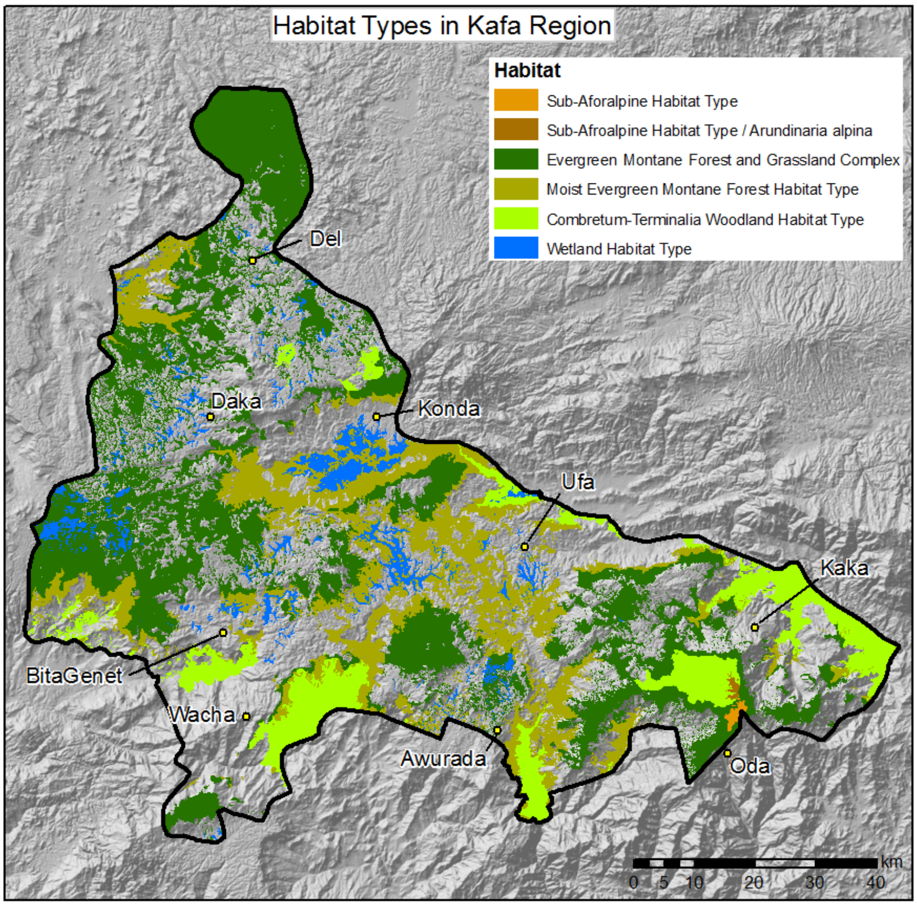

Figure 3: Habitat Types in Kafa BR (Source (Dresen 2011))

Biodiversity

The Kafa BR is located at one of the world listed biodiversity hotspot zone; which is the Eastern Afromontane Biodiversity Hotspot. All Ethiopia's endangered highland and lowland forests falls in to this hotspot zone, where in this case an approximation of 6% of the *Eastern Afromontane* hotspot are found in the Kafa BR (BARD 2009). This highly threatened ecosystem in Ethiopia is home to large number of diverse endemic species and floristic diversity (Schmitt 2006). These forests are also famous for being the genetic home of *wild arabica coffee* varieties growing in the undergrowth of the forest trees (Riechmann 2007). There has been little research done to identify the biological composition of this area, but it is coming to be a growing interest of different researchers.

Flora

According to the report by Nune (2008) on research conducted at the Bonga, Boginda, and Mankira forests of the Kafa zone, 70% of these forests were covered by natural forests of different strata, where 92 tree/shrub/liana species above 10 cm diameter were recorded. A regeneration of 57 species in Bonga, 36 species in Boginda, and 30 species in Mankira were also recorded in the sites. Bonga forest had the largest plant cover (including regeneration, saplings, herbaceous plants and grasses), followed by Mankira and Boginda forests which had a relatively lower flora density.

These forest sites have their own heterogeneous composition of flora, where 9 species in Mankira, 30 species in Bonga and 18 species in Boginda were found to be rare species. Nune (2008), and Schmitt (2006) recorded the endemic plant species present in the sites, which are namely: *Erythrina brucei*, *Milletia ferruginea*, *Solanecio gigas*, *Tiliacora troupinii*, *Vepris dainelli*, *Aframomum corrorima*, *Brillantaisia grotanellii*, *Satureja paradoxa*, *Vernonia tewoldei*, *Mikaniopsis clematoides*, *Lippia adoensis*, *Clematis longicauda*, *Clematis longicauda*, *Pilea bambuseti ssp aethiopica*, *Pentas tenuis*, *Dorstenia soerensenii*, *Phyllanthus limmuensis* and *Cyrtorchis ehrythraeae*.

The research by Bekele (2003) documented that, the Upland Rain Forest Vegetation's present in altitude of 1,500 - 2,200 m.a.s.l contains big tree species as *Olea welwitschii*, *Scheffleria abyssinica*, *Euphorbia obovalifolia*, *Croton macrostachyus*, *Albizia schimperiana*, *Prunus africana*, *Syzygium guineense*, *Polyscias fulva*. It also includes common smaller trees and shrubs such as *Milletia ferrugina*, *Teclia nobillis*, *Dracaena steudneri*, *D.afromontana*, *Galiniera saxifraga* and *Coffea arabica*. While the Upland Humid Forest Vegetation occurring in altitude of 2,450 -2,800m contains tree and shrub species such as *Hagenia abyssinica*, *Ilex mitis*, *Myrsine melanophloeos* (*Rapaenia simensis*), *Maesa lanseolata* and *Barsama abyssinica*. Whereas, the *Sinarindunaria* /Bamboo Thicket vegetation type with an altitude of 2,400 - 3,050 m are characterized by pure and mixed bamboo undergrowth, including species as *M. melanophloeos*, and *Hypericum revolutum*.

Fauna

Research conducted by Ethiopian Wildlife and Natural History Society (EWNHS) (2008), reports that a total of 294 animal species exist in the Kafa forest areas. It contains 61 mammalians, 210 birds, 10 reptile, 7 amphibians, and 6 fish species. These species are diverse as the Mammals belongs to nine orders of 26 families, while the Bird composition has 16 orders and 51 families, whereas Reptiles belong to one order of two Families, and Fishes belong to three orders and five families.

According to this survey, the Mammal group consists of: *Chiroptera* (Fruit and Insect Bats), *Insectivores* (Shrews and Hedgehogs), *Rodents* (Squirrels, Porcupines and Rats), *Primates* (Colopids, Cheek-pouch Monkey, Bush Baby), *Carnivores* (Mongoose, Dogs, Cats, Hyena, Genet and Civet), and *Even-toed Ungulates* (The Artiodactyls). Another study performed by Riechmann (Riechmann 2007), in Bonga forest site reports the existence of colobus and Vervet Monkeys and notifies about the information from the local community about the presence of Lion, Leopard, Buffalo, Elephant, Porcupine, Aardvark, Wart Hog and Forest Pig. Meanwhile, the Bird species residing in the area accounts for 61 % of the total bird families in Ethiopia. The top four families were found to be: *Accipitridae* (birds of prey), *Sylviidae* (Warblers and Cisticolas), *Turdidae* (Thrushes, Chats and Wheatears) and *Hirundinidae*

(Saw-wings, Martins and Swallows), where each family has 22, 16, 13, and 10 species respectively. In terms of movement, these bird species were categorized as residents and migrants. As for *Herpetiles* (Reptiles and Amphibians), the group includes reptiles as snakes, lizards, tortoise; and amphibians such as frogs and toads which resides in the rivers and the surroundings of Kaffa Montane forest. Meanwhile, only six species of Fish group exists in the running waters, rivers and ponds of the forest.

The Ethiopian Wildlife and Natural History Society (2008), emphasized that there are ecological imbalance both in the prey-predator and animal-habitat interactions in the area which calls for careful manipulation and management considerations in order to safeguard and maintain the diversity of animals and habitats.

Threats on forest and biodiversity in the study region

As indicated by Riechmann (2007) and supported by Nune (2008), the forest resource and biodiversity are being heavily exploited. It was reported that by 1900 almost the entire South-western Ethiopian highlands were covered by montane rainforest. Subsequently, between the years of 1971 and 1997, a large decline in forest cover of the area was recorded due to forest degradation (decline of forest quality); and deforestation occurring in the area (Reusing 2000).

Nune (2008) specified the causes of deforestation in the area, including clearing and burning of natural forest for cultivation of food crops, planting coffee (small or large scale), settlement, chasing wild animals, pit-sowing, harvesting of fuel wood, construction materials and cutting of big trees to harvest honey. These activities lead to heavy exploitation on selected trees such as *Cordia Africana*, *Pouteria adolfi-friederici* and *Prunus Africana*, hence leading these species to an endangered state. Similarly, the causes of degradation were attributed to coffee growing in the forest, livestock rearing, and harvesting of fuel wood and construction material. Clearing of the forest floor for coffee plantation affects the seedlings and sometimes saplings of important tree species as they also get to be cleared out together. Furthermore, removal of tree canopies so as to allow sun light and to eliminate competing undergrowth aggravates the situation. Livestock rearing also has its share of impact in limiting plant growth through trampling, browsing, and on breaking of young saplings and trees (Nune 2008).

The study by Dresen (2011), also indicated that the forest status in Kafa is under a severe threat mainly due to conversion of the forest in to agricultural land. This conversion is in turn resulting fragmentation and isolation of the forest; hence the remaining forest patches locate within a landscape matrix of intensively used agricultural lands. Gove et al., (2013), studied tree species density and compositions in the tropical montane sites of Bonga and their impact on bird populations. His studies on the other hand indicated that structurally and taxonomically diverse farmlands can have a similar or higher avian diversity compared with forests in all feeding guilds.

Local conservation initiatives

In order to combat the loss of forest habitats and their associated biodiversity loss, Ethiopia's government has shown its commitment through adaptation of key environmental conventions, such as the Convention on Biological Diversity (CBD), the Convention to Combat Desertification (UNCCD), the Convention on Climate Change (UNFCCC) and the Convention on International Trade in Endangered Species (CITES). As a result, these forested areas in Kafa zone have been registered and put under the management of the regional state as "Regional Forest Priority Areas" (RFPA) (Nune 2008).

Alongside the movement of the government, the German based biodiversity conservation institution NABU1 (Nature and Biodiversity Conservation Union) has been operating in the area supporting the establishment of the UNESCO Kafa Coffee Biosphere reserve (2006-2010). The Kafa BR was successfully accepted by the UNESCO "Man and Biosphere" programme in June 2010. NABU's four year project (2009-2013) aims to conserve Ethiopia's afromontane cloud forests and also improve the livelihoods of the local community (NABU 2011). Along its activities of biodiversity conservation and support of local population, the project also supports the local REDD+ implementation (geoSYSnet undated). Through this project, demonstration and pilot activities will be performed aiming to preserve 200,000 ha of Kafa's cloud forest and hence prevent an emission of two million tons of CO2 (VRD 2012).

2.3.2 Data sources and acquisition methods

Landsat Thematic Mapper (TM) satellite imagery, already existing land use land cover (LULC) maps, analysis software, and supporting literature were used to carry out this case study (Table 2). These dataset were selected based on their availability and potential to indicate the state, and fragmentation trend in the case study area. These data were mainly gathered from satellite imagery and other secondary sources (existing maps). Since no field information could be collected during the study, the training and validation points were taken from the already existing LULC datasets.

This geo-data analysis was mainly based on Landsat TM imagery, which were originally acquired by former WUR student (Tessema 2012), from the United States Geologic Service (USGS)[2] for the year 2000, 2005, and 2010. These Landsat scenes were acquired as level 1 product with radiometric correction. However, as the location of the study area is at a high altitude and in a tropical zone, it still had high cloud cover. Furthermore, as the scenes were acquired with Scan Line Corrector (SLC) off, they contained defects of alternating scan lines of missing data. Therefore these data needed to go through further pre-processing (Tessema 2012).

A Land use Land Cover (LULC) shape file data from Sustainable Poverty Alleviation in Kafa (SUPAK) 2001 project was used for establishing a training dataset for the 2000, and 2005 imagery. This dataset was initially produced to support the land use planning study of the

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[1] http://www.nabu.de/en/aktionenundprojekte/kafa/

2 http://landsat.usgs.gov/

project. The LULC, soil type, population density, forest cover and other spatial characteristics of the area were mapped. Similarly, another recent LULC shape file was also used to establish a training dataset for the year 2010. This data was acquired from the NABU office in Kafa, where Dresen (2011) performed an analysis on the forest status of Kafa BR.

Table 2: Input dataset

Data Type	Year	Specification
Landsat ETM imagery	2000, 2005, 2010	SLC off, Level one product Path: 169/170 Row: 54/55
SUPAK Dataset	2001	Land use Land cover data
Kafa LULC	2011	Land use Land cover data

To carry out the classification and geo-spatial analysis, ArcGIS, and ERDAS IMAGINE software were used. Furthermore, open source software's as, Landscape Fragmentation Tool (LFT), Graphical User Interface for the Description of image Objects and their Shapes (GUIDOS), and FRAGSTATS were employed to visualize and quantify the fragmentation status of the study area.

2.3.3 Methodology used for the study case

To analyse the actual fragmentation condition of the study site, certain classification and fragmentation analysis procedures were needed to be carried out. Figure 4 presents the main work flow for executing the case study.

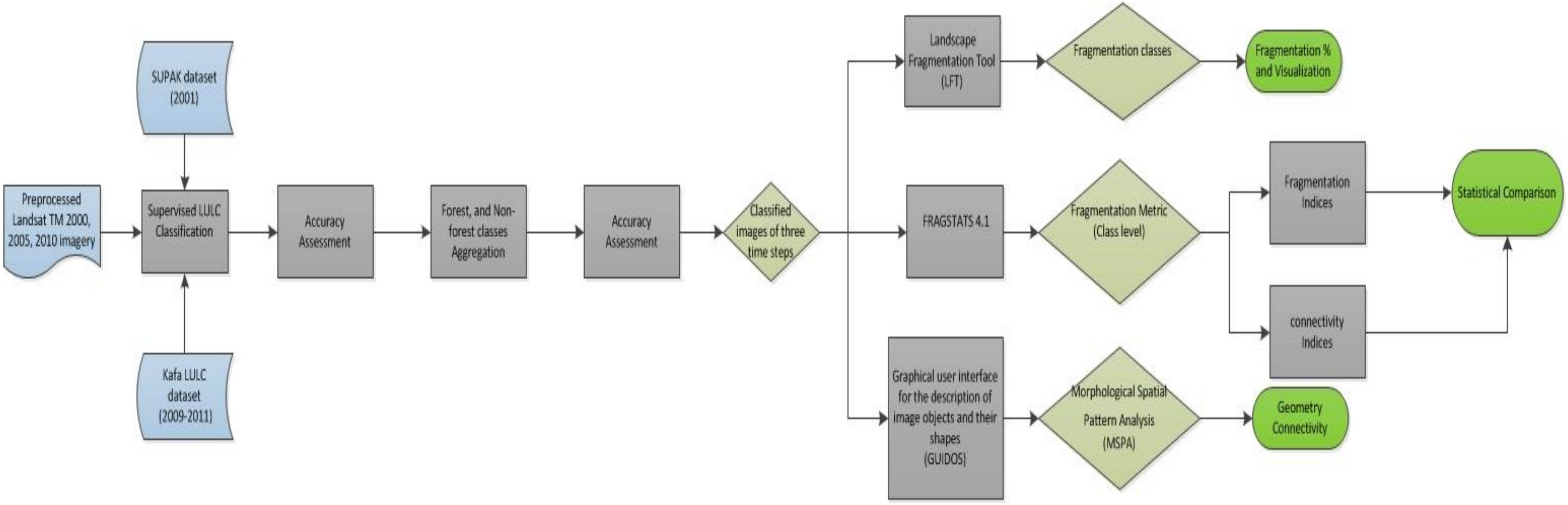

Figure 4: Case study flowchart

2.3.4 Classification

An already pre-processed set of satellite imagery by Tessema (2012) was used for proceeding with the classification. Independent random sample points were selected in ArcGIS. The selection was made so that the points fall inside the boundary of their corresponding training and validation datasets (SUPAK, Kafa LULC). These points were subsequently used in ERDAS IMAGINE to create Areas of Interest (AOI) for five distinctive LULC classes according to the training dataset. These classes were namely: Forest, Cultivation, Shrub/ Bush, Wetland, and Savannah. Spectral signatures for each class of the training dataset were acquired (Appendix 3). The signature files were further used to perform a supervised classification with a maximum likelihood function. The resulting rough classification outputs were put through a neighbouring filter (3 by 3 window; majority class selected) in ERDAS to remove the salt and pepper effect of the classified images. The process was performed to all the three time steps (2000, 2005, and 2010). Finally, accuracy assessment was performed to investigate the accuracy of the classification outputs. A total of 30 points were identified with equalized random method. Each LULC class had validation assessment points. Next, a class aggregation was performed to obtain Forest and Non-forest maps of the study area, to be further used with the forest fragmentation tools. Therefore, cultivation, shrub/bush, wetland, and savannah classes were merged to represent the non-forest areas against the forest coverage in Kafa BR.

2.3.5 Fragmentation Analysis

The fragmentation analysis of the three classification results were performed using three fragmentation analysis software packages. The Landscape Fragmentation Tool (LFT), and GUIDOS serves as a tool to map fragmentation and Connectivity, while FRAGSTATS provided means to compute landscape composition and configuration. These software requires some parameters to be specified which might be dependent on species characteristics, or in general, might depend on the research interest.

Thus, while using LFT, the forest/non forest classification images of 2000, 2005, and 2010 were consequently entered to analyse the type of fragmentation existing in the Kafa BR with a specified edge width of 100 meter, which is a commonly used value for general purpose (CLEAR undated).

The fragmentation analysis made with GUIDOS was performed using the *Morphological Spatial Pattern Analysis* (MSPA) function which provides the description of the geometry and connectivity of the image components. Geotiff image format of the classified forest/non forest data were used to perform the processing. These images had a foreground layer of forest which is the target of interest, and a background layer of non-forest which is a complement to the foreground and therefore considered as fragmenting factor. The three parameters (FG Conn, transition, intext) of MSPA were taken as a default except the edge depth, which was modified to 3 pixels so that it can match with the parameter set for LFT.

The statistical computation was made using FRAGSTATS which computes various statistical values for analysing landscape composition and configuration at Patch, class, and landscape level. The Forest and Non-forest classification maps were also used to perform this analysis. The analysis parameters (Table 3) were mostly left as default, except the search radius and threshold

Table 3: FRAGSTATS computation parameters

Parameter	Specification
Fixed Edge Depth	100 m
Neighbour rule	8 cells
Multi-level structure	Class metrics
Search radius	10,000 meter
Threshold distance	8,000 meter

distance, these were specified based on literature recommendation in considering dispersal distance (Zaitchik, Smith et al. 2002; García-Feced, Saura et al. 2011)

2.4 Up-scaling to national level REDD+ MRV

Up-scaling of the proposed monitoring method to Ethiopian national level REDD+ MRV was assessed based on the investigation made on the current initiative of Ethiopian government to launch REDD+ activities at a national level and its motives towards biodiversity monitoring. This was analysed through review of REDD “Readiness Preparation Proposals” (R-PP) and based on first hand observation of the “Ethiopia REDD MRV roadmap meeting” held in Addis Ababa, Ethiopia from October 30 - November 1, 2012.

3. Result and Discussions

3.1 CCBA project review

According to the review, 51 potential projects were identified that met the specified conditions. 22 projects out of the total were found to be REDD activities while 14 of them were CDM implementations, and the rest 15 belonged to A/R, IFM, CMR, and JI projects. In general the reviewed documents contained 43 % of REDD projects, 28% of CDM, and the rest 29% were A/R, IFM, CMR, and JI activities.

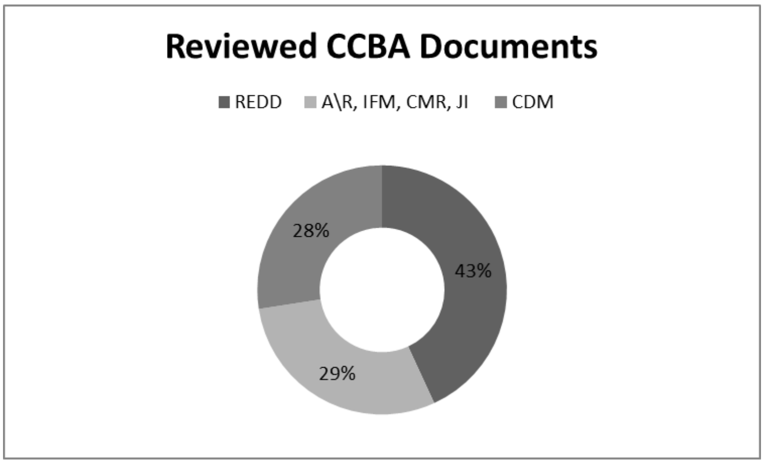

Figure 5: Share of reviewed project documents

3.1.1 Geographic Distribution

The analysis covered 22 REDD projects and 19 other non-REDD projects. Looking at the geographic distribution of these selected projects, it is observed that they are being implemented in 27 countries of the world (Figure 6a). Their distribution spreads in Africa, Asia, Australia, the Far East, North America, and South America. This diversity can give an insight to how climate change mitigation programs are taken internationally. There is however a great tendency of putting much focus to the tropical regions, especially for REDD projects (Figure 6b). The Southern parts of Africa, South America, and Asia-Pacific regions take the highest share of this distribution. These regions encompasses 11 countries of REDD implementation. Brazil has 6 Projects operating, While in Peru there are 3 projects running. Kenya, Indonesia, DRC, Colombia, and Paraguay each have 2 Projects. Cambodia, Madagascar, Mozambique, and Zimbabwe each have one on-going REDD project. These reviewed activities were found to be mainly practiced in countries with tropical ecosystem. It had also been mentioned by Harvey and Dickson (2010; 2012) that REDD+ activities have the potential to affect vegetation covers and biodiversity resources in tropical regions.

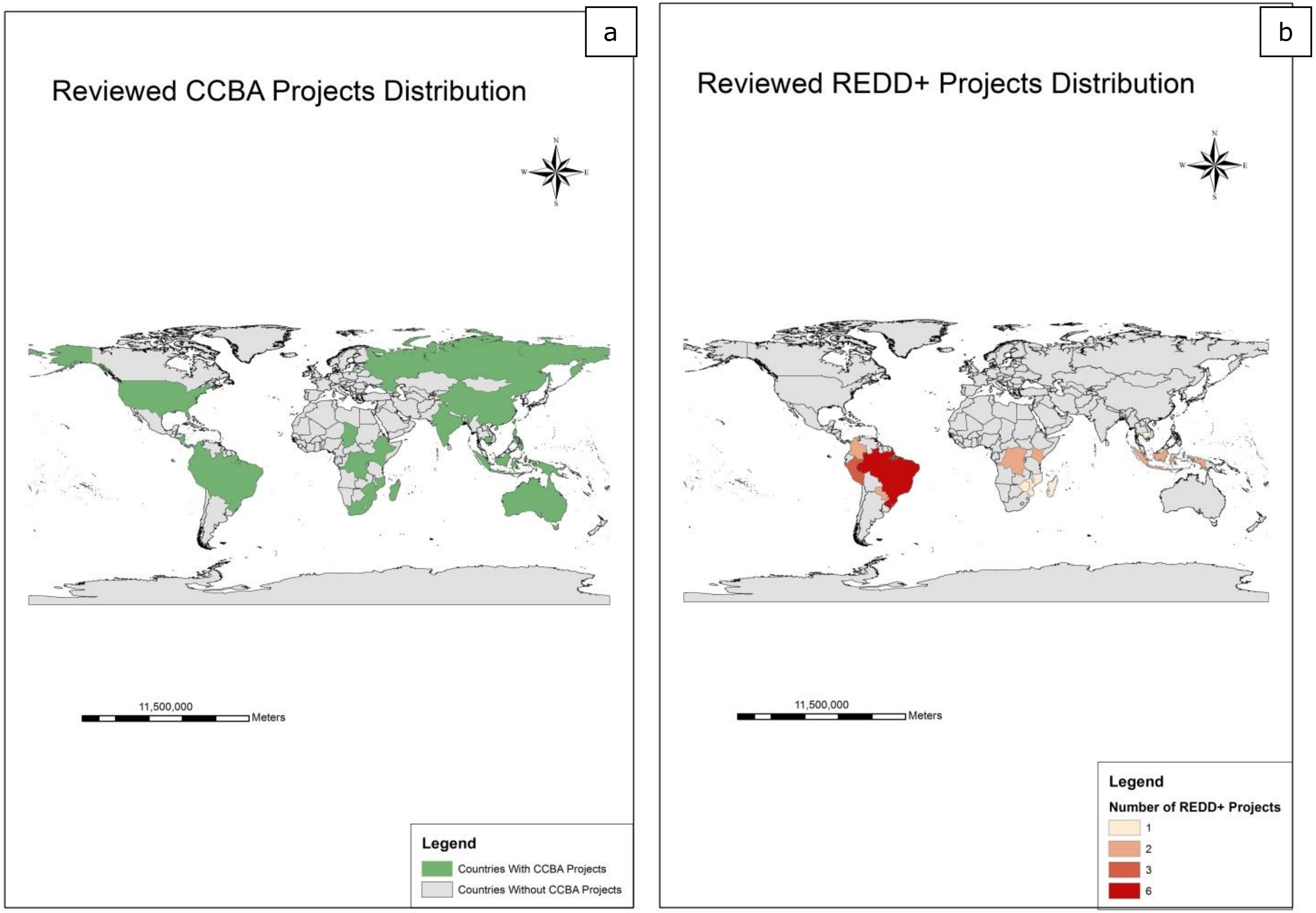

Figure 6: Reviewed CCBA Projects global distribution (a) All projects (b) REDD+ projects only

3.1.2 Biodiversity indicators

Biodiversity variables/ indicators are ecosystem or community attributes that can serve as a proxy for the health of natural systems. According to the CCB Social and Biodiversity Impact Assessment (SBIA) standards, these indicators are expected to have clear links to conservation targets and management interventions, have multiple indicators, and should make use of PSR (Pressure, State, Response) indicators. These indicators also need to be monitored with relative ease and should be reflective of local conditions (Pitman 2011).

The reviewed projects appear to be designed in a manner that coincides with these standards with an exception of one project where the indicators intended to be used were not specified. Out of the complete documents, 55% of the projects proposed a combined use of flora and fauna indicators for monitoring project impacts, while combination of flora + fauna + ecological footprint indicators were proposed in 13% of the projects, 15% used only flora indicators for monitoring, and 13% took fauna variables as sole indicators. Ecological footprint + fauna indicators also account for 4% of indicator choices.

Numerous flora indictors were proposed for monitoring. These were: species populations, change in forest cover and condition, vegetation cover, floristic composition, exotic weed and pest dominance, key economic plant species spatial distribution and growth rates, tree species and volume, total canopy, and canopy of each species. While for fauna monitoring, detailed indicators such as population density, presence of HCVs, sighting of key indicators, observed snares and traps, animal tracks and signs, habitat loss and fragmentation, maintenance of connectivity, poaching and targeted species population decline, hunting and fishing, stability of food chain, change in habitat type boundaries, and species-habitat relationship were proposed. Furthermore, ecological footprint and market related indicators were also presented such as, use of biodiversity by the community, markets, illegal activities and impacts, hunting and fishing, use of non-timber forest products, infrastructure development and spatial planning. The differences in indicator selection might be related to the nature of the ecological systems under which the projects are operating, monitoring capability, and the projects' conservation interest.

Table 4: Proposed biodiversity indicators

Indicators combination	Projects (%)
Flora+ Fauna	55
Flora	15
Fauna	13
Flora+ Fauna+ Ecological footprint and market indicators	13
Fauna+ ecological footprint and market indicators	4

3.1.3 Biodiversity Monitoring Methods

Once the indicators to be measured are determined the next task is to establish a suitable method to monitor them. Monitoring methods should produce accurate results and indicate the project impact on the biodiversity of the implementation area. The CCB standards (B3.3) sets a requirement for project designers to provide technical skills required to successfully implement biodiversity assessment and monitoring of indicators over time (Pitman 2011).

During the analysis of the CCB projects, it was observed that the proposed monitoring systems have many technical components, however, varying among projects. Though all the project proposals align with the CCB standards, their method of biodiversity monitoring were found to be heterogeneous. This can mainly be attributed to the indicators chosen for monitoring. These projects apply a combination of different methods to monitor their chosen indicators. As Figure 7 indicates, majority of the monitoring methods employ field based activities. These accounts for 77% of the total monitoring methods employed in the projects, while the use of Geo-information was only limited to 13% out of the total share. Other methods, as use of existing data, and interviews provided 10% of monitoring opportunities. Relating these biodiversity monitoring techniques to the indicators used will simplify the case since some methods can only be suitable to monitor specific indicators (Table 5).

Table 5 presents an overview of indicators and their commonly applied method of monitoring as derived from the reviewed projects. From this table, one can observe the tendency of applying field based monitoring for assessing more accessible and recognizable indicators, and for gathering up-to-date information. While coming to assessing more challenging indicators as fragmentation and connectivity, relatively sophisticated approaches as Geo-information techniques were needed. Whereas for factors which are relatively latent and need references, there was a tendency to incorporate interviews and existing historical data.

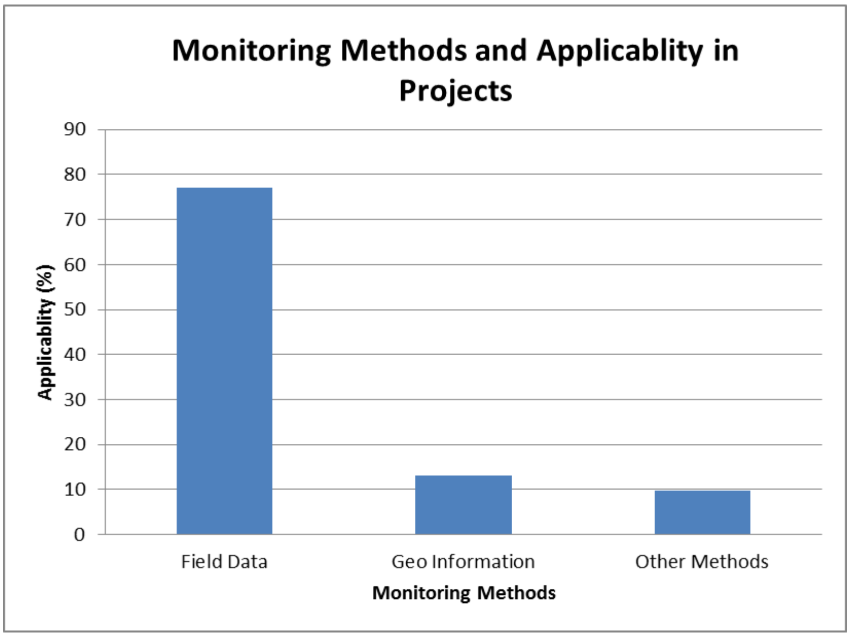

Figure 7: Proposed biodiversity monitoring methods

Table 5: Biodiversity monitoring methods vs. biodiversity indicators

Methods	Indicators
Field Based	Species counts and identification, wild life observation, species richness and change, species-habitat relationships, quality and quantity of forests, change in forest cover and condition, change in habitat type boundaries , ground cover, forest types composition, vegetation structure, number of incidents, illegal activities and markets, water resources and quality.
Geo-Information	Landscape fragmentation, habitat loss/availability, maintenance of connectivity, deforestation, deforestation rate, change in habitat type boundaries, infrastructure development, and threat assessment.
Other methods	Use of biodiversity, legal protection and impact of human activities, key biodiversity areas, infrastructure development, habitat fragmentation.

There were many cases where combinations these different techniques were needed for monitoring some indicators. Detection of landscape fragmentation with a combination of Geo-information (remote sensing) and field based operations can be mentioned as an example.

Having a detailed look of these general methods can give an implication to the most frequently practiced approaches in biodiversity monitoring.

Field Based Methods

As presented in Figure 8, the systematic approach (planned field surveys), non-systematic approach (irregular field observations), and community monitoring appears to be highly practiced. These methods provide an up-to-date and reliable ground data. Monitoring of biodiversity contents in certain sample plots and transects in a given time interval was also proposed in 10 and 9 projects respectively, while photographs and camera traps were used for 8 and 6 projects respectively. Photographs were used to document changes in habitat type while camera traps were mainly used for monitoring fauna existence. Whereas point counts and acoustic records were specifically proposed in 3 and 2 projects respectively for monitoring bird richness. Finally, quality control of water resources was also proposed in 2 projects. Community based monitoring was suggested in 20 projects. This action of involving the local community goes in harmony with the SBIA guidelines advising projects to avoid sophisticated methods and rather apply community participatory monitoring (Richards and Panfil 2011).

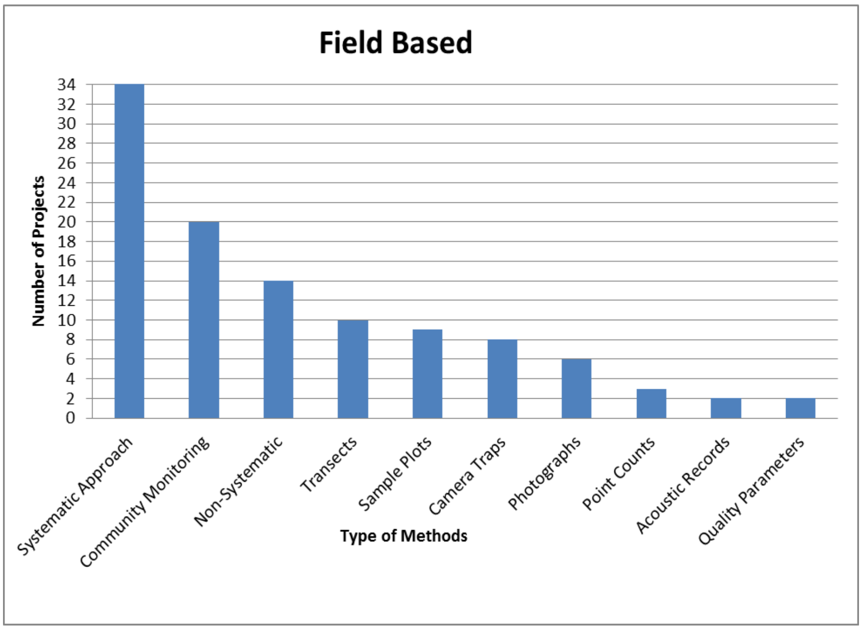

Figure 8: Field Based Biodiversity Monitoring Methods

Geo-Information

Around 15 projects took remote sensing as one component of their monitoring system. 3 projects proposed GIS operations to perform threat assessment and change detection, while aerial surveillance was proposed as a method to monitor deforestation rates. In general, the applicability of Geo-information as a monitoring method was proposed mainly for detection of landscape fragmentation and habitat loss. Remote sensing was specifically taken as a valuable tool to implement this. The GOFC-GOLD sourcebook also acknowledges that remote sensing technology cannot solely be used to monitor species richness and abundance but can be used to derive indirect proxies as habitat quality of forest (GOFC-GOLD 2010).

Other methods

Other data sources, as already existing surveys, reports, maps, and conducted interviews were also mentioned as part of the monitorng systems. Available documents on species records, market products, vegetation maps and illegal activities were employed to monitor and confirm activities and changes present in the study area. Interview was used as a method to identify species of conservation interest, and use of certain species by the society.

Non Specified

Though many of the documents (96%) has specified their monitoring method according to the CCB standards, some projects has not specifically provided their monitoring mechanisms. In some cases (Appendix 1, # 12, 48) the monitoring method has not been put for a single indicator, while in others (Appendix 1, #25, 28) the whole monitoring plan was not found present. One document (Appendix 1, #31) has specified its method was under development.

Overall, it was observed from the project review, that there is no one specific optimal methods of biodiversity monitoring. Each project adopts its monitoring system with the biodiversity content of the area and based on availability of resources, which influences the choice of indicators and proposed monitoring systems. Most of the identified monitoring systems appear to have overlapping contents, and at times are presented vaguely. Coupling of different methods (from data gathering to analysis) were observed to be common for monitoring indicators.

3.2 Forest Fragmentation and Monitoring

The effect of forest fragmentation on biodiversity loss has been discussed in literature (Saunders, Hobbs et al. 1991; Andren 1994; Debinski and Holt 2001). However, different definitions were given by authors for describing the concept of fragmentation. In this case the famous definition by Wilcove (1986) as cited in (Fahrig 2003; Pacha, Luque et al. 2007) was taken, which describes habitat fragmentation, as a “process in which a large expanse of habitat is transformed into a number of smaller patches of smaller total area, isolated from each other by matrix of habitats unlike the original” (Figure 9). As it was discussed by Fahrig (2003), the impact of forest fragmentation on biodiversity can mainly be attributed to the effect of the process in the removal of habitats.

Several impacts of forest fragmentation on flora and fauna species were taken as considerable research focus. The impact of fragmentation on pollination and plant reproduction was recognized (Aizen and Feinsinger 1994), while its consequences on species richness was studied as well(Gigord, Picot et al. 1999). Impact of fragmentation on insects was also a focus of study (Klein 1989). Furthermore, its influence on the dynamics of bird population (Hagan, Haegen et al. 2002; Newmark 2005; Rolstad 2008) and fauna population, and predator prey relationships were also recognized (Saunders, Hobbs et al. 1991; May and Norton 1996; Didham 1997; Vallan 2000).

Various methods for quantifying forest fragmentation were proposed in literature (Pfister 2004; Hadi, Wikantika et al. 2005; Lister, Square et al. 2009). Annex 2, presents fragmentation indicators, data sources and, monitoring methods used in the reviewed literature. The reviewed literature essentially recommends the use of satellite imagery and field observations for estimating forest fragmentation. In addition, elements of fragmentation considered for the monitoring were also found to be rather consistent. The monitoring methods employed were based on remote sensing technology and mainly applies landscape metrics to quantify fragmentation. Thus, it justified the hypothesis that forest fragmentation can be used as a potential proxy for assessing biodiversity status in forested areas. Furthermore it also supports the use of remote sensing and geo spatial statistics for monitoring and quantifying forest fragmentation.

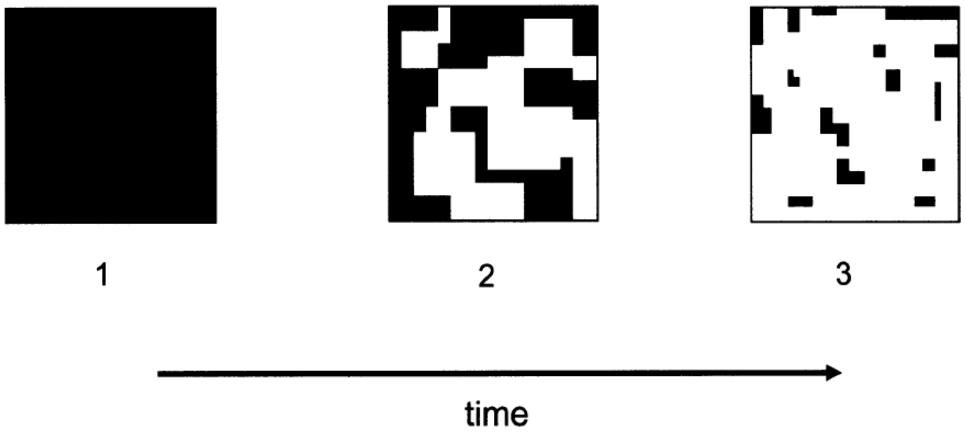

Figure 9: The process of forest fragmentation. Black areas represents habitat while white areas represent matrix, Wilcove, 1986 cited in (Fahrig 2003)

3.3 Case study results

3.3.1 LULC Classification

LULC maps were produced (Figure 10) for the three time steps. Apart from enabling visualization, these maps have the ability to indicate the share and trend of the selected LULC classes in Kafa BR. From these maps, the area and percentage share of the LULC classes were also calculated (Table 6).

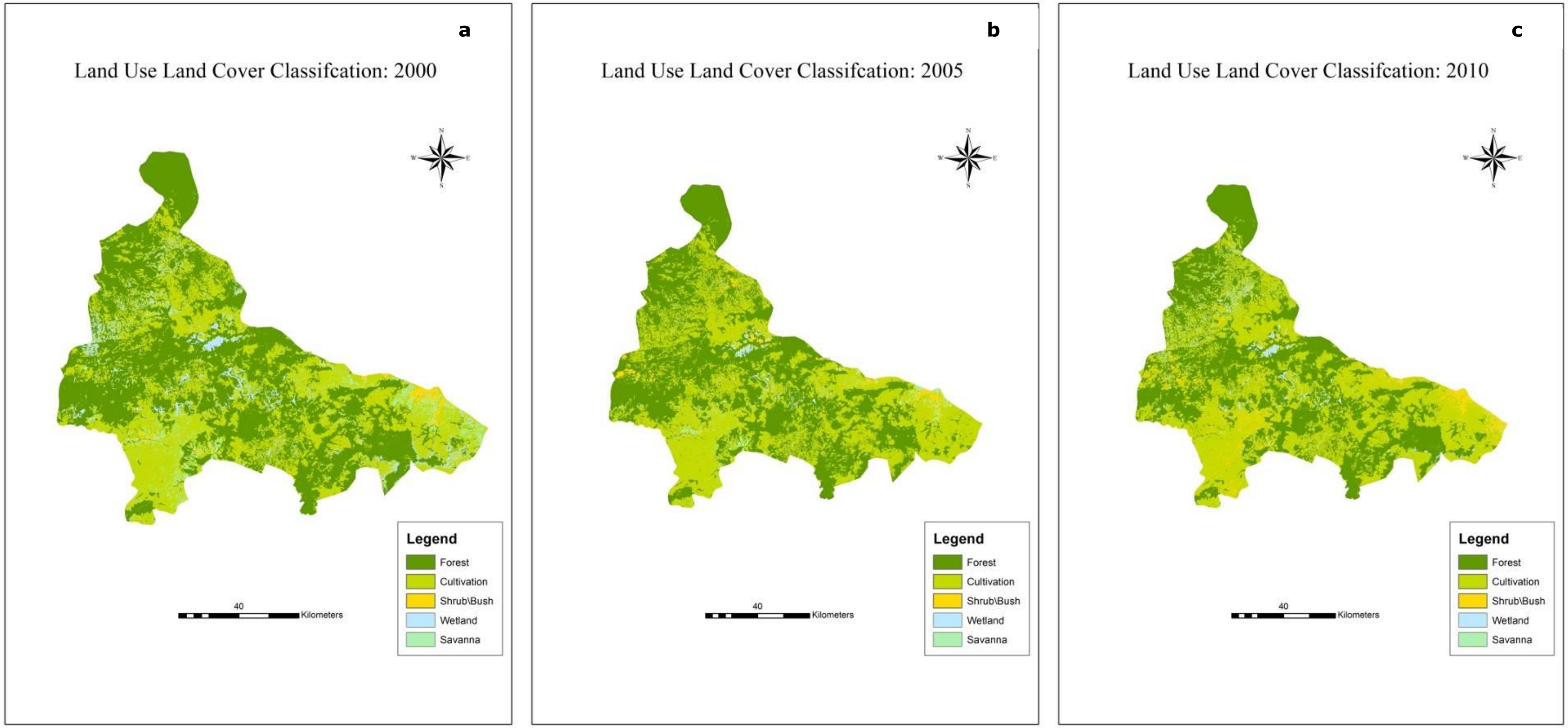

Figure 10: Land use Land cover classification of Kafa BR for year (a) 2000, (b) 2005, and (c) 2010

The classification results of the LULC classes for the three study years had a noticeable pattern (Table 6). A decline in area coverage of forest class can be observed where 1.86% of decline existed between 2000 and 2005, and another 5% decrease was observed between 2005 and 2010. On the other hand the complementary classes, cultivation and shrub/bush had an increasing share of the Kafa BR through the years. Both of these classes showed an increase of coverage in the time steps. Especially, cultivation exhibits a continuous increase, with around 6% rise from 2000 to 2005, and a 2.7% increase between 2005 and 2010. A similar study by Dresen (2011) listed agricultural expansion as one of the main forest loss drivers in the area. A declining trend was also recorded on the Savannah class while wetland presented a fluctuating trend, which can be attributed to impacts of erroneous classification due to coarseness of the imagery.

Table 6: Area coverage of LULC classes of Kafa BR in year 2000, 2005, and 2010

Year / LULC Type	2000		2005		2010	
	Area (ha)	Coverage (%)	Area (ha)	Coverage (%)	Area (ha)	Coverage (%)
Forest	390599.19	52.45	376724.16	50.59	339484.77	45.59
Cultivation	280914.48	37.72	328161.24	44.07	348688.08	46.82
Shrub/Bush	7923.42	1.06	14919.39	2.00	29522.52	3.96
Wetland	39645.45	5.32	13727.7	1.84	24326.01	3.27
Savannah	25627.77	3.44	11177.46	1.50	2664.81	0.36

3.3.2 Forest and Non-Forest Classification

Aggregation of the four LULC classes (cultivation, shrub/bush, wetland, savannah) in to a general Non-Forest class was done to make a subsequent analysis of forest fragmentation in the Kafa BR. Therefore, the following map of Forest and Non-Forest classes of Kafa BR for year 2000, 2005, and 2010 were produced (Figure 11).

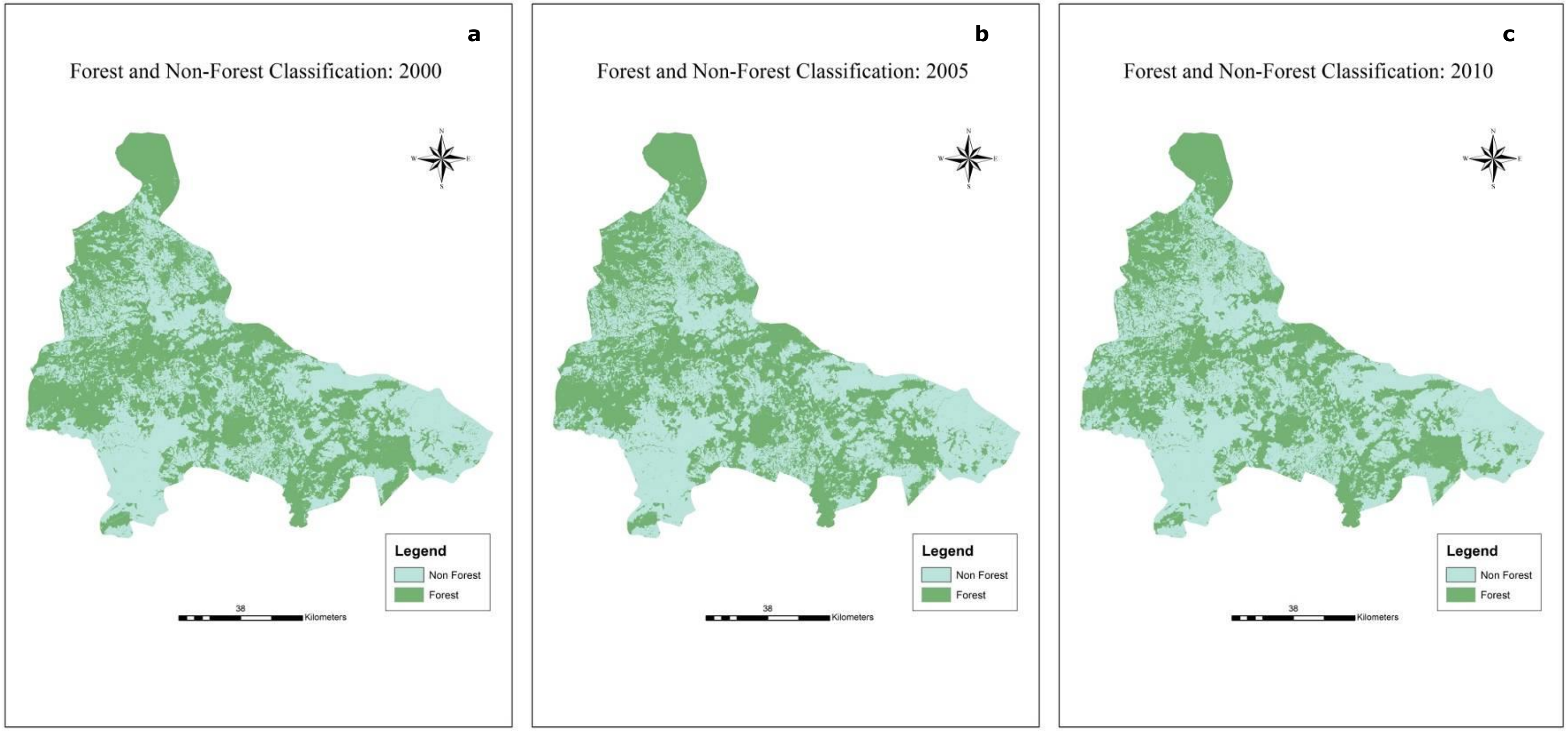

Figure 11: Land use Land cover classification of Kafa BR, year (a) 2000, (b) 2005 and (c) 2010

Table 7: Area coverage of Forest class in Kafa BR in year 2000, 2005, and 2010

Attribute	2000	2005	2010
Area (ha)	385637	371153	334117
Coverage (%)	51.8	49.8	44.9

Along with the mapping of these land cover classes, their area coverage was computed to identify the trend in Kafa BR.

The total area of the Kafa BR was found to be approximately 744.8 ha, out of which 51.8%, 49.8%, and 44.9% of the area were covered by forest in the year 2000, 2005, and 2010 respectively. These numbers resembles findings of a similar study by Dresen (2011) where the total BR area in 2011 was recorded to be 744.919 ha, having a 349.641 ha (47%) coverage of natural forest. The difference in the total area, and forest coverage can be attributed to the input data used. The research by Dresen (2011) employed satellite imagery of higher resolution (Aster, SPOT 5) and also had incorporated ground based verification.

As can be observed in Table 7, the area coverage of forest class had shown a remarkable decrease throughout the study years, resulting a counter change in expansion of the non-forest class. This classification result shows a decrease of 14484.33 ha (1.95%) in forest area from year 2000 to 2005 and another 37035.99 ha (4.97%) forest area loss between year 2005 and 2010. Similar studies carried out in the Kafa BR also confirms the decreasing trend of forest coverage in the area (Dresen 2011; Tessema 2012).

3.3.3 Accuracy assessment

The selected five LULC classes had a distinguishable spectral signature as they were demarcated by AOI (Appendix C). All the LULC classes had a distinguishable pattern throughout the spectral bands. The signature of forest had its specific character of higher reflectance in the Near Infra-Red (NIR) of the spectrum than the other land cover types due to its higher leaf area index. However, in the case of the LULC classification, the spectral signature of class wetland had a higher reflectance value, followed by cultivation and forest, which had similar reflectance in the NIR region. Savannah and shrub land cover types had resulted lower reflectance in the NIR zone.

The Error/Confusion matrix presents the accuracy assessment of the supervised classifications. These matrices provide statistical report on how accurate the randomly selected validation points were classified. Accordingly, the confusion matrix produced for the LULC classification of year 2000 showed an accuracy of 100% for forest, cultivation, and wetland, while shrub/bush, and savannah were poorly classified (< 50%). While looking in to the year 2005, it was indicated that only 33% of forest validation points were correctly classified, and Cultivation had 50% accuracy. In the meantime, wetland validation points were 100% correct, while shrub/bush had greater than 50% error, and savannah was 50% misclassified as other class. Likewise, year 2010 provided a classification result of 100% for forest and cultivation, and shrub/bush had 60% accuracy; while savannah and wetland had >50% misclassification (Appendix 3).

The overall classification accuracy for both LULC and forest and non-forest (FNF) classification is presented in Table 8.

The classification results were observed to be influenced by the spatial resolution, remaining atmospheric effects in the satellite imagery, and also the availability of independent training and validation datasets. The case study was performed using Landsat TM imagery, which had 30m*30m resolution. This was later found to be coarse for the specific LULC classification.

Table 8: Overall accuracy of LULC, and Forest and Non-Forest (FNF) classification

Year	LULC Overall accuracy (%)
2000	77.78
2005	61.90
2010	63.33

Chen et al., (2004) also acknowledges this case and informs that the choice of satellite imagery and their spatial resolution should match with type of environment, desired information, and should be compatible with methods used to extract information.

The accuracy level of the LULC classification appears rather low for the year 2005 and 2010. These images had high cloud cover and shadowing effects, which were still present even after going through pre-processing. This is especially true for that of 2010.

In addition, since there were no available training and validating dataset that can be used for the 2005 data, the SUPAK dataset that was produced in 2000/2001 was put to use in making the LULC classification. This can also promote errors in classification and accuracy of outputs. Therefore, visual checking was made to avoid errors due to possible major land cover change. Since the intention of the research is to monitor and analyse forest fragmentation and its possible impacts in biodiversity, the accuracy results of the forest class were found to be reasonably acceptable to carry on with the case study.

3.3.4 Fragmentation Analysis

The forest and non-forest classification maps were used to perform fragmentation analysis tasks. For this purpose three fragmentation analysis tools were used. *Landscape Fragmentation Tool* (LFT), and *Graphical User Interface for the Description of image Objects and their Shapes* (GUIDOS) provided visual and statistical values of the forest fragmentation, while *FRAGSTATS* gave statistical output on the composition and configuration of forest cover in Kafa BR.

Fragmentation analysis with LFT

LFT allows a pixel level classification, mapping, and change monitoring. It therefore produced a fragmentation map that presents the type of fragmentation classes existing at the Kafa BR. It provided six fragmentation classes (Figure 12 a, b, c) where each class conquers its own characteristics in terms of area and connectivity.

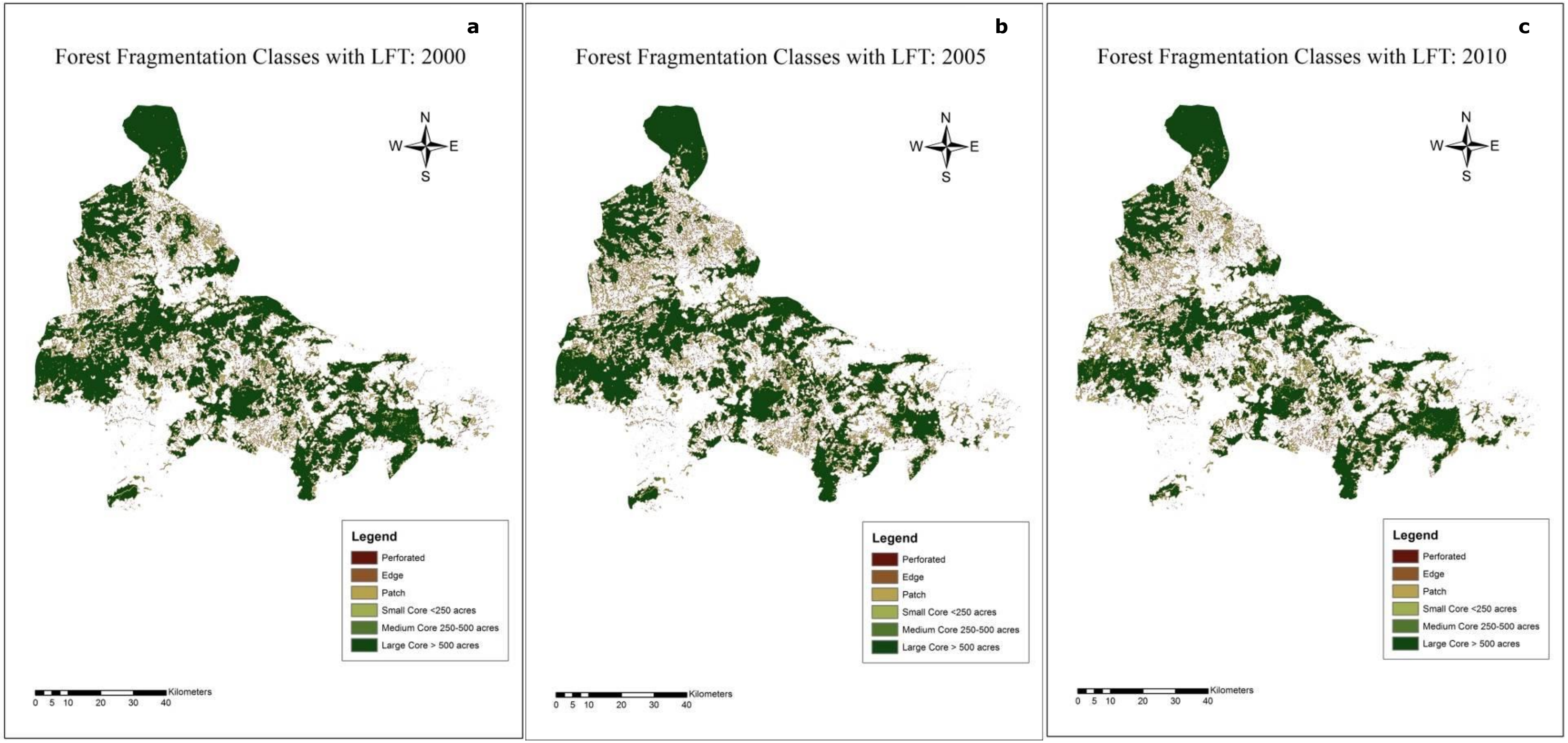

Figure 12: LFT produced forest fragmentation map of Kafa BR for year: (a) 2000, (b) 2005 and (c) 2010

Table 9: Area coverage of LFT produced forest fragmentation classes of Kafa BR in year 2000, 2005, and 2010

Fragmentation Type	Year		
	2000	2005	2010
Perforation	2.1%	3.07%	3.42%
Edge	20.91%	22.22%	23.14%
Patch	4.15%	4.2%	5.4%
Small Core <250 acres	2.59%	2.86%	3.12%
Medium Core 250-500 acres	0.95%	0.96%	1.45%
Large Core >250 acres	69.3%	66.69%	63.47%

Table 9 presents results on percentage of forest pixels that were identified under the main categories of forest fragmentation, and sub division of core areas. The coverage percentage of these classes shows a consistent pattern. The large core covers the highest share of the forest types in all years, but its share shows a declining trend. A slight decline of 2.6 % and 3.2% between 2000 and 2005, and 2005-2010 respectively was recorded. On the other hand all the other forest classes showed a rise in their share. As can be observed from the table, the large core is eventually being fragmented in to the medium and small core classes through the years. As a result those forests with smaller coverage and habitat are existing. The patch and edge categories which promotes fragmentation also shows increasing shares through the years.

Fragmentation analysis with GUIDOS

GUIDOS software was used as another alternative and complementary tool for performing fragmentation analysis. It provided visualization (Figure 14 a, b, c) and statistical outputs (Figure 15& 16) that characterized the type of fragmentations existing in Kafa BR. The results obtained provided seven fragmentation categories (Core, Islet, Perforation, Edge, Loop, Bridge, and Branch), each having their distinctive share of the biosphere area. Figure 13 presents a caption from the western part of Kafa BR, where the changes in fragmentation classes were also visible. Those areas demarcated by the circles represent fragmentations. For example the core class demarcated in year 2000 was fragmented to smaller cores in 2005 and bridge forest types existed to connect them.

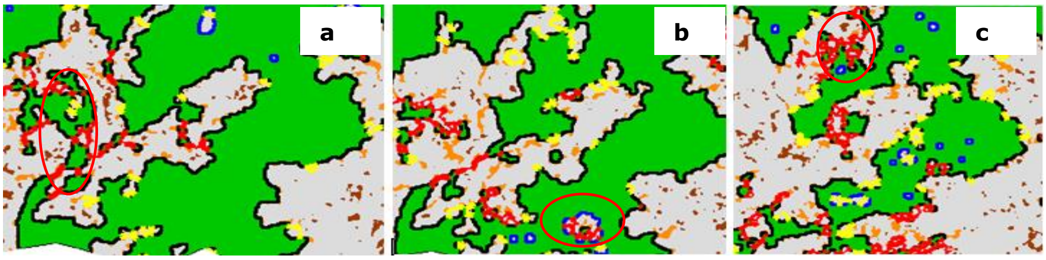

Figure 13: Change in fragmentation types in a same location: (a) 2000, (b) 2005 and (C) 2010

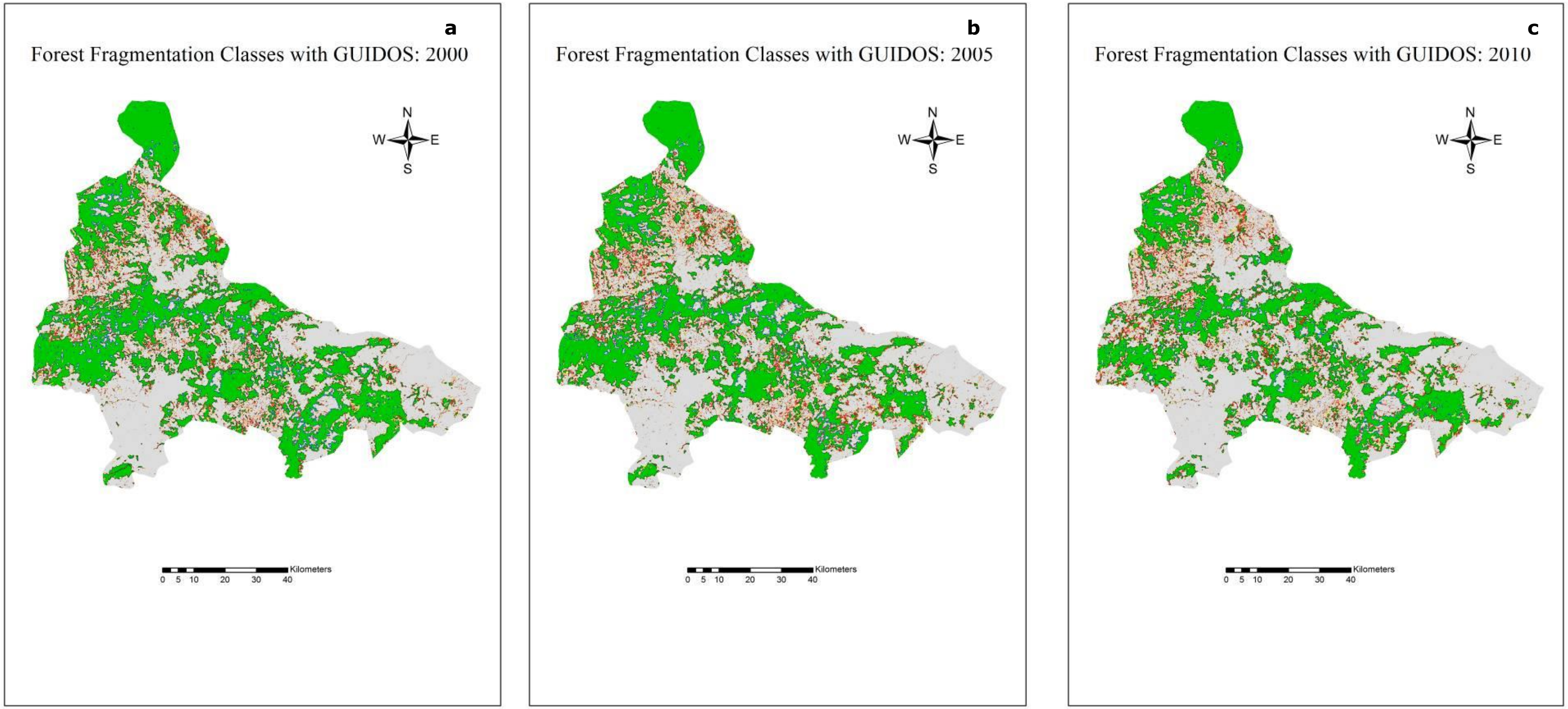

Figure 14: GUIDOS produced forest fragmentation map of Kafa BR for year (a) 2000, (b) 2005 and (c) 2010

The distribution of these classes in Kafa BR is presented in Figure 15 and 16. As can be observed, the *Core* and *Edge* classes hold higher percentage share in overall terms. However, they have different trend of change. The *Core* class which represents forest area without an effect of a fragmenting factor, showed a declining trend through the years. A 2.3% decline existed between 2000 and 2005, followed by a 2.6% decrease from 2005 to 2010. On the other hand, the category *Edge* showed a total of 1.06% increase from 2000 to 2010.

The *Islet* and *branch* categories also show a slight increase through the years (Figure 16). As the trend of fragmentation increases, loop and bridge also tends to appear more often. These fragmentation groups provide internal connectivity between same patch types and among cores respectively.

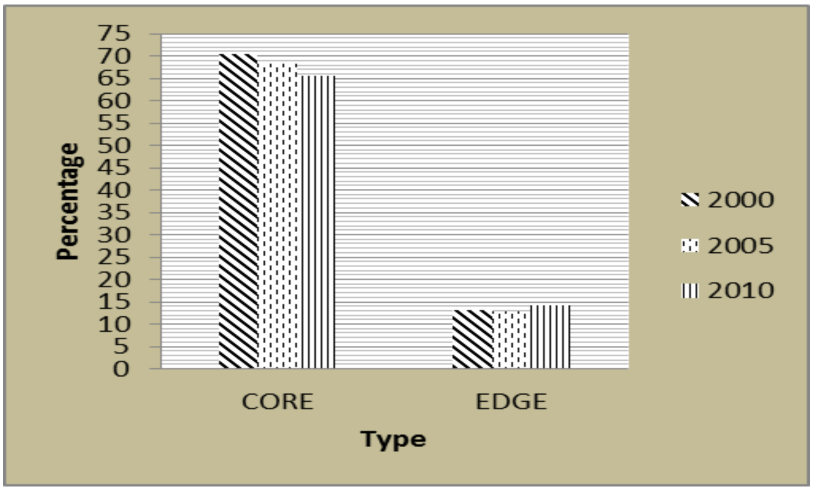

Figure 15: Percentage share of Core and Edge classes in Kafa BR, Year 2000, 2005, and 2010

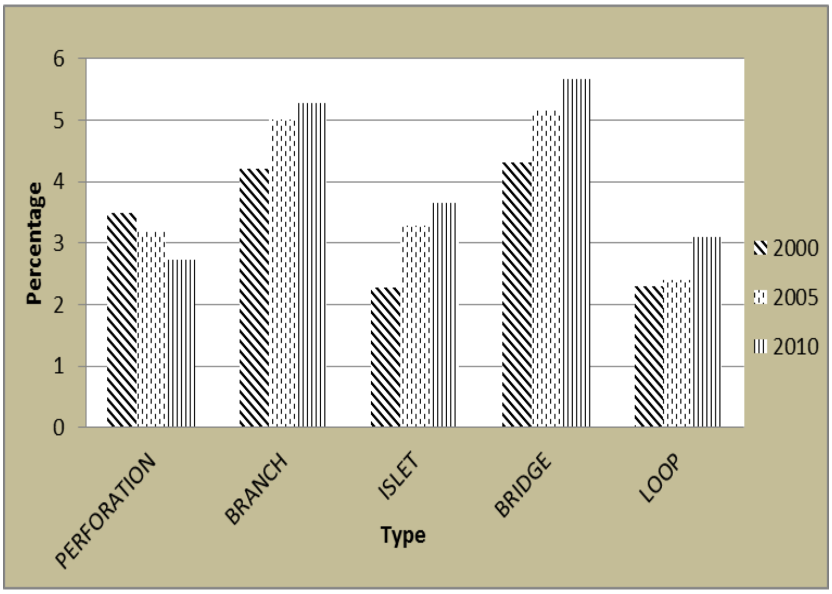

Figure 16: Percentage share of Core and Edge classes in Kafa BR, Year 2000, 2005, and 2010

Fragmentation analysis with FRAGSTATS

FRAGSTATS provides statistical indices that quantify forest fragmentation, and inner connectivity. The results of these selected indices are presented in Table 10 and 11. These results were put in to two groups based on the information they provide. The first one contains six indices which describe fragmentation (Table 10); *Number of Patches* (NP), *Patch Density* (PD), *Clumpiness Index* (CLUMPY), *Percentage of Like Adjacencies* (PLADJ), *Aggregation Index* (AI), and *Normalized Landscape Shape Index (*nLSI). The next category had two indices; *Connectance Index* (CONNECT), and *Cohesion Index* (COHESION) that specifically addresses connectivity (Table 11).

NP and PD both presents an increase in the number of patches through the study years in Kafa BR. Additional patches of 3212 existed between 2000 and 2005, while relatively smaller number of patches (224) were also created between 2005 and 2010. CLUMPY index showed a slight decline from value of 1 which represents maximal aggregation. PLADJ and AI both showed identical slightly declining values. These indices stand for degree of aggr egation and can be used in substitution. The nLSI index also provides aggregation information, where the result only increased by 0.1 to year 2010. This index indicates maximal disaggregation when the value reaches 1. Even though these indices appear to be redundant, they all conveyed similar patterns and information; an increase in subdivision or fragmentation of patches resulting decline in aggregation of forests.

Regarding the connectivity of these increasingly disaggregating forests, FRAGSTATS provides *CONNECT* and *COHESION* indices for quantification. *CONNECT* measures functional joining between patches, and reports on maximum possible connectivity given a number of patches, while *COHESION* quantifies the connectivity of habitats as perceived by organisms (McGarigal, SA Cushman et al. 2012).

Table 10: Statistical values of FRAGSTATS on Kafa BR forest fragmentation

Year	NP	PD	CLUMPY	PLADJ	AI	nLSI
2000	6218	0.35	0.95	96.4	96.49	0.03
2005	9430	0.53	0.95	95.9	95.92	0.04
2010	9654	0.54	0.94	95.5	95.58	0.04

Table 11: Statistical values of FRAGSTATS on Kafa BR forest connectivity

Year	CONNECT	COHESION
2000	3.46	99.9
2005	3.52	99.9
2010	3.7	99.8

As can be observed in Table 11, the results doesn't show seizing change of values through the years. However, a slight increase in CONNECT index can be seen. This should be related with the results of NP where an increase in number of patches was reported. Though the CONNECT index gave an increasing connectivity value, it can be argued that the growing number of patches promoted the increase in connectivity by creating forest bridges between fragmented patches. However, this does not indicate actual restoration of connectivity but rather a decline in original connectivity of the forest. The result obtained from COHESION index only showed a 0.1% decline in 2010. It should be noted that the COHESION index is only sensitive until the percolation threshold is nearly reached (UMass 2012) therefore as pointed out in a similar study by Zaitchik (2002), its results are less illustrative in measurement of dominant classes.

Over all, one can see from this fragmentation analysis results, how the forest patches are becoming increasingly disaggregated, however the status of their connectivity might be difficult to generalize. The NP and PD indices tend to provide more information on the fragmentation status of the forest while CONNECT was found to be more informative while assessing connectivity. Furthermore, it should be taken in to account that the fragmentation computations made are influenced by certain input datasets such as the spatial resolution of satellite imagery. (Benson and MacKenzie 1995; Saura 2004) investigated the effects of sensor spatial resolution on landscape parameters, and their results indicated that such indices as NP and COHESION had higher sensitivity towards grain size of input imagery. Hence, these indices tend to provide lower fragmentation with the use of coarse spatial resolution data. Higher resolution imagery might provide an opportunity to detect detailed changes and quantify the latent nature of fragmentation. The specified parameters used for computation, such as edge width, also affect the fragmentation computation results. Especially, in case of FRAGSTATS, computation of some matrices requests for inputs that might be species dependent. Defining the search radius parameter to calculate the proximity of patches, and adjusting the threshold distance to derive the connectivity of the patches can be taken as an example. Gracia-feced (2011) also emphasized that the enabling or hindering impact of the forest depends on the dispersal capability of various species. In addition, knowledge on the habitat preference (open space and compactness) of species in Kafa BR is required to analyse how this increasing fragmentation trend can affect the biodiversity species existing in the area. Still, one can speculate that forest fragmentation might result lower impact on species with longer dispersal distance, while it might hinder movement among patches for those with shorter dispersal distance. However, higher fragmentation rate might lead to increasing rate of habitat loss and also introduce other threats as increasing human impact such as hunting which can affect those species with a higher dispersal capability and poses threat to HCVs.

Finally, this fragmentation trend is expected to result declining changes in the forest habitat of Kafa BR. It can be estimated that the growing share of cultivation land in the area promotes increasing human activities in the biosphere, assisting the fragmentation of core areas in to buffer and transition zones through time. Therefore one can expect the negative impact this can have on the biodiversity population that seeks habitat from the forest. However it should be noted that the relationship between forest cover and biodiversity might not always be strong. The study by Gove and Hylander et al. (2013) in the tropical montane sites of Bonga indicated, structurally and taxonomically diversified farm lands can host similar or even higher avian diversity compared with forests. This indicates land cover types that exists after fragmentation can also impact the biodiversity status of the area. However, since field data are not present to confirm on the actual situation of the area, speculations can only be made at this stage.

3.4 Up-scaling of the proposed method to National level REDD+ MRV

Ethiopia's national level initiative towards REDD+ implementation is mainly ignited by the countries "Climate Resilient Green Economy" (CRGE) policy which aims towards environmentally sustainable growth. As one part of this motive, Ethiopia has submitted the REDD "Readiness Preparation Proposals" (R-PP) on March 2011 (EPA 2011). This document specified the national level preparation to implement REDD activities. Concerns on REDD+ strategies, reference scenarios, and monitoring and evaluating frameworks were addressed in the document. Accordingly, REDD impact towards biodiversity was proposed to be monitored by taking two indicators: the number of plant/animal species, and extent of ecological network. For this purpose the monitoring methods proposed were remote sensing (for mapping of ecological corridors), and field based forest monitoring and inventories. Though the details were not provided, the document showed that remote sensing potential for biodiversity monitoring was recognised.

The current status of the national level REDD+ activity in Ethiopia is on readiness phase. This was officially launched with the opening of a workshop in Addis Ababa in October 2012. This workshop aimed to bring together the major stakeholders operating at national and sub national level. On this meeting available datasets, capacities, experiences and other resources were assessed to identify the potential of implementing REDD+ MRV at national level. In addition, identification of stakeholders, discussion on establishment of consistent monitoring methods, and selection of suitable indicators was carried out. Even though there was a specific session during the workshop (Oct, 31st) to discuss explicitly on REDD+ MRV, the issue of biodiversity was rarely mentioned as one entity. As many have argued, the attention given to REDD+ impact on biodiversity was observed to be rather low in this case as well. A similar concept was also brought up by Dickson and Kapos (2012) where they emphasized that discussions on REDD+ monitoring have centred mainly on greenhouse gas emission and removals at national levels while undermining the impacts on biodiversity. This was mainly presented to be due to challenges related to biodiversity monitoring. However, since the R-PP document indicated that there is a room to introduce biodiversity indicators that can be monitored through remote sensing; forest fragmentation could be considered as one potential indicator. It can be implemented for recording reference scenario of forest fragmentation prior to REDD+ implementation and can be further applied to assess the impact of REDD+ activities throughout the project implementation phase.

Finally, it's expected that the proposed method can be further synchronized in to projects operating at sub-national level. As it had been expressed during the workshop, there are a number of forest based climate change mitigation projects operating at sub national level with a potential to advance to REDD+ projects. Since these REDD+ activities are at the starting phase both at national and sub national level, this can be a good stage to introduce potential biodiversity MRV systems and create harmony from the very start. Thus, forest fragmentation and its impact on biodiversity can be quantified from a bench mark at T_0 (project start) which can be taken as a baseline. Next, status of fragmentation and resulting impacts on biodiversity can be recorded and reported to the national MRV body in a defined time interval. Therefore, these consistent records from sub-national levels can be integrated to the national level REDD+ MRV. To this aim, experts in biodiversity could develop local specific translation rules from a series of forest fragmentation indices into a metric representing the state of biodiversity. These should account the local circumstances but standardised in such a way the results can be up-scaled at the national level.

4 Conclusions and recommendations

4.1 Conclusions

The study of the CCBA reports has shown that there are wide and growing operations of REDD+ activities mainly in tropical forest regions of the world. Apart from advancing the carbon sequestration capacity, the impact on the biodiversity of these forests was considered. However, as many have argued and as it has been seen on the project reviews, there are still space for improvement in advancing the attention towards REDD+ impacts on biodiversity and methods of monitoring. This study promotes the idea of using an already existing platform in REDD+ MRV to monitor subtle indicators of biodiversity change. One potential indicator was found to be forest fragmentation which can be monitored through remote sensing. The use of remote sensing is already present for monitoring carbon stock changes and can potentially be used in biodiversity monitoring too.

The relation of forest fragmentation to habitat loss and therefore its resulting impact on biodiversity was recognized from the literature review. Its ability to be used as a proxy of biodiversity change was acknowledged and the use of remote sensing in monitoring was also supported by scientific literature.

The execution of the case study showed the potential applicability of remote sensing in monitoring forest fragmentation at the Kafa BR. However, it was observed that input data sets and certain parameters can have an influence on the accuracy of the computation. For example, the classification results were influenced by the quality and spatial resolution of input satellite imagery, and availability of independent training and validation datasets. Whereas the fragmentation quantifying tools results were influenced by some specified parameters. The classification results of the three years in general indicated a decline in forest coverage of the Kafa BR. When computing the forest fragmentation, the tools used were found to be effective in providing the status of fragmentation in Kafa BR. The LFT and GUIDOS provided means to map fragmentation classes, while FRAGSTATS was found helpful for identifying detailed characteristics of fragmentation at different scale (patch, class, landscape). Even though the indices provided by FRAGSTATS were redundant, they have the capacity to report on the fragmentation trends. Overall, the result from LFT and GUIDOS showed the declining trend in core forest classes, creating smaller patches and intensifying edges in Kafa BR, while FRAGSTATS results described the details of these trends. Based on this, the increasing trend in forest fragmentation is expected to cause habitat loss, increase difficulty to access resources, hinder movement among patches, and introduce human interference in the biosphere reserve. Hence, this will hypothetically result negative impact on biodiversity. However, the findings of this case study were not coupled with the actual biodiversity change in Kafa BR due to a lack of field information on the large mammal and avian populations.

Finally, applying the proposed methodology in Ethiopia’s national level REDD+ MRV is seen as a possibility. Since REDD+ implementation is just about to kick off at a national level, this can be a good time to synchronise the method with the launching MRV system.

4.2 Recommendations

Based on the findings of the project reviews, and the case study performed, the following recommendations are made:

- Multipurpose use of existing REDD+ MRV structure must be practiced. Remote sensing capacity should be exploited to the fullest for monitoring biodiversity proxies. This will not require a lot of extra efforts and resources since the fragmentation indices can be easily computed and derived from land cover maps already produced for the MRV of carbon-related activities.

- Since fragmentation is a subtle change, application of higher spatial resolution imagery as Aster and SPOT is recommended. Monitoring of forest fragmentation (and hence biodiversity monitoring in forested regions) will benefit from the advent of higher spatial and temporal resolution imagery. The European Space Agency (ESA) Sentinel constellations and the United States Geological Survey (USGS) Landsat Data Continuity Mission (LDCM) initiatives can be considered as sources. These imagery should also be supported by updated ground based training and validation dataset which will help improve the classification accuracy.

- As forest fragmentation is only a single proxy, it should be coupled with other ground based validation data providing the actual status of change in the biodiversity species composition of the study area. This data can be acquired using the existing capacities in REDD+ MRV, and by involving the local community and authorities.

- Further research is recommended to relate how the fragmentation trend can influence the specific species in the study area.

- Finally, this approach should be integrated with REDD+ from project start at time T_o and should be performed in a defined time interval, to monitor biodiversity changes that can be attributed to REDD+ activities. Furthermore, the Possibility of synchronising this method to the national level REDD+ MRV of Ethiopia should be considered by implementing bodies.

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Appendices

Appendix 1. Climate, Community & Biodiversity Alliance: (CCBA) Review

CCB Project Design Standards

GENERAL SECTION

G1. Original Conditions in the Project Area

Concept

The original conditions at the project area and the surrounding project zone before the project commences must be described to determine the likely impacts of the project.

Indicators

The project proponents must provide a description of the project zone, containing all the following information:

General Information

- The location of the project and basic physical parameters (e.g., soil, geology, climate).
- The types and condition of vegetation within the project area.
- The boundaries of the project area and the project zone.

BIODIVERSITY SECTION

B3. Biodiversity Impact Monitoring

Concept

The project proponents must have an initial monitoring plan to quantify and document the changes in biodiversity resulting from the project activities. The monitoring plan must identify the types of measurements, the sampling method, and the frequency of measurement.

Indicators

The project proponents must:

- Develop an initial plan for selecting biodiversity variables to be monitored and the frequency of monitoring and reporting to ensure that monitoring variables are directly linked to the project's biodiversity objectives and to anticipated impacts .
- Develop an initial plan for assessing the effectiveness of measures used to maintain or enhance High Conservation Values related to globally, regionally or nationally significant biodiversity present in the project zone.
- Commit to developing a full monitoring plan within six months of the project start date or within twelve months of validation against the standards and to disseminate this plan and the results of monitoring, ensuring that they are made publicly available on the internet and are communicated to the communities and other stakeholders.

General Section

#	Variables / Project	Type	Location	Vegetation Type	Area (ha)	Project proponent	Funding	Start Year	Credit Period(yr)	CCB Certifier	Status
1	Madre de Dios Amazon	REDD	Inapari, Peru	Tropical humid rainforest	100,000	Maderacre and Maderyja	Maderacre and Maderyja	2005	20	Scientific Certification Systems (SCS)	Validation Approved
2	The Kasigau Corridor REDD Project Phase I: Rukinga Sanctuary	REDD	Taita Taveta, Kenya	Montane Forest, Dryland Forest, Savannah Grassland, Agricultural encroachment	30,168.66	Wildlife Works Carbon LLC	Wildlife Works Carbon LLC	Jan, 2006	20	SCS	Validation Approved
3	The Kasigau Corridor REDD Project Phase II: The Community Ranches	REDD	Coast Province, Kenya	Mountain Forest, Acacia-Commiphora Dry land Forest, Savannah grassland.	169,741	Wildlife Works Carbon LLC	Wildlife Works Carbon LLC	Jan, 2010	30	Det Norske Veritas	Validation Approved
4	The Rimba Raya Biodiversity Reserve Project	REDD	Central Kalimantan (Borneo), Indonesia	Tropical Peat Swamp Forest	47,237	PT Rimba Raya Conservation Ltd	Revenues from initial contracts	Nov, 2008	30	SCS	Validation Approved
5	Kariba REDD+ Project	REDD	Matabeleland North, Midlands, Mashonaland West, and Mashonaland Central,	Woodland	1,077,930	South Pole Carbon Asset Management	South Pole Carbon Asset Management, carbon-related income	Oct, 2011	30	Environmental Services, Inc	Validation Approved

			Zimbabwe								
6	Cordillera Azul National Park REDD Project	REDD	San Martín, Ucayali, Huánuco, and Loreto, Peru	Alluvial Forests, Hill Forests, Mountain Forests, Wetlands	1,351,963.8	CIMA-Cordillera Azul	USAID, Betty Moore foundation, and future : Carbon marketing	Aug, 2008	20	SCS	Undergoing Validation
7	Biocorridor Martin Sagrado REDD+ Project	REDD	San Martin, Peru	Tropical forest	313,687	PUR Project, Fundacion Amazonia Viva	PUR Project	Jan, 2010	40	SCS	Validation Approved
8	ADPML Portel- Pará REDD Project	REDD	Pará, Brazil	Dense Ombrofile Low-Land Forest, Flood forest, Flood plain area, Savanoid open area	113,026	Avoided Deforestation Project (Manaus) Limited	ADPML, revenues from carbon credit sale	Jan, 2008	40	Det Norske Veritas	Validation Approved
9	RMDLT Portel-Pará REDD Project	REDD	Pará, Brazil	Dense Ombrofile Low-Land Forest, Flood forest, Flood plain area, Savanoid open area	115,872.9	RMDLT Property Group Ltd	RMDLT, revenues from carbon credit sale	Jan, 2008	40	Det Norske Veritas	Validation Approved
10	Mai Ndombe REDD Project	REDD	Bandundu, DRC	Upland non - inundated forests, swamp forest, savannah, Inundated grassland	299,645	Ecosystem Restoration Association (ERA), Wildlife Works Carbon (WWC)	ERA, revenues from carbon credit sale	March, 2011	30	Det Norske Veritas	Validation Approved

11	Genesis Forest Project: Reforestation of Brazilian Savannah Native Species	REDD	Tocantins, Brazil	Riparian forest, ClosedSavannah, Stricto Sensu Savannah Open Savannah, Wetlands	1,076.49	Ecologica Institute	Ecologica Institute (funding from public and private companies)	May, 2009	20	-	Project withdrawn before CCB Standards validation
12	Jadora-Isandi, Reduced Emissions from Degradation and Deforestation Project	REDD	Orientale Province, DRC	Wet forest, Upland forest, Woodland	348,000	Jadora LLC	Jadora LLC	Mar, 2010	30	Rainforest Alliance	Undergoing Validation
13	The Juma Sustainable Development Reserve Project	RED	Amazonas, Brazil	Submontane Ombrophyllous Dense Forest, Lowland ombrophyllous Dense Forest, Ombrophyllous Dense Alluvial Forest	589,612.8	FAS (Amazonas Sustainable Foundation)	FAS	Jan, 2008	42	TÜV SÜD	Validation Approved
14	The Paraguay Forest Conservation Project	REDD	Itapua and Caazapa, Paraguay	High mesoxerophytic forest, Low mesoxerophytic woodland and thicket, Mesoxerophytic forest/palm savannah transition, Palm savannah.	1.68 million	Swire Pacific Offshore (SPO)	Swire Pacific Offshore (SPO)	Feb, 2011	20	Rainforest Alliance	Validation Approved

15	Makira protected forest area project	REDD	Analanjirofo, Sava and Sofia regions, Madagascar	Dense humid Eastern Rainforest	335,173	Wildlife Conservation Society (WCS)	WCS and the WCS Madagascar Program	Jan, 2005	30	Rainforest Alliance	Undergoing Validation
16	Reduced Emissions from Degradation and Deforestation in Community Forests	REDD	Oddar Meanchey, Cambodia	Lowland evergreen, Semi-evergreen, Dry deciduous forests.	64,318	Forestry Administration of the Royal Government of Cambodia	PACT Cambodia	2008	30	TÜV SÜD	Validation Approved
17	Reducing Carbon Emissions from Deforestation in the Ulu Masen Ecosystem	REDD	Aceh, Indonesia	Lowland broadleaf forest, Pine forest, Submontane broadleaf forest, Montane broadleaf forest	750,000	Province of Aceh, Fauna and Flora International, Carbon Conservation Pty Ltd	FFI	2008	30	Rainforest Alliance	Validation Approved
18	Sofala Community Carbon Project	REDD/ Agroforestry	Sofala State, Mozambique	Woodland mosaic, Riverine woodland, Dry forest	511,392	Envirotrade Mozambique Limited (EML)	Carbon Livelihoods programme	Sep, 2008	5	Rainforest Alliance	Validation Approved
19	Surui Forest Carbon Project	REDD+	Rondônia and Mato Grosso, Brazil	Tropical rain forest, Open sub-montane rain forest, Dense sub-montane Ombrophyllous Forest	31,994.2	Metareilá Association of the Suruí Indigenous People	Forest Trends	Jan, 2009	30	Rainforest Alliance	Validation Approved
20	The Paraguay Forest Conservation Project	REDD	Chaco-Pantanal, Paraguay	Atlantic Forest, Wet semi-evergreen, , Riparian forest, Secondary forest, and	69,304	Swire Pacific Offshore (SPO)	Swire Pacific Offshore (SPO)	2010	20	Rainforest Alliance	Validation Approved

				Bamboo stands							
21	The Purus Project	REDD+	Acre, Brazil	Open forest with bamboo and palms, Open forest with palms bamboo, and dense forest, Open forest with palms and dense forest, Open forest with bamboo	35,169	CarbonCo, LLC, International Group, LLC and Moura & Rosa Investments.	Carbonfund.org	Oct, 2010	30	Scientific Certification Systems	Undergoing validation
22	The Chocó-Darién Conservation Corridor	REDD	Chocó, Colombia	Undisturbed humid and very humid tropical forests Grazing land, Pasture, Intervened shrub land	13,465	Cocomasur	Cocomasur, Fondo Acción, and Anthrotect	Jan, 2011	30	SCS	Validation Approved
23	Abote community-managed reforestation program	A/R CDM	Oromia, Ethiopia	Acacia-Commiphora (small-leaved) deciduous woodland	8,119	World Vision Ethiopia	World Vision (Canada, International, Australia)	2006	30	SCS	Undergoing Validation
24	April Salumei Rainforest Preservation Project	FMA	East Sepik, Papua New Guinea	Swamp and succession (seral) swamp forests Lower montane forest Woodlands Wetlands	521,000	April Salome Foundation	April Salome Foundation	May, 2009	25	SCS	Validation Approved

25	Avoided Deforestation in the Coffee Forest in El Salvador	CDM	El Savador	Shade grown coffee plantation	160,945	Banco Multisectoral de inversiones/ FIDECAM	Banco Multisectoral de inversiones/ FIDECAM	Oct, 2007	25	SGS	Validation Approved
26	Bikin Tiger Carbon Project	JI	Primorye, Russia	The Bikin Nut Harvesting Zone (99% forest) Riparian Zone (93% wooded area)	461,500	The Tribal Commune Tiger (TCT)	WWF Germany and WWF Amur Branch (Russia)	2009	49	TÜV SÜD	Undergoing Validation
27	Boden Creek Ecological Preserve	Ecological preservation	Toledo, Belize	Wet tropical broadleaf Mixed cohune/tropical broadleaf forest Forested stream buffer Grassland Wetland	5,211	Boden Creek Ecological Preserve (BCEP)	Forest Carbon Offsets, LLC (FCO)	2010	20	SCS	Validation Approved
28	Forest Again Kakamega Forest	A/R	Western Province, Kenya	Closed indigenous forests, Plantation, Natural grass glades, Disturbed and secondary successional vegetation's	490	Eco2librium LLC	Eco2librium LLC	May, 2008	40	Rainforest Alliance	Validation Approved
29	Forest Carbon Project in Quirino Province, Sierra Madre Biodiversity Corridor, Luzon, Philippines	A/R	Luzon, Philippines	Grassland and Shrub land.	177	Conservation International (CI-Philippines)	CIP	2007	23	Rainforest Alliance	Validation Approved

30	Humbo Ethiopian Assisted Natural Regeneration Project	A/R CDM	Humbo wereda, Ethiopia	Ethiopian montane grassland Woodland Ethiopian montane forest	2,728	World Vision Ethiopia	World Vision Australia	Dec, 2006	60	JACO	Validation Approved
31	Kachung forest project: Afforestation on degraded lands	A/R CDM	Dokolo, Uganda	Degraded savannah environment	2,669	Lango Forest Company (LFC)	GRAS (Green Resource AS)	Apr, 2006	60	TÜV SÜD	Validation Approved
32	Kamula Doso Improved Forest Management Carbon Project	IFM	Middle Fly District, Papua New Guinea	Mixed tropical lowland forests, Medium Crowned forest, Dry evergreen forest, Mixed Swamp Forest	791,200	Tumu Timber Development Limited	Investment funds, Revenue from carbon credit	2009	80	Det Norske Veritas	Undergoing Validation
33	Kikonda Forest Reserve Reforestation Project	A/R	Kiboga, Uganda	Natural forest, wet land, bush-land	12,182	Global-woods	Global-woods	Sep, 2001	50	TÜV SÜD	Validation Approved
34	Watershed Restoration in the Cantareira Water System: Carbon, Community and Biodiversity Initiative	CDM	São Paulo, Brazil	Secondary forest, Degraded secondary forest, Highly degraded secondary forest	185.56	The Nature Conservancy Brazil (TNC-BR)	Dow Foundation	Feb, 2009	30	Rainforest Alliance	Validation Approved
35	Working for Woodlands Thicket Restoration Project	A/R CDM	Eastern Cape, South Africa	woodland	24,054	Republic of South Africa Department of Water (DWA)	Republic of South Africa Department of	Jan, 2004	60	SGS	Undergoing Validation

							Water (DWA)				
36	Panama Canal Authority Sustainable Forest Cover Establishment Project	A/R CDM	Panama Province, Panama	Mature forests, Secondary, Intermediate secondary forests	10,000	Panama Canal Authority (ACP)	Panama Canal Authority (ACP)	2007	20	Environmental Services, Inc.	Validation Approved
37	Philippines Penablanca Sustainable Reforestation Project	A/R CDM	Cagayan, Philippines	Grassland, Open canopy forest, Closed Canopy Forest	2,943	Conservation International Philippines	Toyota Motor Corporation (TMC)	Sep, 2007	6	Rainforest Alliance	Validation Approved
38	Protection of the Bolivian Amazon Forest Project	Habitat Protection	Pando, Beni and Santa Cruz, Bolivia	Tropical Amazon rain forests ecosystem	235	Not Specified	Carbon finance, From project proponent	2011	30	Environmental Services, Inc.	Validation Approved
39	Reducing Carbon Emissions by Protecting a Native Forest in Tasmania	IFM	Tasmania, Australia	Temperate rainforest	1,433.9	REDD Forests	REDD Forests	February 2009	25	SCS	Validation Approved
40	Reforestation of Degraded Land in Chhattisgarh, India	A/R CDM	Chhattisgarh, India	Tropical Moist Deciduous forest Tropical Dry Deciduous forest.	282	Prakash Industries Limited (PIL)	Prakash Industries Limited (PIL)	2002	20	Rainforest Alliance	Validation Approved
41	Restoration of degraded areas and reforestation in Cáceres and Cravo Norte,	A/R CDM	Cáceres and Cravo Norte, Colombia	Grassland Gallery /evergreen forests	11,000	Asorpar Ltd	Asorpar Ltd	2002	30	Environmental Services, Inc.	Validation Approved

	Colombia										
42	Reforestation project in Yingjing County, Sichuan Province	A/R CDM	Sichuan, China	Evergreen broad-leaved forest, Deciduous broad-leaved forest, Cold temperate coniferous forest, Temperate coniferous forest, Meadow grass, Bamboo grove	779.13	Nibashan Farm	Conservation International (CI)	2011	30	TÜV NORD	Undergoing Validation
43	Reforestation with Native Species in the Pachijal and Mira River Watersheds for Carbon Retention	ARR CDM	Pichincha and Imbabura provinces, Ecuador	Montane cloud forest, Pre-montane evergreen forest, Coastal foothills evergreen forest	383.5	Mindo Cloudforest Foundation (MCF)	Mindo Cloudforest Foundation (MCF)	Nov, 2011	20	Rainforest Alliance	Undergoing Validation
44	Restoring a Forest Legacy at Marais des Cygnes National Wildlife Refuge	A/R IFM	Kansas, United States	Temperate broadleaf and mixed Grassland, shrubland, Agricultural crops	314	US Fish and Wildlife Service, The Conservation Fund	USFWS	2008	100	SCS	Validation Approved

45	Restoring a Forest Legacy at Mingo National Wildlife Refuge	A/R IFM	Missouri, USA	Forested wetland, Upland forests, Oak hardwood bottomland forests, Agricultural fields	8738	US Fish and Wildlife Service, The Conservation Fund	USFWS	2010	100	SCS	Validation Approved
46	Return to Forest, Nicaragua	Reforestation	Rivas Province, Nicaragua	Forests and Natural Areas, Pastures and Agriculture	406	Paso Pacifico	Paso Pacifico	2007	40	Rainforest Alliance	Rainforest Alliance
47	Sodo Community Managed Reforestation (Forest Regeneration) Project	CMR	Mt Damota, Ethiopia	Forests Shrubland in montaine moist condition.	503	World Vision (Ethiopia, Australia)	World Vision	2006	35	Rainforest Alliance	Undergoing validation
48	Sustainable Agriculture in a Changing Climate	A/R CDM	Nyanza District, Kenya	Degraded agricultural land, Remaining dense forest	208,185	CARE International	CARE International	Sep, 2010	35	Environmental Services, Inc	Undergoing validation
49	The Australian Wet Tropics Region Biocarbon Sequestration Project Based on Regional Natural Resource Management	ARR/IFM/REDD	Queensland, Australia	Wet tropics bioregion	730	Degree Celsius	Terrain NRM Ltd, Biocarbon Pty Ltd	2007	30	-	withdrawn before CCB Standards validation
50	The Community Ecosystem Restoration	A/R	British Colombia, Canada	Temperate coniferous	350	Ecosystem Restoration Associates	Ecosystem Restoration Associates (ERA)	Sep, 2005	100	KPMG Forest Certification Services	Validation Approved

	Project					(ERA)					
51	The Monte Pascoal - Pau Brasil Ecological Corridor: Carbon, Community & Biodiversity Initiative	A/R CDM	Bahia, Brazil	Tropical moist Atlantic Forest	17.4	Instituto BioAtlântica		2002	30	Rainforest Alliance	Validation Approved

Biodiversity Monitoring Section

#	Variables Project	B3.1. Initial Plan for selecting biodiversity variables to be monitored, and monitoring frequency			B3.2. Initial plan for monitoring HCVs	B3.3. Commitment to developing a full monitoring plan
		Indicators Used	Methods Applied	Monitoring Frequency		
1	Madre de Dios Amazon	Population density of fauna indicator species % of seedling and remnant tree of flora indicator species	Systematic field based Non-systematic field based	Annual	Not specified	Not specified
2	The Kasigau Corridor REDD Project Phase I – Rukinga Sanctuary	Number of poaching incidents Species populations Wildlife-human conflict	LEM	Measured daily and reported annually	Are covered by the standard monitoring as outlined in 3.1	within 12 months of validation against CCBA standards.
3	The Kasigau Corridor REDD Project Phase II – The Community Ranches	Species population count	Transects Camera traps	Measured Daily and reported annually	Are covered by the standard monitoring as outlined in 3.1	within 12 months of validation against CCBA standards.
		Number of poaching incidents	LEM/CPM			
		HCV species population statistics Number of cattle grazing incursions Acres deforested in project area and Zone Acres reforested in community land	LEM			
4	The Rimba Raya Biodiversity Reserve Project	Change in forest cover and condition	RS/non-systematic field based	Annual	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
		Plant and wildlife population Quality and condition of aquatic habitats Fires	Systematic field based	Quarterly interim reports and annual summary.		
5	Kariba REDD+ Project	Number of wire snares encountered Number of poached game	Non-systematic field based	At least every 5 years	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
		Number of tree species on permanent carbon monitoring plots.	Systematic field based			
6	Cordillera Azul National Park REDD Project	Deforestation, areas with disturbance	RS	Annual	Are covered by the standard monitoring as outlined in 3.1	Not specified
		Presence and abundance of HCVs	LEM	Quarterly measurements and annual analysis		

		Information on key species	Reports	Monthly measurements and annual analysis		
7	Biocorridor Martin Sagrado REDD+ Project	Community information about conservation project	Survey	Five years	Are covered by the standard monitoring as outlined in 3.1	Within Six months of the project start date.
		Number of hectares of degraded forest in project area Number of hectares burned last year	Systematic field based	Annual		
		Number of sightings of key indicator species	Camera traps			
8	ADPML Portel- Pará REDD Project	Area-limited species	CPM, Non-systematic field based	Monthly	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
		Resource-limited species	CPM, Systematic field based	Monthly		
		Process-limited species	CPM, Non-systematic field based	Every 2 months		
		Invertebrates groups	CPM, Non-systematic field based/Systematic field based	Every 2 months		
		“Special interest” species	CPM, Non-systematic field based	Monthly		
		Bryophytes to assess environmental quality	CPM, Systematic field based	Every 2 months		
		Land use and changes in vegetation cover	CPM, Non-systematic field based	Weekly		
9	RMDLT Portel-Pará REDD Project	Same as #8	Same as #8	Same as #8	Are covered by the standard monitoring as outlined in 3.1	Validation Approved
10	Mai Ndombe REDD Project	Quality and quantity of native forests Status of species and habitat Frequency/intensity of anthropogenic impacts Progress on implementation status of project activities	CPM	Annual	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
11	Genesis Forest Project: Reforestation of Brazilian Savannah	Natural communities	Non-systematic field based	Biannual	Not specified	Not specified
		Use of biodiversity				

	Native Species	Species of conservation interest	Interview	Annual		
		Vegetation cover	RS			
		Legal Protection Impact of human activities	Survey	Biannual		
		Water resources	Quality parameters			
12	Jadora- Isangi, Reduced Emissions from Degradation and Deforestation project	Identifying animal tracks, signs and scat	Systematic field based	Annual	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
		Number of observed snares and traps Quantity and variation in bush meat trade	Survey (Market) Photograph	On market days		
		List of fauna	Non-systematic field based LEM	Annual		
		Hunters, fisherman's, traps, camps	LEM Reports	Not specified		
		Deforestation rates	Not specified	Annual		
13	The Juma Sustainable Development Reserve Project	Presence and quantity of animals	CPM, Non-systematic field based	Every 15 days	Not specified in the PDD	Not specified in the PDD
		Data on production, marketing, and sale of fish at the major docks of the municipality	CPM, Systematic field based	Daily		
		Transit of boats at strategic points in the protected area	CPM, Non-systematic field based			
		Information on natural resource use	CPM, Systematic field based	Weekly		
14	The Paraguay Forest Conservation Project	Important bird areas Important biodiversity areas	REA Systematic field based	Every 5 years	Are covered by the standard monitoring as outlined in 3.1	Monitoring plan is already developed
15	Makira protected forest area project	Habitat loss and fragmentation	RS/Systematic field based	Two years/Annual	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA
		Species loss and density estimation Poaching and targeted species population decline	LEM/Transect/Camera traps			
		Maintenance of connectivity	Systematic field			

			based/RS/GIS	Bi-annual		standards.
		Erosion	Quality parameters			
16	Reduced Emissions from Degradation and Deforestation in Community Forests	Land Use Land Cover (LULC) change	RS	Every 2 years	Are covered by the standard monitoring as outlined in 3.1	Within Six months of the project start date.
		Natural disturbances and events	CPM/Systematic field based	AO		
		Illegal activities and impacts on site		Monthly		
		Presence of key indicator species Nests of important species	CPM/Systematic field based Camera traps			
17	Reducing Carbon Emissions from Deforestation in the Ulu Masen Ecosystem	Vegetative cover	RS	Not specified	Not specified	Not specified
		List of complete mammal and bird species	Camera traps			
		Water resources Soil surveys	Systematic field based			
18	Sofala Community Carbon Project	Landscape fragmentation/ degradation Encroachment at park boundaries	RS	Annual	Are covered by the standard monitoring as outlined in 3.1	Within Six months of the project start date.
		Floristic composition and status of vegetation type Tree biodiversity	Systematic field based/LEM			
		Difference between project area and non-project area	BDI			
19	Surui Forest Carbon Project	Hunting and fishing monitoring	LEM, Systematic field based	Every 7 days	Are covered by the standard monitoring as outlined in 3.1	Will develop the full monitoring plan after validation against CCBA standards.
		Biological inventories (mammals, birds, reptiles, fish)	Non-systematic field based, Systematic field based	Every 4 years		
		Use of non-timber forest products	Survey	Every 6 months		
20	The Paraguay Forest Conservation Project	Identify and monitor key biodiversity areas	National biodiversity survey REA	Five years	Are covered by the standard monitoring as outlined in 3.1	Within Six months of the project start date.
21	The Purus Project	Habitat loss/ availability	RS	Annual	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA
		Deforestation rate	Aerial surveillance/Non-systematic field based	Weekly/semi-monthly		
		Diversity /population of medium –to-large mammals	Camera traps			

		Project activities and outcomes	Theory of change			standards.
22	The Chocó-Darién Conservation Corridor	- Structure and composition of the ecosystem: (Climatic units, Hydrological units, Flora species, Fauna species, Endemic flora and fauna, Dominant species, Associated species, population structure, Fragmentation etc.) - Ecosystem Functioning: (Type of land use, Disturbance, Inter-species interaction etc.) - Ecosystem health: Invasive species, presence of contaminants, change in state of soil, change in watercourses etc.) - Goods and services provided by the ecosystem: (Biomass, Basal area, population density, change in species dominance, change in species density etc.)	Non-systematic field based Systematic field based RS	Annual /in some cases twice a year	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
23	Abote community-managed reforestation program	Sprouting, Enrichment, Dominant species	Non-systematic field based/ Systematic field based/Reports	Annual	Are covered by the standard monitoring as outlined in 3.1	Within Six months of the project start date.
		Cup trees		Every 6 months		
		Endangered species, Local species, Exotic species	Systematic field based/Reports	Annual		
		Wildlife	Systematic field based			
24	April Salumei Sustainable Forest Management Project	Land cover changes Integrity of natural communities	RS/Systematic field based/LEM	Annual	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
		Infrastructure development Spatial planning	RS/Survey			
		Information on forest area and communities Availability of Natural resources Maintenance of ecosystem services use and consumption of BD Exotic weed and pest dominance	Systematic field based/LEM			

		Water quality Bird species abundance Mammal species abundance		Immediate/Annual		
		Ecosystem disruption (fire, illegal logging) Contiguous forest cover	Systematic field based /RS/LEM			
25	Avoided Deforestation in the Coffee Forest in El Salvador	Abundance indicator of plant or bird species Relationship between area and number of species present	Not specified	Not specified	Not specified	Not specified
26	Bikin Tiger Carbon Project	Balance of the mammal population, Stability of the food chains, Water purity and biodiversity			Are covered by the standard monitoring as outlined in 3.1	A full monitoring plan is already developed
		Tiger monitoring	Non-systematic field based/Systematic field based	Seasonal (summer/Winter)		
		Bird Monitoring	Non-systematic field based/Systematic field based	Seasonal (Summer)		
		Fish Monitoring	Non-systematic field based/Systematic field based	Seasonal (Autumn/Winter)		
27	Boden Creek Ecological Preserve	Bat Species Assemblage	Acoustic detectors	Every 5 years	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
		Medium-Large Mammal Assemblage	Camera traps			
		Observations of IUCN listed species	Systematic field based			
28	Forest again Kenya	Fragmentation analysis Bird species persistence Habitat analysis	Not specified	Annual	Are covered by the standard monitoring as outlined in 3.1	Will develop full monitoring plan by Feb, 2010
29	Forest Carbon Project in Quirino Province, Sierra Madre Biodiversity Corridor, Luzon, Philippines	Trends in population of indicator/priority species Change in land uses Changes in species composition, Abundance and richness in the birds and bats.	BMS Systematic field based Transect Photographs CPM	Annual	Not specified	Not specified

30	Humbo Ethiopian Assisted Natural Regeneration Project	Not specified	CPM LEM	Every 5 years	Not specified	Not specified
31	Kachung forest project: Afforestation on degraded lands	Species abundance and its richness, Species diversity, Species composition in a given strata, Effects of reforestation to their habitats	Under development	Annual	No HCV is present in the area.	Within 12 months of validation against CCBA standards.
32	Kamula Doso Improved Forest Management Carbon Project	Flora inventories Aquatic invertebrate and diatom assemblages Key economic plant species spatial distribution, growth rates, phenology, seedling establishment and Survival	Systematic field based/CPM Survey	Not specified	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
		Fauna survey (birds, butterflies)	RBA Parataxonomy			
33	Kikonda Forest Reserve Reforestation Project	Flora- inventories Fauna inventories Habitat fragmentation of certain species	Sample plots Systematic field based Transect BDI	2-5 years	Not specified	Not specified
34	Watershed Restoration in the Cantareira Water System: Carbon, Community and Biodiversity Initiative	Landscape connectivity and fragmented size	RS/GIS	Not specified	Not specified	Not specified
		Bird Assessment	Systematic field based			
		Threat assessment	GIS			
35	Working for Woodlands Thicket Restoration Project	Species count Insect traps	Sample Plots	Every five year	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards.
		Record plant, bird, mammal, and reptile species	Transect			
36	Panama Canal Authority Sustainable Forest Cover	Change in habitat type boundaries Change in total area of a particular habitat type	RS/ Vegetation Maps /GIS photographs	Every 5 years	Are covered by the standard monitoring	Within 12 months of validation

	Establishment Project	Change in number and composition of species Change in abundance and distribution of keystone/indicator/species of special interest	Systematic field based Transect	Annual	as outlined in 3.1	against CCBA standards
37	Philippines Penablanca Sustainable Reforestation Project	Change in habitat type boundaries Change in total area of a particular habitat type	RS/Vegetation Maps Fixed point photography BMS	Every 3 years	Are covered by the standard monitoring as outlined in 3.1	full monitoring plan has already been developed for the project
		Change in number and composition of species Change in abundance and distribution of keystone/indicator/species of special interest	Transect/CPM	Seasonal (Dry, wet)		
38	Protection of the Bolivian Amazon Forest Project	Tree species Tree volume (DBH)	Systematic field based	Every 5 years	Are covered by the standard monitoring as outlined in 3.1	Within Six months of the project start date.
39	Reducing Carbon Emissions by Protecting a Native Forest in Tasmania	Vascular plant species richness	Sample Plots Systematic field based	Every 5 years	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards
40	Reforestation of Degraded Land in Chhattisgarh, India	Animal/ Plant species names Number of encounters Species richness	Systematic field based	Every 5 years	Not specified	Not specified
41	Restoration of degraded areas and reforestation in Cáceres and Cravo Norte, Colombia	Increase in forest cover Fauna and flora species	Sample Plots Systematic field based Photographs	Every 5 years	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards
42	Reforestation project in Yingjing County, Sichuan Province	Flora: Total species, Number of each species, Total canopy, Canopy of each species, Height of each tree, DBH of each tree	Sample Plots Systematic field based	Every 5 years	Not specified	Not specified
		Amphibians: species, number of each	Sample Plots			

		species, Traps				
		Small mammals: hole number, number of small mammals . rodent holes	Sample plots			
		Bird: species, number of each species Large mammals: trace type, trace number, mammal species, location	Sample Plots Systematic field based Infrared camera trap			
43	Reforestation with Native Species in the Pachijal and Mira River Watersheds for Carbon Retention	Birds richness	Point counts Transects Systematic field based	Not specified	Are covered by the standard monitoring as outlined in 3.1	Within six months of project start/12 months of validation against CCBA standards
		Avifauna census		Annual		
44	Restoring a Forest Legacy at Marais des Cygnes National Wildlife Refuge	Bird species richness Changes in bird species richness	Systematic field based	Annual Every 5 years	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards
45	Restoring a Forest Legacy at Mingo National Wildlife Refuge	Bird species richness overtime	Sample plots point counts	Annual	Are covered by the standard monitoring as outlined in 3.1	Within 12 months of validation against CCBA standards
		Changes in bird species richness		Every 5 years		
46	Return to Forest, Nicaragua	Monitor trees, vegetation, butterflies, beetles, reptiles and amphibians, primates, and birds.	Systematic field based/LEM	Every 5 years	Are covered by the standard monitoring as outlined in 3.1	Not specified
47	Sodo Community Managed Reforestation (Forest Regeneration) Project	Total hectares of the project Number of tree by species Number of indigenous trees by species. Hectares of indigenous trees	Systematic field based	Annual/Every 5 years	No HCVs within the project boundaries	Within 12 months of validation against CCBA standards
		Tree inventory of each project area	Sample plots			
48	Sustainable	Change in crown cover percent	Not specified	Annual	Has developed an	Within 12 months

	Agriculture in a Changing Climate	Change in vegetation along watercourses	RS/Transect/Systematic field based	Not specified	independent initial plan for HCVs	of validation against CCBA standards
		introduction and Increase in number of new animals	Non-systematic field based			
		Area of riparian Vegetation type Boundary of riparian vegetation	Transect Interview			
49	The Australian Wet Tropics Region Biocarbon Sequestration Project Based on Regional Natural Resource Management	Detection of tree clearing for grazing Vegetation cover of states	RS	Every 5 years	Not specified	Not specified
		Foliage cover, Special life forms present, Canopy height, Ground cover	Transects Systematic field based			
50	The Community Ecosystem Restoration Project	Forest types composition Monitoring of both treated and non-treated areas	Sample Plots BDI Systematic field based Photographs	Every 5 years	Are covered by the standard monitoring as outlined in 3.1	Not specified
51	The Monte Pascoal - Pau Brasil Ecological Corridor: Carbon, Community & Biodiversity Initiative	Composition, vegetation structure, functional categories of flora indicators	Sample Plots	Peak of birds' reproductive season (September - December)	Are covered by the standard monitoring as outlined in 3.1	Not specified
		Population trends and bird-habitat relationships	Systematic field based/ Acoustic detectors Point counts			

Appendix 2. Forest fragmentation review

Fragmentation indicators, data sources and, monitoring methods

Study Area	Land coverType	Data	Fragmentation indicators	Monitoring Method	Reference
Celaque National Park, Western Honduras	Park	Landsat TM images: March 1987, 1991, 1996, and 2000	Slope, elevation and distance to roads of park boundaries	Remote sensing, GIS and landscape pattern analysis (patch size, shape index of each patch, and the Euclidean nearest neighbor (ENN) distance).	(Munroe, Nagendra et al. 2007)
Methods of fragmentation monitoring and assessment	General	- CORINE Land Cover database: derived from satellite images - Detailed topographical and cadastral maps, airphotos, field mapping	Patch size, shape, edge length, perimeter-area ratio, interpatch distance	- Landscape metrics and indices Eg. (index of heterogeneity, Shannon´s diversity index, edge and boundary characteristics, patch characteristics and measures etc.) - Remote sensing and GIS applications	(Lipský 2007)
New Brunswick, Canada	Old Hardwood Habitat, Old Spruce-Fir Habitat, Old Mixedwood Habitat, Old Pine Habitat, Old Tolerant Hardwood Habitat	Habitat maps: based on forest inventories of the three years Satellite imagery of three time periods (1984, 1993, 1999)	Habitat cover, patch size, edge effect and nearest neighbour	Arcview Spatial Analyst: habitat cover, patch size, edge effect and nearest neighbour ArcView extension: “nearest.ave”	(Betts and Taylor 2002)
New Zealand	Unfragmented lowland rain forest and highly fragmented montane forest	Forest survey data of seven consecutive years	Patterns of plant community composition in relation to a range of fragmentation measures.	- Calculated an index of community similarity (Bray–Curtis) between forest plots forest areas. - Multiple nonlinear regression technique that incorporates spatial autocorrelation effects	(Lafortezza, Coomes et al. 2010)

Prince George forest district, British Columbia, Canada,	Sub-Boreal Spruce biogeoclimatic zone	Land cover dataset from Landsat-7 ETM	edge density, number of forest patches, area of largest forest patch, mean perimeter area ratio, corrected mean perimeter area ratio, and aggregation index	Landscape pattern indices (LPIs)	(Long, Nelson et al. 2010)
Prince George's County, Maryland	Fragmented state forests	Digital aerial imagery	Land-cover distribution and composition Landscape metric calculated from plot-based data	Aerial Photo interpretation Forest Fragmentation Metric: Point Aggregation Index (PAI)	(Lister, Square et al. 2009)
Rondônia, Brazilian Amazon	Amazon rain forest	Landsat TM scene and topographic maps Field data	Edge, shape and core area indices	Satellite image processing and landscape indices calculation	(Batistella, Brondizio et al. 2000)
State of Maryland	Fragmented state forests	Land cover maps derived from Satellite imagery	Area/edge/density, shape, core area, proximity/ isolation, contrast, contagion/interspersion, connectivity	Fragmentation indices Spatial pattern analysis program(FRAGSTATS), principal components analysis	(Pfister 2004)
Switzerland	Jura, Lowlands, Northern Alps, Central Alps, southern Alps	Digital topographic maps	Anthropogenic barriers only, Combination of anthropogenic and Natural barrier elements	Effective mesh size	(Jaeger, Bertiller et al. 2008)

United States of America	Forest Vs. Urbanization	Remotely sensed imagery Field data	- Stream samples - Correlations between fragmentation variables and aquatic chemistry, flora, and fauna. - Forest composition, structure, and condition measurements - Quantification of patch size and shape, edge, interior area, land use composition, forest isolation, human use, landscape pattern, and parameters describing landscape texture and the degree of connectivity.	Intensive Site Research and Monitoring Gradient-based Data Collection Network Regional Survey Monitoring Remote Sensing and Mapping	(Riemann, Riva-Murray et al. 2008)
West Java, Indonesia	Extensive mountain forests [3]	Remote sensing imagery and vector-based topographic data for deriving Digital Elevation Model (DEM)	Detect the percentage of crown closures (canopy)	Remote sensing: Forest Canopy Density Model	(Hadi, Wikantika et al. 2005)

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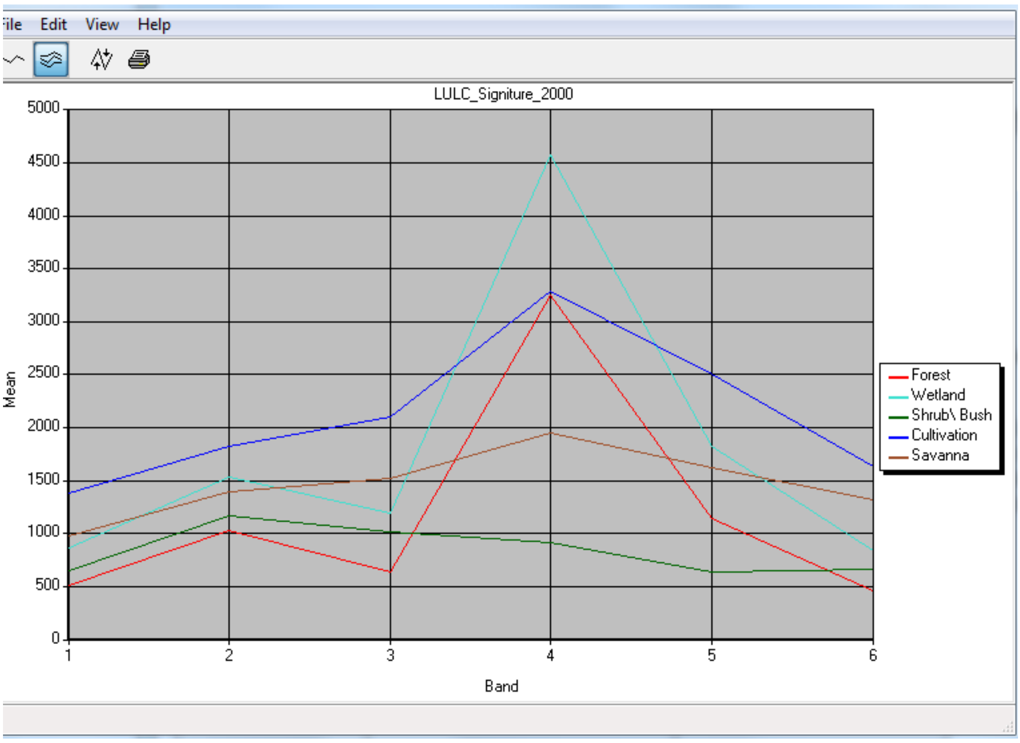
[3] http://dpc.uba.uva.nl/cgi/t/text/text-idx?c=ctz;sid=1409159c182679425e088d1562e82e69;idno=m6903a02;view=text;rgn=div1;cc=ctz;node=m6903a02%3A4

Appendix 3. Analysis

❖ Signature Files of Selected AOI regions

LULC signature year 2000



❖ Confusion Matrices of selected validation points

Confusion Matrix results in percentage for year 2000

	Forest	**Cultivation**	**Shrub/Bush**	**Wetland**	**Savannah**
Forest	**100**	0	0	0	0
Cultivation	0	**100**	0	0	0
Shrub/Bush	0	20	**20**	60	0
Wetland	0	0	0	**100**	0
Savannah	0	33.3	0	33.3	**33.3**

Confusion Matrix results in percentage for year 2005

	Forest	Cultivation	Shrub/Bush	Wetland	Savannah
Forest	**33**	77	0	0	0
Cultivation	25	**50**	0	25	0
Shrub/Bush	0	33.3	**33.3**	33.3	0
Wetland	0	0	0	**100**	0
Savannah	0	25	25	0	**50**

Confusion Matrix results in percentage for year 2010

	Forest	Cultivation	Shrub/Bush	Wetland	Savannah
Forest	**80**	20	0	0	0
Cultivation	20	**80**	0	0	0
Shrub/Bush	0	20	**20**	20	40
Wetland	40	60	0	**20**	0
Savannah	0	0	0	0	**100**

❖ Fragmentation Class Description

- Landscape Fragmentation Tool (LFT)

    - Core: occurs outside of the "edge effect" zone, not degraded by fragmentation. (small core patches : <250 acres, medium core patches : 250 to500 acres, large core patches: >500 acres)
    - Perforated: occurs within the "edge effect" zone along the edge of a small clearing in a non-patch tract.
    - Edge: occurs within the "edge effect" zone along the outside edge of a non-patch tract
    - Patch: small fragments that are completely degraded by the "edge effect"

- Graphical user interface for the description of image objects and their shapes (GUIDOS)

    - Core: Interior foreground area excluding foreground perimeter
    - Islet: Disjoint foreground object and too small to contain core

- Loop: Connected at more than one end to the same core area
- Bridge: Connected at more than one end to different core areas
- Perforation: Internal foreground object parameter
- Edge: External foreground object perimeter
- Branch: Connected at one end to edge, perforation, bridge, or loop