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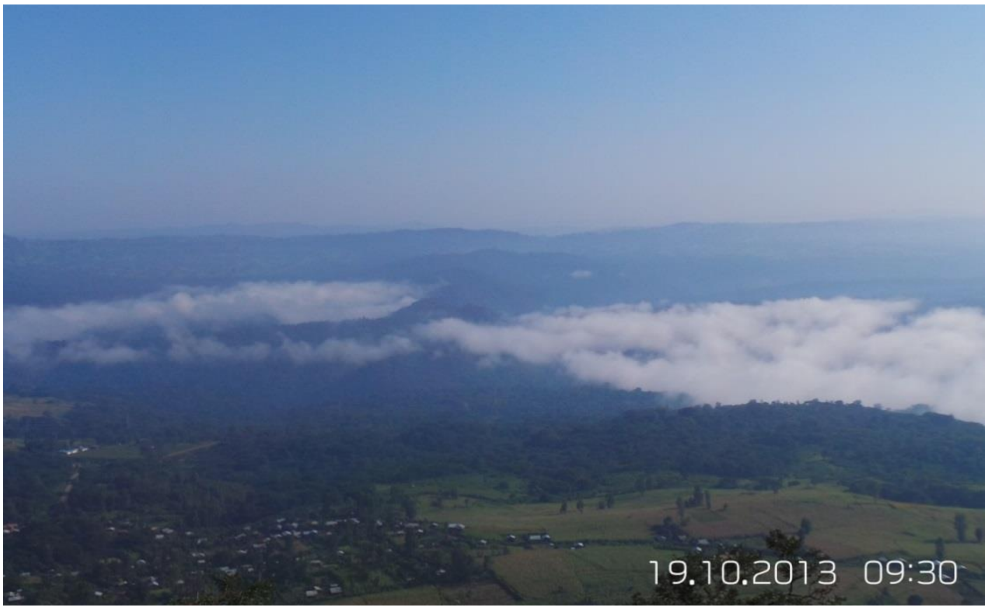
ASSESSING THE IMPACT OF UNESCO BIOSPHERE RESERVES ON FOREST COVER CHANGE

The case of Yayu Coffee Forest Biosphere Reserve in Ethiopia

Dereje Likissa Beyene

April 2014



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Assessing the impact of UNESCO biosphere reserves on forest cover change

The case of Yayu Coffee Forest Biosphere Reserve in Ethiopia

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Abstract

The Afromontane rainforest of Ethiopia is under the threat of deforestation and forest degradation, despite its significance as one of the only homes for wild populations of coffea arabica. One of the management initiatives was the UNESCO forest Biosphere Reserve (BR) aimed at strengthening policy and regulatory actions among local, regional and global governments and reconciling conservation with local development to monitor forest coverage changes. Assessing the impact of BR forest management and conservation on location, time and intensity of forest disturbances through Man and Biosphere (MaB) programme and REDD+ activities is important for regulatory actions. Empirical evidence on the achievement of this programme was not documented so far. This study is aimed at identifying the roles and assessing spatiotemporal impacts of this BR, together with measuring forest cover change dynamics and the drivers of such change in Yayu Coffee Forest BR of Ethiopia. Using multi-temporal Landsat datasets with in-situ field survey, the study employed BFAST monitor to detect historical forest disturbances and mobile devices to signal changes and collect the relevant data from households. Forest cover change was analysed both spatially (within the BR zones, and between the BR area and the leakage belt), and temporally before and after the implementation of the BR. Qualitative analysis on the role of the BR in tropical areas indicated that progresses in reducing deforestation were observed in areas where MaB aims were appropriately enacted. Landsat image analysis of the study revealed that transition zone has more deforestation rate than both buffer zone and core area within the BR, while relatively high deforestation rate was observed in the leakage belt than in the BR area. After implementation of the BR, average annual deforestation rate was declined from 0.29% to 0.16% in the BR area, and from 0.71% to 0.6% in the leakage belt, respectively, indicating the progress of BR program in reducing deforestation. Farm land expansion, mismanagement of coffee forest, access to forest, road and market were observed as the main drivers and underlying causes of forest cover loss. The findings of the study imply that BR efforts with MaB program and REDD+ activities have enhanced forest cover protections and carbon emission reductions in the study area. Therefore, promoting these initiatives at the local level is important for biodiversity conservation and climate change mitigation strategy of the country.

Keywords: UNESCO, biosphere reserve, deforestation, remote sensing, BFAST monitor, Yayu, coffee forest.

Index of Contents

Index of Figures

Index of Tables

Acronyms and Abbreviations

BAU	Business as usual
BFAST	Break For Additive Seasonal and Trend
BRs	Biosphere Reserves
CRGE	Climate Resilient Green Economy
ECFF	Ethiopia Environment and Coffee Forest Forum
ETM+	Enhanced thematic Mapper plus
FDRE	Federal Democratic Republic of Ethiopia
FDRE MoST	Federal Democratic Republic of Ethiopia Ministry of science and technology
GHG	Greenhouse gas
IBC	Institute of Biodiversity conservation
IUCN	International Union for Conservation of Nature
MaB	Man and Biosphere
MAP	Madrid Action Plan
NABU	Nature and Biodiversity Conservation Union
NDVI	Normalized Difference Vegetation Index
NIR	Near infrared
ODK	Open Data Kit
OFWE	Oromia Forest and Wildlife Enterprise
REDD	Reducing Emissions from Deforestation and forest Degradation
R-PP	Readiness preparation proposal
SLC	scan line corrector
TM	Thematic Mapper
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
VI	Vegetation index
WNBRs	World Network of Biosphere Reserves
YCFBR	Yayu Coffee Forest Biosphere Reserve
ZEF	Centre for Development and Research

1. Introduction

1.1 General Context and Background

The rapid disappearance of tropical forest and their biodiversity involves a wide range of changes in biological diversity and global climate (Butler and Laurance 2008). According to FAO (2010), the main contributing factors to tropical deforestation is mainly due to conversion of forests into agricultural land, and this was increased in the last decades contributing to almost 20% greenhouse gas emissions (Gullison et al. 2007). Due to the rapid change in tropical deforestation, degradation and its consequence on global climate change, the United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and Biosphere (MaB) programme for forest conservation and management policies has increased promoting economically viable and ecologically sound forest resources management practices. Besides, the United Nations Framework Convention on Climate Change (UNFCCC) conducted the formation of a mechanism to Reduce Emissions from Deforestation and forest Degradation (REDD+) in developing countries (Wertz-Kanounnikoff et al. 2008).

The Afromontane rainforest of Ethiopia is part of the Eastern Afromontane biodiversity hotspot. Besides, it is the only forest ecosystem with wild coffea arabica populations worldwide. Despite having all these importance, the Afromontane rainforest of Ethiopia was being cleared and degraded at an alarming rate due to social, economic and political factors prevailing in the area in the last decades (Gole 2003b; Groombridge 2002). Since 2010, these wild coffee forest and other forest biospheres of south-west Ethiopia were put under a conservation order of UNSCO biosphere reserve programme (Gole et al. 2009). According to UNESCO MaB programme, Biosphere Reserves (BRs) are meant to demonstrate a balanced relationship between people and nature. Moreover, the concept was targeted to identify ways and means of achieving sustainable development of terrestrial ecosystem aiming at reconciling utilization with long-term protection of forest resources (Gole et al. 2009).

The ultimate aim of the above initiatives is to reduce deforestation and forest degradation through adaptive conservation as well as designing, monitoring and implementing MaB programme and REDD+ activities (Gole et al. 2008; Ishwaran 2012). Monitoring forest cover changes and assessing the impact of BRs on forest management and conservation polices is important task for governments at local, national and global levels. The twenty-fifth session of the MaB programme held at UNESCO Headquarters Paris (France), from 27 to 30 May 2013 indicated that Ethiopia is among many BRs already respond to the concerns of international agreements on the environment and sustainable development (UNESCO 2013). Many methodologies have been also developed to analyse forest cover changes. However, empirical evidences on the achievement and impact of this program on deforestation were not well documented so far. Thus, it is important to establish links between policy and regulatory actions based on the location, time and intensity of forest disturbances.

Understanding the impact this BR programme on deforestation requires forest cover change assessment, monitoring the overtime change in forest cover pattern. Remote sensing is one of the techniques used to routinely monitor and assess forest cover changes since 1970s. This technique provides the ability to acquire explicit information spatially and temporally making more consistent estimates of forest cover change (Wakjira 2010), to understand the impact of this BR program on deforestation. Integration of in-situ ground based forest cover change monitoring with Landsat data time series is also robust and able to show changes in time and space (Turner et al. 2013), playing a key role to pin point rate of deforestation. These monitoring techniques have demonstrated potential as a means to detect, identify, and map changes in forest cover due to deforestation (Coppin and Bauer 1996).

Research in this thesis have used time series remote sensing data from available Landsat imagery (Landsat 5 TM and Landsat 7 ETM+ sensors) and integrated field survey forest cover loss monitoring system to detect and monitor forest cover disturbances in Montane rainforest found in Southwest Ethiopia. Furthermore, results and data obtained from this research help to assess impact of UNESCO MAB programme and REDD+ forest monitoring approach in the region by assessing rate of deforestation inside and outside Yayu coffee forest biosphere reserve.

1.2 Problem statement

The Ethiopian Afromontane forest is the least explored and least protected Eco regions in Africa (Scholes et al. 2006). As part of the East Afromontane biodiversity hotspot, Ethiopia is home to a rich diversity of plants and animals and is one of the top 25 richest countries in the world in terms of biodiversity (Gole 2003b; Lange 2011). It is the only place where wild populations of coffea arabica still existing. However, there are evidences that indicate the forest in this region is receiving pressure from different directions. The vegetation in the region, including the coffee forests is threatened by deforestation mainly due to different socio-economic and political processes, despite coffee forests are important income source for the country and livelihood of local communities (Gole et al. 2008).

However, there are limited information available indicating the level of threat prevailing to this forest and the deforestation rate of this particular forest, particularly after intervention of BR program in the region. As mentioned earlier in this report, remote sensing can be utilized for monitoring deforestation rate and managing other environmental related concerns. It brings together a multitude of tools to better analyze and understand the scope and scale of deforestation problem. It also helps to detect changes based on multi temporal data (Wakjira 2010). Different generations of Landsat images were already used to study forest changes over time in tropical forests including Vietnam (Muller and Zeller 2002), Brazilian Amazon (Espirito-Santo et al. 2005), Tanzania (Luoga et al. 2005) and Thailand (Muttitanon and Tripathi 2005). Moreover, it is important to support the forest cover change study through understanding of local and historical level process to examine the proximate causes and underlying driving forces. As many of the previous studies were focused only on reduction in forest cover of the country using bi-temporal change detection techniques, this study serves to use time series data.

As reported by Groombridge and Jenkins (2002) forests with wild coffee populations are declining in their coverage in this area and not more than 400,000 ha is remaining at present. In earlier report, Reusing (2000) revealed that 61.6% of the forest cover of this region has been subjected to change between 1971 and 1997 and the author estimated that 163,600 ha of annual deforestation rate for the country. Study undertaken by (Wakjira 2010) in south western Ethiopia also reported high rate of change of high forest cover of the area (from 71% to 48%) between the year 1973 and 2005 that makes about 90,127 ha of overall forest cover loss in the region. Contrarily, Lange (2011) revealed that Ethiopia is one of the mountain UNESCO's Network of BR regions contributing to a sustainable development. This requires special attention since these areas constitute Ethiopia's biggest tropical forest blocks, being recognized as a priority area for global biodiversity conservation and plant genetic diversity (Gole et al. 2008).

However, the actual impact of Biosphere Reserves (BR) on forest cover change and deforestation rate has not been documented in scientific literature. Understanding the actual impact of forest BR on deforestation and forest degradation and its effectiveness with respect to forest change is very important. This will help to address knowledge and capacity gaps that currently exist in forest BRs. This study is therefore aims to contribute to a better understanding of deforestation rates of Afromontane forests of south western Ethiopia by addressing the role of UNESCO MaB program and REDD+ activities on forest biosphere reserve using Landsat time series images and integrated field survey approaches.

1.3 Research importance, objectives and questions

1.3.1 Importance of the research

The research undertakes forest cover change analysis and monitoring using remote sensing and in-situ field survey in Montane rainforest of coffee forest BRs in south western Ethiopia. It thus provides precise estimates of historical and current trend of deforestation rates with empirical evidences on a management of forest to promote biodiversity conservation, which is useful for UNESCO in line with MaB and REDD+ programmes and objectives. It also assess the role of REDD+ and MAB on deforestation rates and produce understandable concept of BRs and the processes required to that end.

1.3.2 Research objectives and questions

The main research objective of this study is:
to assess the impact of UNESCO forest biosphere reserve on deforestation rates by detecting forest cover change in Montane rainforest of southwest Ethiopia. The specific research questions were:

1. What is the role of UNESCO biosphere reserve in addressing deforestation issues in tropical regions?
2. What forest cover change dynamics can be observed from multi-temporal Landsat datasets?
3. What is the spatiotemporal impact of the biosphere reserves on deforestation rate within and outside the biosphere reserve and before and after its establishment?
4. What are the proximate causes and drivers (motives) for the forest cover change and how they related to each other?

2. Theoretical background

2.1 Overview of biosphere reserve and REDD+ forest monitoring approaches

Climate change and the conservation of biological diversity are among today's key environmental challenges. Biosphere reserves are designed to deal with these environmental and societal problems that the world is facesing. Reconciling conservation of biodiversity with their sustainable use is the main target of both MaB programme and REDD+ activities (Ishwaran et al. 2008; Kissinger et al. 2012). Biosphere reserves contribute the transition to green societies by investigating green development options through harmonization of conservation of biological diversity with economic and social development, through sustaining equilibrium relation between people and nature. Biosphere reserves are ways for mitigating climate change and serve as models for adaptation to the impacts of this change through sustainable land use and green economies (UNESCO 2011).

Dresden Declaration on BRs and Climate Change was held in Germany (28 June 2011). Pointing to the goals of the Seville Strategy (1995) and the Madrid Action Plan (2008), members of the conference called on the States of MaB Programme to give greater weight to BRs in their strategies against climate change. This is to increase the role of land use in carbon sequestration, in particular in forests through applying voluntary carbon programme (REDD+) in biosphere reserves.

Accordingly, the government of Ethiopia developed the “Climate Resilient Green Economy (CRGE)” to follow green growth path that fosters sustainable development (FDRE 2011a; Melamed et al. 2012). Ethiopia’s green growth path (CRGE) aims to help Ethiopia achieve middle income country status by 2025 while keeping carbon emissions at current level, through its four pillars, namely (i) reducing the environmental impact of agriculture (ii) protecting and re-establishing forests (iii) deployment of renewable power generation and (iv) leapfrogging to modern and efficient technologies in transport and industry.

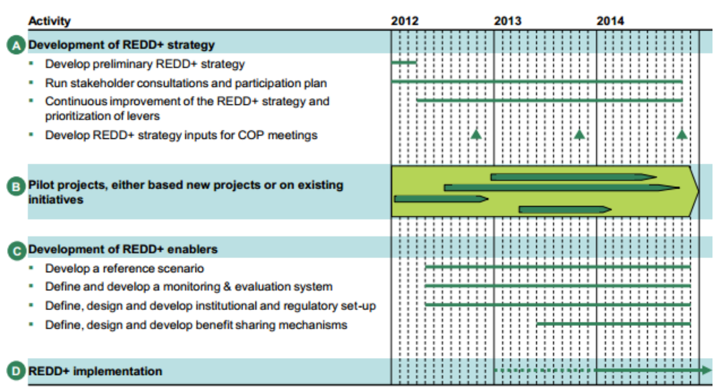


Figure 1.Time line of the REDD+ preparation for Ethiopia. Source: FDRE (2011b)

Ethiopia also designed Readiness Preparation Proposal (R-PP) to get ready for REDD+ implementation as forest carbon partnership facility in forest sector. The main emphasis of Ethiopia’s R-PP is to develop reference scenario of deforestation and forest monitoring system for REDD, and adopt a national strategy for reducing deforestation and forest degradation, which in turn prompt environmentally sustainable green growth path (FDRE 2011b).

2.2 Definition and rationale on forest cover change

The problem of environmental change, alteration in ecosystems structure and the loss of biodiversity are wide spread phenomena in the world. Tropical forest cover change is one of the major environmental modifications that lead to the conversion of native vegetation into different land use. Land cover change is often regarded as conversions from one cover type to another land use type (Mertens and Lambin 2000; Wakjira 2010). In this regard forest cover change is regarded as conversions from forest covered to other non- forest types, while forest disturbance is relatively defined as a discrete event occurring over short time period disturbing the structure of forest ecosystem (Verbesselt et al. 2012) and therefore the key deriver of spatial and temporal dynamics in forest cover. The loss of forest cover, in addition to direct impact on the livelihood of the forest dependent society, it will also alter the flora and fauna diversity of the area and may lead to overall ecosystem collapse (Mishra et al. 2004)

Most estimates of deforestation rates at different study level have been subjected to criticism in terms of variation in deforestation definition, imprecise and open to different methodology and interpretation and fluctuation in rate of forest loss in any one country (Mertens and Lambin 2000; Morton et al. 2005; Wakjira 2010). The variation in size of forest cover and deforestation mainly originate from the use of different concepts in defining forest and deforestation by different authors. Some define deforestation as total and permanent conversion of dense forest landscape to an area with a low tree cover and permanent agricultural land (Mertens and Lambin 2000). Other studies like Pichon et al. (2001) define deforestation as the area that no longer remains in primary forest. On the other hand FAO (2010) defines it in the sense of land use conversion as a result of complete clearing of tree formations and their replacement by non-forest land use or continued reduction of the tree canopy cover below a 10 percent threshold.

In this thesis we followed the definition of forest given and reported by FAO. (2010) in order to identify deforestation in the study site. Forest is thus the land cover greater than 0.5 hectares with 5 m tree height and a canopy cover more than 10%. In this study, a forest area experiencing complete clearing and their replacement by non-forest land uses is considered as deforestation. Therefore, deforestation is land use change from forest covered to other non-forest land use, whereby the primary forest is disturbed and altered structurally and in species composition and no more resembles the character of forest.

2.3 Afromontane biodiversity hotspots

2.3.1 Eastern Afromontane Forests

The Eastern Afromonatane region encompasses several widely scattered, but bio geographically similar mountain ranges in eastern Africa and the Arabian Peninsula, from Saudi Arabia and Yemen in the north to Zimbabwe in the south, covering an area of more than 1 million square kilometres (www.birdlife.org

2012). According to this report, the area contains nearly 7,600 species of plants, out of which more than 2,350 are endemic plants. While, only 10.5 % (106,870 square kilometres) of the original vegetation remain more or less intact and only 15 % (54,132 square kilometres) of the total area remain under some level of official protection.

2.3.2 Southwest Montane rainforest of Ethiopia

There is a cloud of montane rainforest in Southwest Ethiopian highlands. The area is known as the "lungs of Ethiopia" for its role in carbon sequestration, besides its role as the origin of the wild coffea arabica. (www.birdlife.org 2012). More than 50% of the Afromontane region with elevations above 1500 m is found in Ethiopia, where most of these areas have lost their original habitat types (Gole et al. 2009). However, rising population pressure and accelerated deforestation rate mainly for agriculture are impacting the rich biodiversity of the region (Wakjira 2010). Many studies (Getahun et al. 2013; Gole 2003a; Gole et al. 2008; Reusing 2000; Wakjira 2010) indicated that human activity is critically threatening the stability of the forest ecosystems in the region. However, the forest in this corridor is the largest of the few areas in Ethiopia with original habitat types, and is of high significance for conservation of biodiversity at regional, national and continental level. The Kafa, Yayu and Sheka forests within this corridor were designated as UNESCO Biosphere Reserves in 2010 and 2012; to protect these endangered biodiversity hotspots halting deforestation and forest degradation derivers.

2.4 Application of remote sensing and GIS in forest cover change monitoring

Application of remote sensing data in combination with GIS can render reliable information on land use dynamics. Knowing where and when forest disturbance happens is crucial for forest management. Information on forest cover and its related dynamics is valuable to developing countries with limited previous knowledge of their forestry resources. Moreover, remote sensing brings together a multitude of tools to better analyse the scope and scale of forest and deforestation problem. In support of Reduction of Emissions from Deforestation and forest Degradation in developing countries (REDD+) and to monitor changes in land use and forest related activities, remote sensing procedure plays indispensable role and are an important component of forest monitoring (DeVries et al. 2013b; Kissinger et al. 2012).

Forest monitoring as the on-going changes in forest/land cover pattern over a period of time is essential for the assessment of biomass estimation, forest health assessment and forest disturbances (De Jong et al. 2011). Another recent report byAyoola Akinola Akingbogun et al. (2012)has noted that remote sensing and GIS helps to achieve proper forest monitoring and management, creating spatial representations such as maps to know the exact locations and extent of forest disturbances. Similarly, Kissinger et al. (2012) also documented the need of spatial assessments based on remote sensing and ground data to link forest changes to land-use activities in order to capture the spatial and temporal relationships between proximate drivers of deforestation.

2.5 Vegetation indices

Many authors have used vegetation indices to characterise the surface features. Vegetation indices are arithmetic combinations of two or more spectral bands designed to characterise vegetation properties (Tejaswi 2007). Measuring the wavelengths and strength of visible and NIR light reflected back in to sensors, many studies created vegetation maps that identify healthy and disturbed vegetation. In an effort to monitor major fluctuations in vegetation due to natural (e.g. drought as a result of climatic factors) or anthropogenic (e.g. due to deforestation and forest degradation) researchers have used vegetation indices like Enhanced Vegetation Index (EVI) (Rocha and Shaver 2009), Normalized Difference Vegetation Index (De Jong et al. 2011; DeVries et al. 2013b; Verbesselt et al. 2012) and Normalized Difference Fraction Index (NDFI) (Souza Jr et al. 2013).

Vegetation index values were used for spatial and temporal inter-comparisons of vegetation condition, allowing detecting temporal changes of the vegetation disturbances. However, selection of the most important vegetation index that best suit purpose of study and methodology is important. The use of NDVI is considered to be appropriate for the purpose of forest monitoring (Huete et al. 2002). Although NDVI might be affected by soil background and a saturation effect at high biomass levels, it captures seasonal and inter-annual changes in vegetation status (Verbesselt et al. 2012). Based on, Chen et al. (2008) and Verbesselt et al. (2012), NDVI can be calculated.

$$NDVI = \frac{band4 - band3}{band4 + band3}$$

where band3 and band4 are Landsat TM and ETM+ bands representing the "red" and "NIR" respectively. The VI value indicates the amount of green vegetation in the pixel. Higher VI value shows more green vegetation and vice versa.

2.6 Approaches in forest cover change detection

Change detection is the process of identifying differences in the state of forest phenomena by observing it at different times (Singh 1989; Tejaswi 2007). Identification of appropriate forest disturbance change detection technique is important to produce good quality change detection result. Many change detection algorithms were developed by different authors to detect changes in forest cover. However, controversial conclusions are drowning on which change detection techniques are most effective. Some of the category includes image regression, image differencing, image rationing, vegetation index differencing.

Most of these change detection algorithms use bi-temporal approaches (Christie et al. 2007; Leimgruber et al. 2005; Steininger et al. 2001; Wakjira 2010) and/or more imagery dates of Landsat images (Killeen et al. 2008; Masek et al. 2008) to asses post-classification comparisons on forest change. As indicated by (Thonfeld and Menz 2013; Zhu et al. 2012) most of these change detection algorithms are simple to use. This allows for the detection of apparent forest conversion, i.e. the replacement of one land cover by another. However, the main drawbacks in bi-temporal approaches are the requirement that both images have to be at the same time of year to minimize difference in seasonal phenology and are need to be cloud free. In addition seasonal and temporal changes and long-term trends cannot be captured with these approaches. Knowing when the disturbance occurred between the two known dates and understanding the acting processes and the driver of the disturbance in the absence of knowledge and familiarity of the study area can be a problem in such approaches. But these drawbacks can be improved by utilising the full temporal dense time series data.

Over the past years several methods were also developed to explore multi temporal time series disturbance detection based on available image composites. Several studies (DeVries et al. 2013b; Thonfeld and Menz 2013; Verbesselt et al. 2011; Zhu et al. 2012), used all available remote sensing time series image composites to apply time series analysis. This allows detection of abrupt changes, seasonal patterns and long term trends than these threshold based change detection approaches.

2.7 Forest change monitoring using BFAST monitor time series analysis

Break For Additive Seasonal and Trend (BFAST) algorithm has been used to decompose remote sensing NDVI time series data into additive components as described by Verbesselt et al. (2010a). It detects changes occurring in both trend and seasonal components with different slope and intercepts accounting for trends and abrupt changes. It has also shown capability to detect breakpoints in the linear trend highlighting the impact of different environmental factors like climatic conditions (Lambert et al. 2011) in France, (Verbesselt et al. 2012) in Somalia and phenological change in vegetation indices (Verbesselt et al. 2010b). However, BFAST change detection approach is not developed to detect disturbances in recently acquired data to assess the stability. Method to detect changes in near real-time has been developed based on BFAST-type season-trend model to assess the stability of linear regression models (Verbesselt et al. 2012).

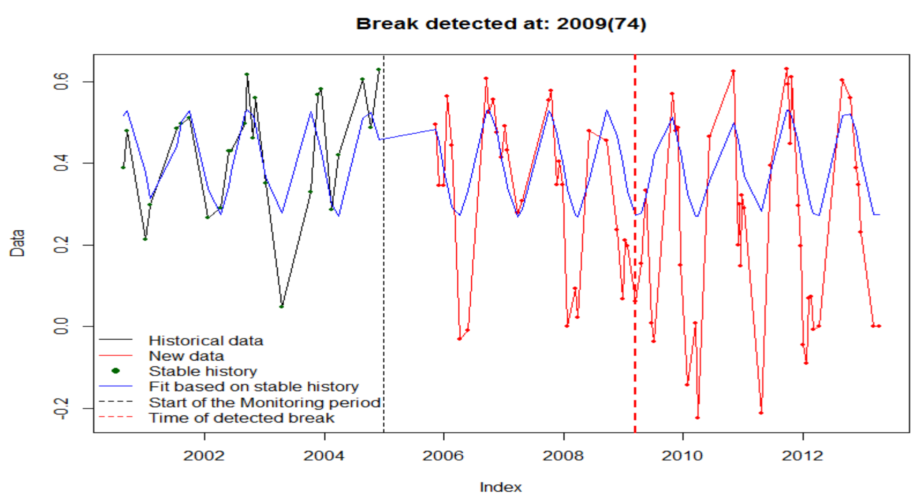


Figure 2.BFAST monitor plot outcome for single pixel time series

BFAST monitor a near real-time disturbance monitoring approach as described by Verbesselt et al. (2012) and tested in drought detection in Somalia has also played a vital role in detecting forest disturbances in tropical Montane forest of Southwest Ethiopia (DeVries et al. 2013). The method was applied to Landsat time series in tropical forests enabling a rapid response by detecting forest disturbances in near real-time. It is a robust method for analysing dense satellite time series images automatically responding time, magnitude and dates of breaks on newly acquired data based on stable history period. As pointed by Verbesselt et al. (2012) BFAST monitor in addition to monitoring and detecting breakpoints, (i) it enables dealing with missing data without need for gap filling which is common problem in Landsat ETM+ since 2003, (ii) it does not require definition of thresholds, and iii) it can analyses the full temporal detail of a time series.

Evaluating BFAST monitor behaviour for different ecosystem and forest disturbance events described above and its huge advantage in dense time series analysis than other forest cover change detection techniques, BFAST monitor was proposed to analyse high temporal and spatially detailed Landsat images. Thus, based on this method, the timing and magnitude of abrupt changes as a result of deforestation were detected and analysed in this study.

2.8 Drivers of tropical deforestation

A growing evidences from empirical studies identified both proximate causes and underlying forces for tropical deforestation (Carr 2004; Kissinger et al. 2012; Wakjira 2010). One causal factor for forest cover change is linked to other drivers forming complex chains of forest cover loss. However, Carr (2004) reported that small farmer agricultural exapnsion along forest frontier is proximate cause of forest clearing followed by timber extraction for fuel and construction and infrastructural expansion. These proximate drivers are more intensified by underlying factors namily population growth, socio-economic and environmental factores. In line with this study, a summery report by Hosonuma et al. (2012) from 46 tropical and sub-tropical countries on deforestation indicated agriculture as the main driver of deforestation

The most prominent driver of deforestation and forest degradation are emanated from conversion of forests to agricultural land, as agriculture is more attractive than forestry in Ethiopia and unsustainable fuel wood consumption (FDRE 2011a). Study conducted by Getahun et al. (2013) in Jimma zone of South-western Ethiopia also showed socio-economic and biophysical factors as of control deforestation, indicating more deforestation in remote location. Under Business As usual (BAU) scenario i.e. if there were no need for sustainable growth path and the current development path way is to continue as usal due to economic interest or lack of funding as described in (FDRE 2011a), greenhouse gas (GHG) emissions from deforestation alone is estimated to increase from 25 Mt CO_2 in 2010 to 45 Mt in 2030 in Ethiopia. One important point in REDD+ forest monitoring strategy is to halt deforestation and forest degradation by altering such BAU senario in sectors currently driving GHG emissions from forest to green growth path development (Kissinger et al. 2012).

3. Materials and Methods

3.1 Study area

3.1.1 Location

The case study was focus on Yayu Coffee Forest Biosphere Reserve (YCFBR) located in Illubabor zone of the Oromia Regional State at 510 km Southwest of Addis Ababa, Ethiopia. Yayu forest is one the first two forest BRs that have been designated as UNESCO MaB reserves in June 2010. It is also located in last remaining Afromontane forest clouds of South-western Ethiopia and is one of the biodiversity hotspot of the country. Yayu coffee forest is one of the world's 34 vital yet threatened areas for biodiversity conservation and has the greatest abundance of wild arabica coffee than anywhere (Gole et al. 2009). The geographical location of the area lies at 8^{O} 0' 42" to 8^{O} 44' 23" N and 35^{O} 20' 31" to 36^{O} 18' 20"E.

Case study site: Yayu Coffee Forest Biosphere Reserve, Oromia, Ethiopia

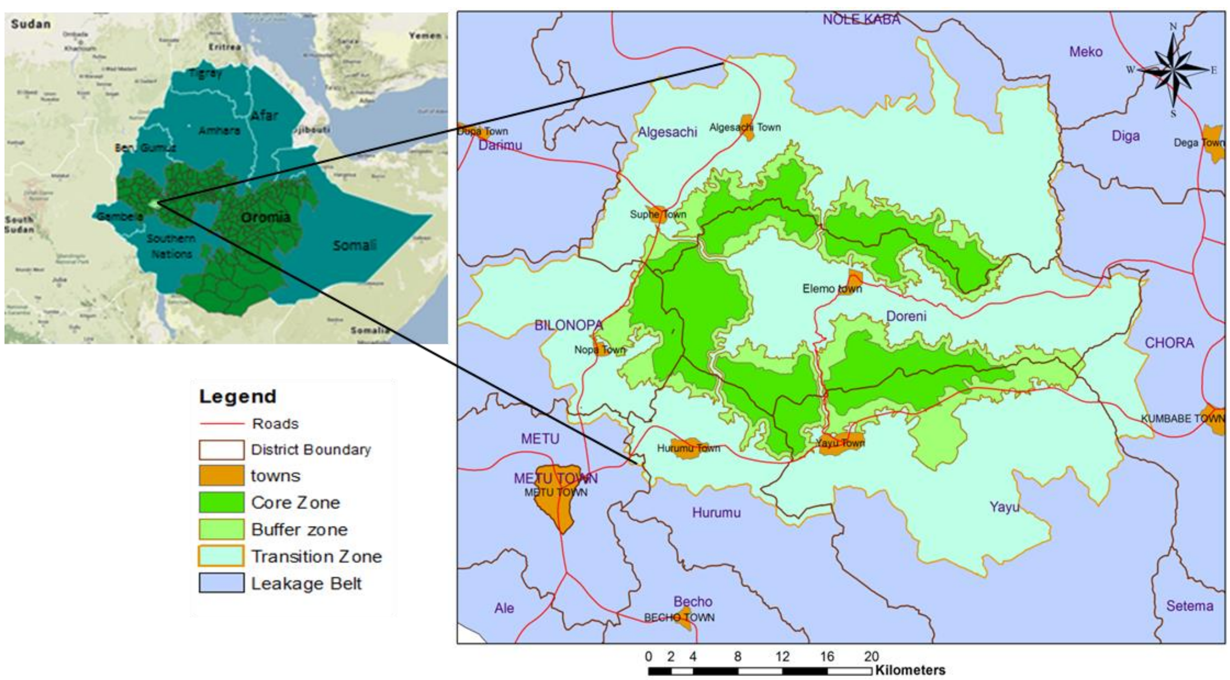


Figure 3.Map of Yayu coffee forest biosphere reserve. The map also indicates the three zone of the BR namely core zone, buffer zone and transition zone. Area 20km outside the BR (Leakage belt) was buffered using ArcGIS 10.2. Source of BR boundaries: ECFF, Ethiopia

3.1.2 Biosphere reserve zonation

Zonation of BRs play an important role in creating appropriate coordination mechanisms for sustainable conservation and development (UNESCO 2010b). The zonation of YCFBR was determined based on past research works and the relevant Ethiopian land and forest laws aimed at designing a management approach that incorporated both conservation and sustainable use (Gole et al. 2009). The forest was part of national forest priority area, mainly for conservation of biodiversity, coffee genetic resources conservation and production. Choosing the designed management option of UNESCO MaB programme, BR area zonation was implemented since 2010. According to the BR nomination report, YCFBR was zoned into core areas, buffer zone and transition zone areas accounting for 27, 733 ha; 21,552 ha and 117, 736 ha respectively, out of the total area of the BR ,167, 021 ha (Gole et al. 2009) . The core area is found at the centre and surrounded by buffer zone and transition areas.

3.1.3 Species diversity

Yayu BR is one of the Montane moist forest ecosystems in Southwestern Ethiopia having diverse ecosystem in composition, structure and habitat types. The BR consist various types of vegetation types, therefore, supporting different plant and animal species living in association. The BR nomination form indicate that, in total, 450 higher plants, 50 mammals, 200 birds and 20 amphibian species have been reported. Over 100 species of plants, birds and mammals are endemic to this area (Gole et al. 2009). There are also 44 threatened spices (IUCN red list) in the area, in which 40 of them are plant species. The structural diversity of the forest allows both animals and plants to occupy different ecological niche.

Wild coffee has been identified as one of the most dominant understory species in Yayu forest (Gole 2003a). A case study conducted by Gole (2008) on floristic composition of coffee forest indicate that, Yayu forest consists of high species of coffea arabica with understory types commonly known as “coffee forest”. Coffee is the major cash crop growing in the study site either as forest coffee system when fully unmanaged and semi-forest coffee when partly managed removing the understory shrubs other than coffee (Gole 2008). According to this author the term ‘coffee forest’ is used to indicate parts of humid forests in Ethiopia with a high number of coffee trees. The findings of the study showed that in Yayu forest, landscapes with higher altitudes and flat to gentle slops have high abundance of coffee, even higher than similar forests of the region studied to date. This landscape position favours for agricultural production, and hence is prone to deforestation. Therefore, this keystone ecosystem together with plant species attracts UNESCO MaB program objectives giving efforts to focus on conservation of these forests as target.

3.1.4 Physical Settings: Topography and drainage

The topography of YCFBR area is characterized by undulating hills and is highly dissected by small streams and one major river, the Geba, and its major tributaries Dogi, Sese and Saki that drained in to Baro River (one of the major tributaries of Nile River). The land repeatedly changes, from flat surface plateaus to very steep slopes and valley bottoms within a short distance. The BR area altitude ranges from 1,100m.above sea level (a.s.l) to lowest elevation at valley bottom to 2, 337m.a.s.l in North eastern part. The largest and continuous forest cover of the area is found along the river basin. On average the area receives an average of 2,100 mm annual rainfall and mean minimum and mean maximum temperatures of 12.7°C and 26.1°C respectively, experiencing hot humid climate (Gole et al. 2009).

3.1.5 Agriculture

For more than 90% of the population in the area agriculture is considered to be main source of livelihood and (Gole et al. 2009). It is characterised by mixed farming systems run by smallholders. These can be depicted as coffee and cereal crop production, use of minor forest products, and animal production which include cattle and beekeeping. Common cereal crops grown in the area are like maize, teff, sorghum, beans, and millet. According to BR nomination report, from the total population whose livelihood is based on agriculture, 98% are generating their income from coffee. Besides, coffee production, processing and marketing are the major sources of employment for more than 60% of the population in the area (Gole 2003a).

3.2 Materials

3.2.1 Data sources

In order to obtain integrated real-time and spatial extent of forest cover change, the study was based on three data streams namely literature survey, remote sensing data and field work.data

3.2.1.1 Literature survey and documentary sources

To establish an overarching and theoretical understanding of how the BR concept could function and address deforestation issues in tropical regions, we have structured the data source in to two i.e. secondary and primary data sources, giving emphasis to UNESCO BR in Ethiopia. The first phase was gathering information from secondary sources of UNESCO websites on the MaB and REDD+ programs, the Madrid action plan, the Seville strategy, the BR nomination form (of Yayu Forest BR) and other related literatures in order to build this understandable concepts. The second phase was obtained through interview method.

With regard to the second phase, first experts at each of the four out of six selected government organisations in Ethiopia were interviewed. The main respondents of this task were agents and government officials in Ethiopia; Oromia Forest and Wildlife Enterprise (OFWE), Ministry of Science and Technology (MoST), Environment and Coffee Forest Forum (ECFF) and Institute of Biodiversity Conservation (IBC). The main point of interview was to determine what BR in Ethiopia is designed to do, what is UNESCO BR in context of forest and its contribution, role of the BR in deforestation issues, whether and/how the MaB program and REDD+ activities are achieved in the region and value of identifying BR in to zones and related questions. Second, an interview was conducted with fifty (50) farmers at each sample locations using ODK. During interview open ended questions (e.g. on how could they see deforestation and land use change in the area after 13 years, the role of biosphere reserve in their area and what changes were achieved after the reserve compared to before BR designation) were asked and collected which are useful for obtaining in-depth information on historical facts of forest cover change in the area.

3.2.1.2 Optical remote sensing data

Available commercial remote sensing data was not considered for this study due to budget constraints. Only Landsat imagery has been extensively used in integration with available online high resolution historical Google earth imagery. Landsat archives are available free of charge and was largely used for forest monitoring from local to global scale (DeVries et al. 2013b; Hansen et al. 2013; Souza Jr et al. 2013).

First, all available Landsat thematic mapper(TM) and enhanced thematic mapper plus (ETM+) images of path/row 170/54 for the study site was downloaded from USGS Glovis server-http://glovis.usgs.gov/ and processed ranging from January 2000 to September 2013. All Landsat images at GLOVIS have a standard processing algorithms and terrain correction applied on them that make them easy to use. Landsat satellite provides imagery with 30m pixels size, a resolution that closely matches the scale at which land management often operates (Czerwinski 2012). However, due to availability of unpublished processed Landsat data by Benjamin DeVries, for the study site post-processing was supported with already processed images.

3.2.1.3 Open data kit data

Open Data Kit (ODK) is an open source program where programmed questionnaires are deployed on Android platform (Jeffrey-Coker et al. 2010). It is a highly flexible and adaptable forest monitoring tool, comprised of a complete ground to cloud data collection and integration system. The ODK was designed to eliminate the challenges and limitations of collecting data using paper forms. It supports data collection and manipulation components that include text, image, audio, video and geo-location.

Here a framework required to assess forest disturbances and drivers of deforestation and forest degradation in YCFBR and its leakage belt area was adopted based on Pratihast et al. (2012) which was implemented in central Vietnam using mobile devices. Mobile devices such as smart phones have great potential in data collection processes and hence, contribute to the effective implementation of forest Monitoring. Compared to traditional paper based questionnaire methods, mobile devices have a potential to signal recent forest changes, including area of change and type of disturbance in near real time. In this study, the developed form was deployed on Android Samsung galaxy mobile platform through ODK collect.

ODK system and procedures

Following the methodology developed by Jeffrey-Coker et al. (2010) and Pratihast et al. (2012) three ODK software have been used to get data from ground measure to deploy it on the cloud server of Geo-information Science and Remote Sensing (Wageningen University). Three ODK software used include (i) ODK built- to design data collection form or questionnaire in .xml format using ODK build online interface, (ii) ODK collect-to deploy the xml format on mobile phone and storage server. Then to Collect the data on a mobile device from field and send it to a server, and (iii) ODK aggregate-to aggregate collected data on a server and extract it in useful formats. Figure 4 shows the ODK collect procedure followed in this study.

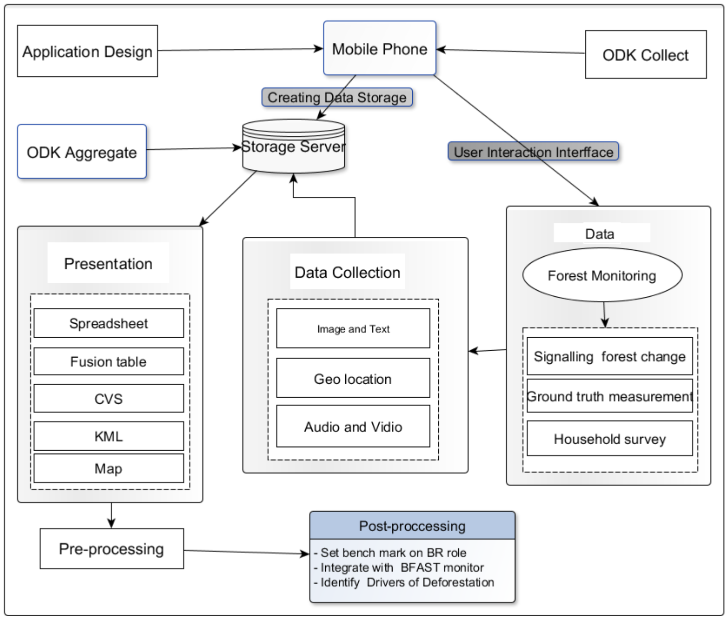


Figure 4.The ODK system design and procedures. Adapted from: Pratihast et al. (2012) The figure provides complete platform which allows for building questionnaire (application design), collect data and obtaining results in different file format to integrate the result to remote sensing data.

Three types of forest monitoring forms were created in .xml format and applied through ODK collect. These include signalling drivers of forest change (for reporting of forest disturbance), measuring disturbed areas and collecting training data to integrate with BFAST monitor result and validation of deforestation result from remote sensing products. Data collection component include text, image, audio and geo-location of disturbed forests. In this way, socio-economic and biophysical variables related to deforestation and forest degradation, the way of living of local households and the possibilities they have access to forest to generate an income through farming or non-farming jobs were collected. Then the data collected on the phone were deployed on the server hosting ODK's aggregate tool.

Further, GPS readings were collected during the field work from each sample plots in order to minimize data loss. Field measurements from different sample land use (e.g. agricultural land, forest land and other coffee plantation areas in YCFBR and its surrounding areas) have been carried out for ground truthing related to forest cover change analysis. Yayu BR zonation boundary dataset was obtained from Environment and Coffee Forest Forum (ECFF) in Addis Ababa. It is an organization currently involved in Yayu coffee forest project. In addition, 20 km outside of the BR was buffered in order to compare the rate of forest cover change inside the boundary with the area outside the reserve, in support of REDD+ forest cover change monitoring strategy. Leakage of deforestation might occur if impacts that would take place inside the BR area restricted due to BR management are displaced to a nearby unrestricted area (Ewers and Rodrigues 2008). This allow us to compare rate of deforestation between the BR area and its leakage belt in order to see the effectiveness of the BR in reducing deforestation in support of REDD+. Figure 5 shows ground data collection technique employed during the field work.

nullnull	
meta:instanceID	uuid:995f9665-976a-40b7-bac cf2af090b483
FormID	32
BasicDetails:Name	dereje
BasicDetails:DataType	validation
BasicDetails:Date	2013-10-19 00:00:00.0
Location:Woreda	yayu
Location:kebele	tiji
Location:SamplePoint	within20kmOutsideBR
Location:DistanceToRoad	MoreThan3km
Location:DistanceToVilage	MoreThan3km
Location:DistanceToCoreForest	MoreThan3km
GPS_Coordinates:Latitude	8.2509196736
GPS_Coordinates:Longitude	35.8670498058
GPS_Coordinates:Altitude	1871.1999511719
GPS_Coordinates:Accuracy	5.0000000000
GPSatThePlotEdges:Latitude1	8.2511469908
GPSatThePlotEdges:Longitude1	35.8669355605
GPSatThePlotEdges:Altitude1	1876.3999023438
GPSatThePlotEdges:Accuracy1	5.0000000000
GPSatThePlotEdges:Latitude2	8.2528062304
GPSatThePlotEdges:Longitude2	35.8674004208
GPSatThePlotEdges:Altitude2	1841.0000000000
GPSatThePlotEdges:Accuracy2	5.0000000000
Topography	ValleyBottom_nearStreamOrRi
IsThisForst	no

Figure 5.Forest disturbance data capturing technique during field work (e.g. sample plot 32). The method applied takes five photographs from each sample plot i.e. one from the measured area (central image) and the other photos are taken in all directions from the measured central polygon. Attribute information for each sample polygon measured from portion of disturbed area was attached to each geo-data (e.g. the right table). Inspecting the area, approximate area of deforestation was estimated and recorded in text format for each sample areas.

3.2.2 Software and materials used

Most activities related to remote sensing and ODK data processing and analysis was performed using ArcGIS 10.2, open source free software R (A Programming Environment for Data Analysis and Graphics, Version 3.0.2) and Microsoft Excel. Google earth engines (e.g. Google fusion table and Google earth imagery) were used linked with ODK collected data and BFAST monitor result and for some online graph production.

Most statistical analysis related to NDVI time series, BFAST monitor change magnitude and breakpoint detection and some graphs and maps were produced using R. Most post-processing results of BFAST monitor were analysed and mapped using ESRI ArcGIS 10.2. Combination of BFAST monitor breakpoint and change magnitude results, threshold application to pick most negative change magnitude to identify deforestation masking non disturbance areas and pixel by pixel calculation of forest cover loss are all performed using ArcGIS environment (Figure 39) for the steps and tools used as an example). Besides, the extracted changes were also exported to R in tiff format to plot time series of forest cover change and Excel was used to plot some graphs and tables.

3.2.3 Sample selection and data collection

For field work that was carried out in October and first half of November 2013, sixty sample points (within the BR and the leakage belt) were selected. Simple random sampling design was used in stratified zones of the BR by taking most negative preliminary BFAST monitor change magnitude results as sampling information (Figure 6).

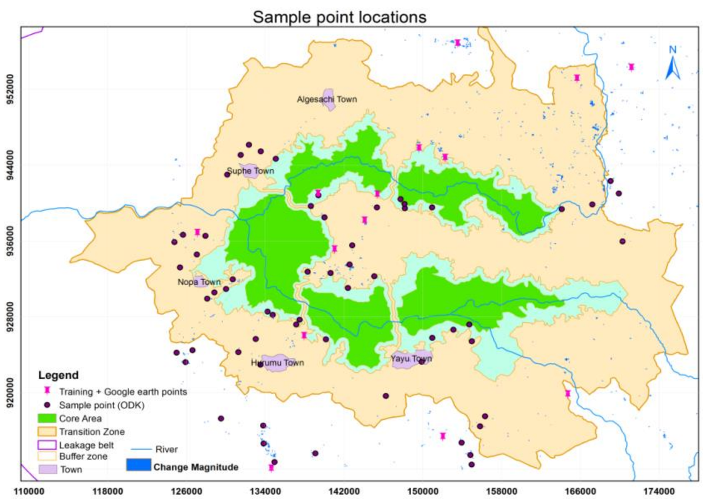


Figure 6.Location of sample points in the Yayu Coffee Forest BR and the Leakage belt. Sample points were selected randomly based on observed preliminary change magnitudes (overlaid on map with blue colour) as information and their accessibility.

Study conducted in Somalia by Verbesselt et al. (2012) showed that forest disturbances can be detected using BFAST monitor large negative change magnitude results in near real-time. Adopting this methodology we applied preliminary BFAST monitor for data collection purpose. Accordingly, 60 sample points were selected from the leakage belt and the BR area from processed BFAST change magnitude result. Accessibility of the area was considered during sampling strategy integrating change magnitude result with high resolution Google earth imagery. Households in the sample point locations were purposively selected considering observed deforestation pixels from Landsat image, distance from road and village. Structured interview was conducted during ground measurement to receive feedback regarding deforestation from their experience and implication of the BR at current state. This helped us to assess forest cover change and its drivers in support of UNESCO - MAB and REDD+ policy and their impact on the forest cover change in the area giving emphasis to deforestation.

3.3 Data analysis methods

This part describes the data processing and analysis phases carried out to answer all research questions. The procedures followed in this study were presented on Figure 7. This flow chart shows the steps followed beginning from the acquisition of multi-temporal satellite image of the study area to the extraction of the required information both from primary and secondary data to answer the research questions. By these methods we have answered the impact of forest BRs on deforestation rate and effectiveness of UNESCO- MAB and REDD+ programmes and objectives in the area.

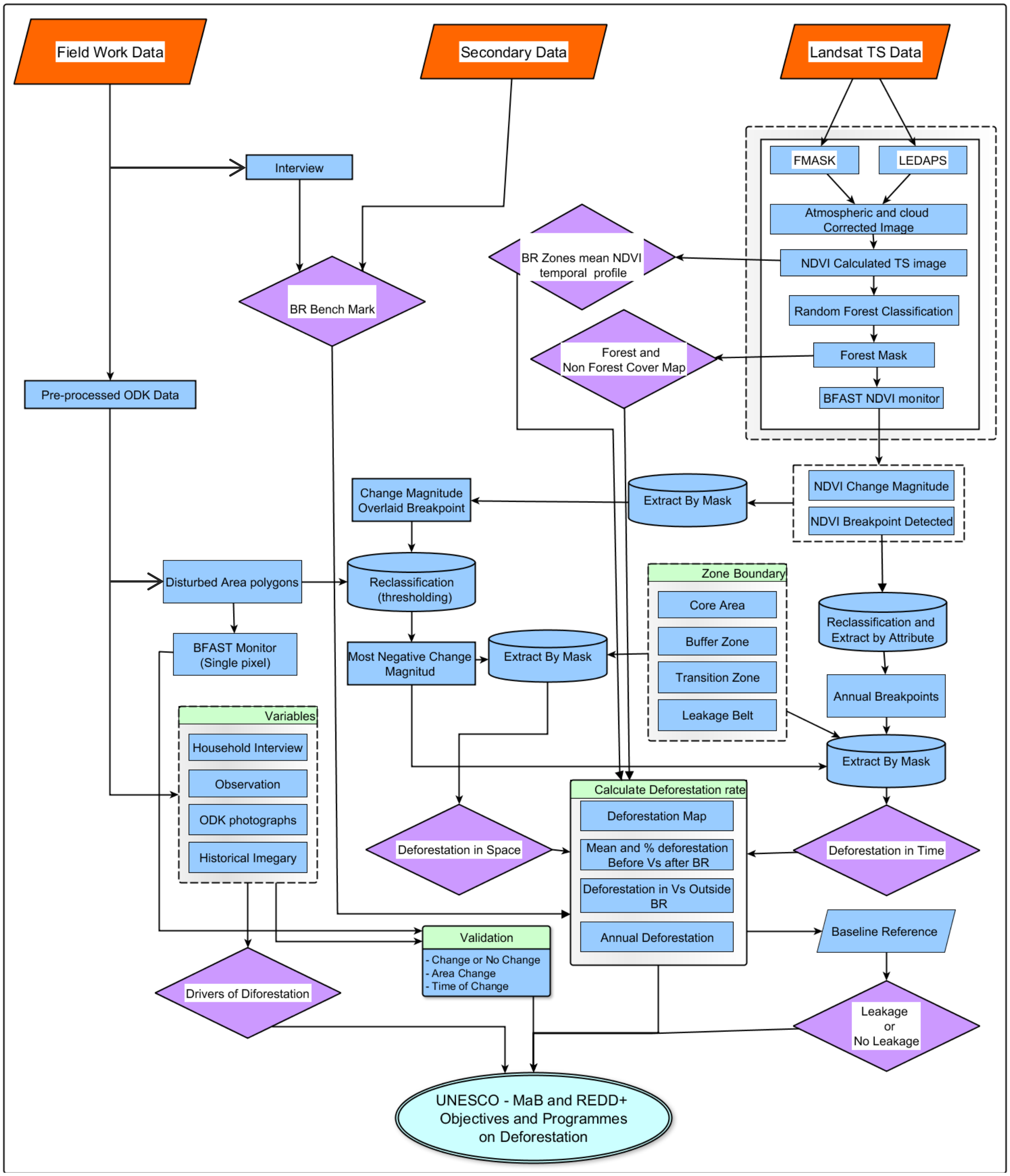


Figure 7 Conceptual Model of overall research Methodology

3.3.1 Pre-processing

Pre-processing of satellite images prior to forest cover change analysis is essential to free from standard remote sensing problems like geometric distortion, cloud cover and atmospheric effects. However, the whole Landsat ETM+ and TM (p170r54) obtained for the study time were processed from atmospheric correction using Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) and from cloud and cloud shadow effect using FMASK. Besides, the obtained data has a processed NDVI calculation, cloud mask and forest mask based on supervised classification to know which pixels to be included in disturbance monitoring algorithm using BFAST monitor.

Related to the ODK data the following pre-processing steps were carried out. These include: i) validating ODK form created in xml format to ensure that the created form work with ODK tools like mobile phone and the server. ii) Each dataset for each sample area has an attribute defining the meaning of each unique feature. After data collection converting the ODK data in CVS format from server, the consistency of each field and its attribute value was checked using Microsoft excel, adapting ODK data in to an appropriate table format for geodatabase in ArcGIS. iii) conversion of point data taken at the edges of disturbed forest from GPS and ODK data to spatial polygons was carried out to integrate the result with BFAST monitoring and area calculation.

3.3.2 Analysis of biosphere reserve concepts and interview results

Questions related to role of UNESCO biosphere reserve and how its address issue of deforestation and forest degradation was answered based on primary and secondary data sources describing qualitative and quantitative information. Before conducting the issues of BR in YCFBR, the study addressed and looked at an overview of some selected UNESCO biosphere reserves in tropical regions and investigated how these BR have addressed the issues of deforestation. The data obtained through the interview result was interpreted in two ways. First, through qualitative description and the secondly by quantifying the data obtained from qualitative one. This quantitative analysis of qualitative data “involves turning the data from words and images into numbers” by coding. In this step listening and reading the interview results and then organizing them and coding steps were followed to construct a category system that allows us to categorize all of the data systematically.

From literature review, expert and farmers’ interview, we created some bench marks of the BR in order to adequately address the issue of deforestation. This provides evidence on what biosphere reserves already have done in this regard and how it explores sustainable use of forest ecosystems. Our expectation and hypothesis was that YCFBR is changing towards achieving its objective and demonstrating adherence to its plans in order to retain its designation.

3.3.3 Landsat Multi-temporal NDVI profile

The NDVI cloud masked images we have obtained were assembled in to time series stack to see the dynamics of NDVI in the study site. Then a linear trend of mean NDVI for each zones of the BR area was calculated at all-time points, to get mean NDVI time series per zones. Mean of all pixels for Core and

Buffer zone are calculated easily. While, calculating mean NDVI for the whole transition zone was not straightforward and computationally demanding processes, where an additional computer memory was needed. For this reason six randomly selected polygons were created in the transition zone. Later mean NDVI for each selected polygon was calculated and comparison for similarity in these NDVI profiles has been carried out for consistency (Figure 37). In this procedure the mean NDVI data was graphed for each of the three BR zones adopting the methodology described by Turner et al. (2013), for irregular Landsat time series data from 2005 to 2013.

The NDVI measures vegetation dynamics ranging from -1 to +1 values, based on photosynthetic structures (Turner et al. 2013) of plant which absorbs radiation in red wavelengths of the spectrum and reflect radiation in the infrared wavelengths. Mean NDVI values calculated for each zone was plotted to show variation in vegetation index and help to integrate the result in BR management plan.

3.3.4 Forest cover map

The BFAST monitoring considers historical data in order to assess the disturbance intensity in monitoring period. However, in order to calculate annual deforestation rates and compare deforestation between BR zones and the leakage belt which was observed from Landsat time series, a reference forest cover data of the area was derived. Forest and non-forest cover map of the study area for 2005 was derived from each individual image, using supervised random forest classification algorithm. Random forest supervised classification accounts for random subset of forest and non-forest training pixels. Many current studies (Gislason et al. 2006; Rodriguez-Galiano et al. 2012) also described the importance of random forest classification for remote sensing and geographic datasets.

Each zone boundary was subsetted to the image and their forest area was calculated pixel by pixel base and converting the area of the pixels (30*30m) to hectares by adopting the methodology described by (Souza Jr et al. 2013; USAID 2013) for Landsat image. This forest area was then used to estimate total and annual deforestation rates in the biosphere reserve and the leakage belt. Later the classified result was compared with other data sources for its accuracy.

3.3.5 Forest Cover Change detection algorithms

Many forest cover change detection approaches have been developed in remote sensing domain (as discussed in section 2.6, where most of them have been applied in a limited temporal scale, using few observation dates. However, in the present study we proposed BFAST monitor change detection algorithm that involves the use of dense time series datasets to discriminate areas of forest cover loss within a time series. The ODK collected were incorporated in forest cover loss detection technique and analysis. The time-series change detection technique applied in this study relies on the computation of NDVI using the formula described under section 2.5.

Break For Additive Seasonal and Trend monitor

The BFAST monitor is a multipurpose change detection approach designed to detect changes in time series data (e.g. deforestation) with in near real time. The BFAST Monitor playas key role in many studies, to detect deforestation and forest degradation at frequent time intervals and realizing large time series datasets (DeVries et al. 2013a; Verbesselt et al. 2012). Here, we adapted the BFAST monitor time series analysis approach developed by (Verbesselt et al. 2011). Having huge advantages as described under section 2.7, BFAST monitor automatically identifies a stable history period within time series to model normal expected behaviour and enables detection of abnormal events (i.e. forest disturbances within new observations. See for more details Verbesselt et al. (2011) and full Package 'bfast' - Cran).

As described by Verbesselt et al. (2011) the following three steps were required in order to apply the real-time disturbance detection on a newly acquired data in time series.

1. History period- data that has been already acquired and serve as a base reference for stability and model normal expected behaviour of vegetation dynamics. We have defined Landsat time series data from 2000 -2005 as history period to obtain normal predict response in the monitoring period (2005-2013).
2. Monitoring period- the period representing new observed data that has been monitored for existence of disturbance.
3. Season-trend fit- fit based on stable history period and predicts normal data variation.

The BFAST monitor detects disturbance if newly acquired data in the monitoring period deviates from this normal expected behaviour. Accordingly, we have detected disturbances due to deforestation, identifying magnitude of change and timing of disturbances as the big outputs of BFAST monitor.

BFAST breakpoints and magnitude of change

Detecting abnormal behaviour of vegetation index (breakpoints) with in a time trend helps to indicate time and where the disturbance occur (DeVries et al. 2013b; Verbesselt et al. 2010a; Verbesselt et al. 2011). The BFAST monitor reports breakpoint i.e. if there is any disturbance during the monitoring period indicating the corresponding date of disturbance (break date). Besides, the magnitude of change and direction of disturbance were estimated i.e. the difference between the median of the fitted season-trend model (expected behaviour) and the new data during the monitoring period with ± signs. Deviation of monitoring period data from predicted response with most negative change magnitude value illustrate the effect of disturbance (e.g. due to deforestation).

3.3.6 Forest cover change analysis

The results of BFAST monitor (NDVI break points and NDVI change magnitude), integrated with in-situ ground based data measured using ODK collect were used to determine forest cover change dynamics and general deforestation observed in the study sites. Based on BFAST monitor results, the timing and magnitude of all abrupt changes were detected and mapped. In our forest cover loss detection analysis change magnitudes with most negative values has received emphasis, while small magnitude spurious changes were excluded from the analysis, since areas with no true changes can sometimes be detected due to noisy time series (Thonfeld and Menz 2013).

We considered most negative change magnitude pixels where breakpoints are detected, and others were masked considering them as non-disturbance during the analysis. The NDVI data of change magnitude with 3*3 median filters applied, to eliminate anomalous spikes from magnitude raster pixels were used in the analysis. Forest cover disturbances due to deforestation were identified as follows:

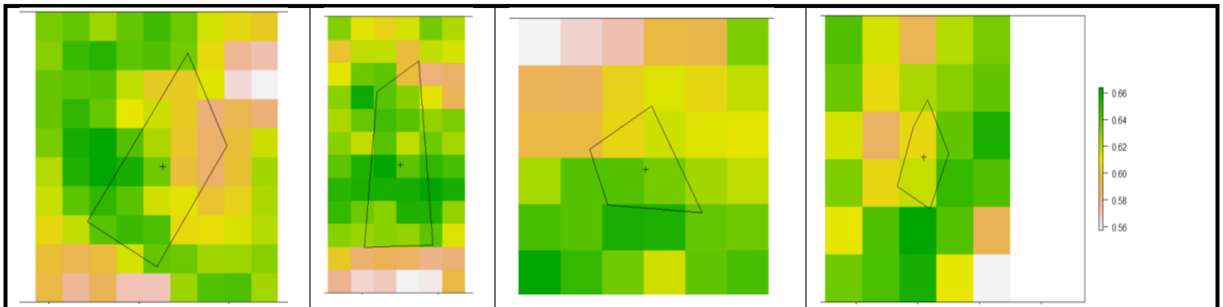
1. Combinations of BFAST monitor NDVI breakpoints and change magnitude results observed in the monitoring period (2005 to 2013).
2. Extracting change magnitude results overlaid with breakpoints detected and masking non-overlap areas.
3. Combination of extracted change magnitude results with ODK collect field work measured disturbed area polygons.
4. Reclassification and threshold application to pick most negative NDVI change magnitude to identify deforestation.
5. Masking non-disturbance areas and pixel by pixel calculation of detected area of deforestation using ArcGIS environment

Based on BR boundary shape files obtained from Environment and Coffee Forum in Ethiopia (ECFF), Landsat image time series results were subsetted to eliminate areas outside of the study region and extract changes observed in each BR zones. In addition, 20 km outside of the BR was buffered in order to compare the rate of deforestation inside the boundary with the area outside the reserve, in support of REDD+ forest cover change monitoring strategy. To check the reliability of leakage belt area, first we have calculated the area of each BR zones pixel by pixel and compared with the area obtained from ECFF. Consistent with our results, ECFF reported in 167,021 ha for the whole area. In agreement with this we have got 167,013 ha based on pixel based calculation using ArcGIS 10.2. This shows that there was no difference observed between our result and ECFF report. Based on this we have calculated 500,605 ha for leakage belt area. This allows us to compare the rate of deforestation between the BR zones and the Leakage belt (20 km outside the BR) to fulfil the stud's objectives.

3.3.7 Forest cover loss detection for single ODK sample points in time series

To determine forest cover loss detection for single ODK data, we have used BFRAST monitor to detect breakpoint of each sample points by taking: 1) fifty sample points collected with ODK during field work, 2) eight sample points as training from non-disturbed areas (forest and agricultural field) using ODK and, 3) two sample points from historical Google earth imagery by digitizing. In total, we have monitored 60 sample points by taking the central pixel of each sample polygon. Further this helped us to confirm disturbances observed for the whole area by BFAST monitoring and evaluate the reports of the interviewees collected during the field work.

Pixel based break detection using BFAST monitor detects the dynamics in time series by decomposing defined time series data in to season, trend and noise components. Taking these components to model the expected behaviour of time series data, we detected near-real time disturbances (breaks) for each single pixel found at the centre of each polygon measured using ODK data. We have used BFAST monitor for each (sixty) sample polygons taking 2005 and 2009 as start of monitoring period and 2000 to 2005 as history period. Figure 5 bellow shows example of sample polygons we applied to identify break detection individually in the monitoring period. The central pixel with + sign was the target pixel detected from the area measured using ODK.



Sample 25 (regeneration) | Sample 32 | Sample 44 | Sample 105 (coffee Forest)

Figure 8.Examples of individual field collected polygons and method of monitoring time series of the centeral pixel located at + sign for each disturbed polygon at different locations. The image where the polygone ovelaid is NDVI calculated image for single layer 137

3.3.8 Validation

Initially, we have collected field work data based on preliminary BFAST monitoring result. However, comparison of BFSAT monitoring result observed from remote sensing domain with field work data was important to indicate the reliability of both methods if applied. Forest disturbance events (change or no change), their size and the timing of events recorded and observed from both methods have got more emphasis in this section. Comparisons between in-situ grounds based measurements from ODK data and changes observed from Landsat analysis using BFAST monitor was carried out by simple linear regression taking them as independent and dependent variables. The results of BFAST with most negative NDVI change magnitude was overlaid with Google earth imagery to determine existence of deforestation in that period. However, due to limitation of the historical imagery for this site, we have selected four years based on the availability of the imagery to validate our BFAST result that was based on ODK data we collected from the field. Totally 60 sample points (50 samples from ODK and 10 samples from Google earth) were visually checked on Google earth for the existence of forest and to compare area of deforestation.

3.3.9 Calculating the spatial and annual deforestation rate

The annual deforestation rate is an estimate of the area of forest affected by deforestation or by forest degradation in a given year (Souza Jr et al. 2013) and, expressed as hectares per year in this study. While spatial deforestation rate is deforestation rate observed in each BR zones and in the leakage Belt area. Taking combined effect of breakpoint times and change magnitudes of BFAST monitor to an annual scale as described by (DeVries et al. 2013b), disturbance timing observed in each BR zones in study period was used to produce deforestation rates. We have used pixel by pixel based deforestation estimation for the entire study period based on this BFAST monitoring approach and applied on Landsat imagery.

Forest cover map result from year 2005 was used as a reference date for estimation of deforestation rates, since we started forest monitoring using BFAST monitor from the beginning of 2005. Deforestation detected and observed in each time step was calculated and mapped for each successive year and in each BR zones. Mean and percentage area of deforestation derived from pixels in hectares was calculated based on Lambert et al. (2011) to get the extent of forest cover change spatially and temporally. Spatially pixel based rate of forest cover change between the BR zones and the leakage belt and in time deforestation rates before and after the establishment of the Biosphere Reserve was assessed. Later on, all results were compared to each other within time series using maps and graphs giving emphasis to UNESCO- MaB and REDD+ objectives and goals obtained from the first research question which was used as benchmark.

3.3.10 Drivers of deforestation

Since the study was intended to identify change in forest land as a result of deforestation investigating the drivers of forest cover loss help to support the ongoing MaB and REDD+ forest monitoring approach. Both quantitative and qualitative approaches were employed for data collection, addressing different questions.

The objective of these interviews was to obtain more precise and topical information on forest cover changes and to assess whether the BR effectively addressed these drivers, verify and integrate with remote sensing estimates, and to signal new current forest cover changes in the study area. In total fifty household surveys were conducted together with ground measurement. Forest cover change patterns are linked to variables that describe the socio-economic or biophysical characteristics of the land units (Getahun et al. 2013; Wakjira 2010).

The collected data was presented in a tabular and map/graphic form for visualization and analysis. The tabular forms was created in the form of CVS and converted to excel data from where tables and charts were produced. Google Fusion Tables (GFT) online data management application tool and KML (keyhole Markup Language) data transformed from server was used to facilitate easy collaboration and data visualization. Besides, information collected through structured interview (SI) was further used to explain the forest change obtained from remote sensing domain qualitatively.

To understand the underlying derivers of deforestation additional buffer zone rings were created around road, town (village) and core forest layers with 2 km interval adapting the methodology applied by (Getahun et al. 2013). This GIS- layer was developed to assess how accessibility to road, village and core forest can affect the deforestation rate and to explore deforestation pattern linked with the BR management approaches. The distance factors (distance from roads, local towns and core area of the forest) were considered to be proxies for accessibility to forest. Later deforestation rates observed in the BR were extracted corresponding to the buffer rings and deforestation rate related to each sated factors were mapped depicting hotspots of deforestation in the BR area.

4. Results

This chapter presents the main findings of the study. The four research questions formulated to address the issue of deforestation in support of MaB and REDD+ activities are presented in consecutive sections. Section 4.1 introduces the results of literature and documentary analysis on an international experiences. In section 4.2 interview results with organizations and households during the field work related to BR role, concept and practices in general and Yayu BR in particular are presented. These two sections set the bench mark of the rest three research questions. Section 4.3 and 4.4 present result and interpretation of change dynamics in deforestation and the validation of this result. Section 4.5 presents impact of BR on deforestation in time and space and in section 4.6 the drivers of forest cover loss analysed from remote sensing and ODK data are presented.

4.1 UNESCO Man and Biosphere programme: literature review

In these section results of literature review on international experiences of MaB programme strategies in implementing BR concepts, rules and goals are presented. Section 4.1.1 presents UNESCO biosphere reserve roles, concepts, definition and rules while section 4.1.2 addresses BR practices and in-situ realities in tropical regions in addressing deforestation issues.

4.1.1 UNESCO biosphere reserve concepts, definition and rules

4.1.1.1 The World network of biosphere reserves

The World Network of Biosphere Reserves (WNBRs) is the largest network of protected areas of MaB program in the World, with a surface area of over five million square kilometres by 2010 (UNESCO 2010b). The MaB programme was launched by UNESCO in 1971 (Ishwaran 2012), two years later after the idea of setting up BRs resulted from the UNESCO biosphere Conference held in Paris from 1 to 13 September 1968 (Ishwaran 2012; Mehring 2011). The main objective was rational use and conservation of the resources of the biosphere. Through establishment of BRs, UNESCO's MaB is aimed at developing the bases for sustainable use and conservation of biological diversity in equitable way establishing a new system of relationships between people and their environment (Mehring 2011).

According to Coetzer et al. (2013), when the first set of BRs was designated, the conservation role was prioritised, while development and logistic roles were neglected, and links between environmental resource use and development were not addressed. The expansion of BR concept and practices in to development dimension show a noticeable trend in the 1980s (a trend that was noted at the First International Congress on BRs in Minsk, Belarus in 1983). This concept was more matured at second International Congress on BRs in Seville, Spain in 1995 (Ishwaran et al. 2008). Currently, the priority aim of the MaB Programme is to foster function of individual BRs, increasing their involvement in the WNBRs (UNESCO 2010b). This Network is considered to be an efficient tool for the implementation of conservation and sustainable resource uses, development of scientific programmes and integrated natural resources management, through the application of the BR concept in the field (Coetzer et al. 2013; UNESCO 2010b). The WNBR fosters the balanced relationship of people and natural environment for sustainable development through participatory discussion, knowledge sharing, and human livelihood improvements, giving respect for cultural values and society's ability to cope with change (Jackson et al.).

4.1.1.2 The Biosphere reserve concept

Biosphere Reserves (BRs) are "areas of terrestrial and coastal/marine ecosystems or a combination, which are internationally recognized within the framework of UNESCO's programme on MaB" (UNESCO 1996, 2010b). The BR concept, as the pillar of MaB conservation work was developed in 1974 to encourage establishment of protected areas (UNESCO 2010a), and also to address the need to balance conservation of biological and cultural diversity with economic and social development (Coetzer et al. 2013; UNESCO 2010b). UNESCO BRs are currently served as "living laboratories for sustainable development" and are "the only sites under the United Nations system that calls for conservation and sustainable development to proceed along mutually supportive paths" (UNESCO 2010a).

The modern-day BR concept has evolved to represent an interdisciplinary idea to solve the ecological, social and economic dimensions of biodiversity loss (Coetzer et al. 2013) placing more emphasis on the relationships between people and biodiversity (Price 2002). In its spatial approach BR is an environmental management tool in which valuable ecological resources, constituting a preservation core, are protected by buffers and transition of the surrounding land organized in a gradient of increasing intensity of human use (Coetzer et al. 2013; Gole et al. 2009). Thus, according to these sources, there is decreasing intensity of land use and management interventions with proximity to the core areas. These reserves are nominated by national governments; in which each reserve must meet a minimal set of criteria and adhere to a minimal set of conditions before being admitted to the Network of world BRs. In general, each BR is intended to fulfill three major interconnected functions: conservation of biological and cultural diversity; economic and social development; and logistic support for research and education (Fritz-Vietta and Stoll-Kleemann 2008).

The practices of BRs have evolved since 1976 when the first 58 BR sites were recognized two years later the launch of the concept in 1974 (Coetzer et al. 2013). According to different studies, BRs are increasing spatially and temporally, as an example, by 2010, 563 sites in 110 countries (UNESCO 2010b); by 2012, 610 reserves in 117 countries (Coetzer et al. 2013) and by 2013, this had increased to 621 reserves (including 12 Trans boundary sites) across the world (www.unseco.org) and will looks continue to expand over the next decade. Figure 9 shows the spatial and temporal expansion of the BRs.

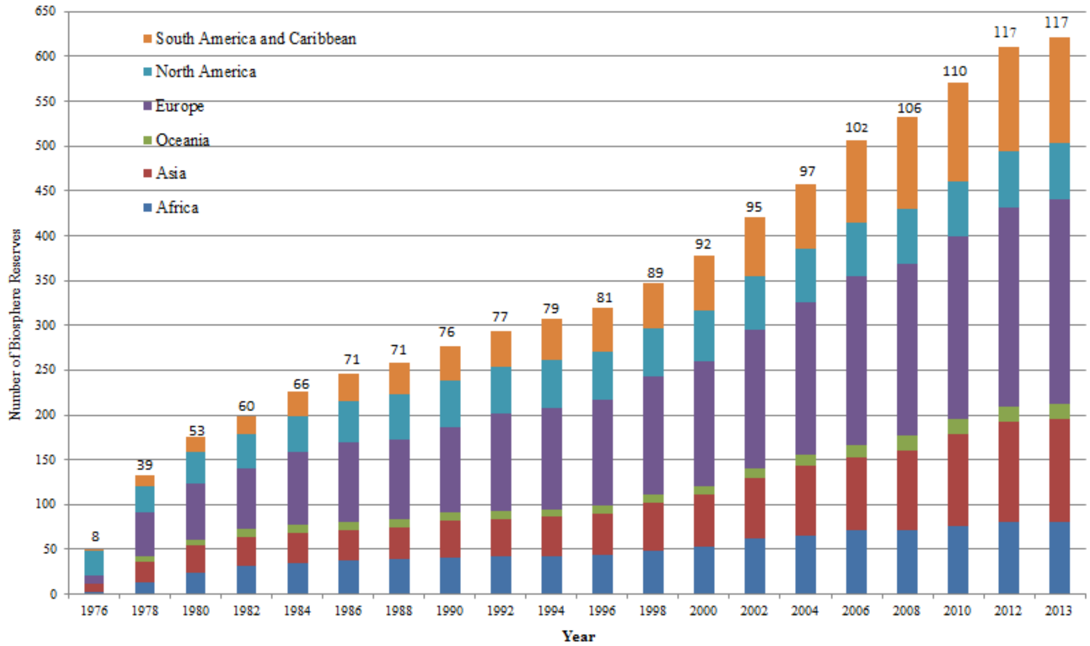


Figure 9.Time series of BRs by region from (1976-2013) including number of countries involved at the date (above the bar). The BR number indicated not include BRs withdraw from the MaB program. The data was extracted from UNESCO MaB database engine (2013), World Network of Biosphere Reserves (2010) and different literature sources. Source: adapted from Coetzer et al. (2013)

4.1.1.3 Goals of Seville strategy and the Madrid action plan on biosphere reserves

The UNESCO has prepared the Seville Strategy and the statutory framework in order to provide recommendations for developing effective BRs and for setting out the conditions for the appropriate functioning of the networks. On an International conference held in Seville, Spain (1995) a new starting point for the development of the network and reorientation of the concept BR was arranged. The conference was organized to enable an evaluation and reflection on the role and functioning of BRs in the 21st century and started a new era for the WNBRs (UNESCO 1996). Examining past experiences and identifying feature emphasis that should be given to the three functions of the BR were adopted from the conference. A number of general recommendations for the implementation of the four goals of the Strategy, i.e. 1) use BR as conservation of cultural and natural diversity, 2) utilize BR models of land management and approaches to sustainable development, 3) use BR for research, monitoring, education and training, and 4) implementation of the BR concept were made (Mehring 2011; UNESCO 1996). Moreover, the strategy provides recommendations for developing effective BRs and confirmed on the validity of the three functions in the feature, extending the concept of BR further than protected areas (UNESCO 2008).

In combining the three functions of BRs, Statutory Framework explored that, individual BRs should strive to be sites of excellence. For example, in article four the criteria to be qualified for designation as BR were listed (UNESCO 1996). Paragraph five explicitly refers to appropriate zonation and defines; 1) the core area as "devoted to long-term protection", according to the conservation objectives of the BR, 2) the buffer zone as "the area surrounding or contiguous to the core area(s), where only activities compatible with the conservation objectives can take place", and 3) an outer transition area "where sustainable resource management practices are promoted and developed" (UNESCO 1996). Unable to satisfy these criteria within a reasonable period i.e. 10 year anniversary of the designation date (Coetzer et al. 2013) may eventually lead to a site's withdraw, not to be referred to as a biosphere reserve (Coetzer et al. 2013; UNESCO 1996).

On 3rd World Congress of BRs which was held in Madrid, Spain in February 2008, the Madrid Action Plan (MAP) was agreed. This action plan builds on the Seville Strategy and aims to capitalize on the strategic advantages of the Seville instruments and raise BRs to be the principal internationally designated areas dedicated to sustainable development in the 21st century (UNESCO 2008). The action plan was intended to respond to the emerging challenges accelerated climate change and loss of biological and cultural diversity which impact the ability of ecosystems to provide services. The MAP also attempt to re-orient the MaB and WNBR activities over the period 2008-2013 to strategically address these new challenges, translating global principles of sustainable development in to locally relevant praxis (UNESCO 2008). For this MAP identified 4 main action areas, with 31 targets and 65 actions that are critical to achieving the vision and mission of the MaB Programme to ensure effective BR functions. The four main actions are: 1) cooperation, management, and communication, 2) zonation – linking functions to space, 3) science and capacity enhancement, and (4) partnership. Furthermore, action 2 of MAP indicate that consideration will be taken in order to make BRs more effective in combining conservation, sustainable use of resources and knowledge generation through integrated zonation. Thus, target 12 of the MAP give emphasis to the implementation of zonation and fulfilling their functions.

Generally, we have designed to track implementation of UNESCO MaB and REDD+ objectives in Yayu Forest Biosphere reserve, giving emphases to deforestation issues in and outside the boundary of the site guided with UNESCO BR strategies and goals and concepts presented.

4.1.2. Biosphere Reserve practices and in-situ realities in tropical regions

4.1.2.1. Deforestation in tropical regions

Tropical forests are earth's richest ecosystems providing largest biological diversity of plants and animals playing vital roles in hydrology, global climate and carbon storage worldwide. Evidences estimated that they contain at about 50% animals and 75% plant species worldwide (Butler and Laurance 2008). On the other hand, tropical deforestation is the source of 12 to 17 % of GHG emissions from human activities (rainforests.mongabay.com). Even if, there was variability in global deforestation, hotspots of deforestation were found in tropical regions like Southeast Asia, Latin-America and Africa (Getahun et al. 2013). However, some recent studies revealed that deforestation rates in many parts of the tropical area are slowing down (Christie et al. 2007; Lange 2011). In some cases studies forest transitions, i.e. the transition from a phase of net deforestation to net reforestation have been reported (Mather and Needle 1998; Rudel et al. 2005).

Table 1.Summary of some Studies on Forest Cover change in Tropical Regions

Study	Subject Area	Study Region	Period	Data type used	Some findings
Steininger et al. (2001)	Tropical Deforestation	Bolivian Amazon	mid-1980s and early 1990s	Landsat TM and MSS	Documented the area deforested 15,500 km^2 in the mid-1980s and 24,700 km^2 by the early 1990s. The rate of tropical deforestation in the forest zone of Bolivia was 1529 $km^2 yr^{-1.}$
Killeen et al. (2008)	Historical Land-Use Chang	Eastern Bolivia	Five temporal periods: pre-1976 to 2004.	Ortho-rectified Landsat images	Documented twice increase in deforestation during 1986–1991, declined in the 1990s, and then increased again in the most recent period due to land use change.
Leimgruber et al. (2005)	Forest cover change patterns	Myanmar (Burma)	1990−2000	Landsat-5 TM and Landsat-7 ETM+	Documented annual decline of forest cover by 0.3%, although variation in deforestation among administrative units observed.
Christie et al. (2007)	Fragmentation and clearance of forests	Liberia	1986 - 2000	Landsat TM and MSS	Estimated low rates of forest loss and fragmentation, i.e. 0.2% per year during these periods
Getahun et al. (2013)	Factors controlling patterns of deforestation	Afro montane forests of Southwest Ethiopia	1957 and 2007	Quick bird, SRTM and aerial photograph	Indicated 19% decline in forest cover since 1957, where way of living and the inaccessibility to markets have the share for deforestation rate.

Note: TM/ETM, Thematic Mapper/Enhanced Thematic Mapper; SRTM, shuttle Radar Topography Mission

4.1.2.2. Implication of UNESCO biosphere reserve on deforestation rate: some evidences from tropical regions

Similar to other parts of the world, several innovative approaches to address environmental problems were undertaken through MaB program in tropical regions. Specifically, achieving sustainable balance between people and nature through increasing human participation on tropical forest ecosystems has a great concern. In this MaB approach many forest BR sites were designated as WNBR, since 1976 in different parts of tropical regions. As pointed by Ishwaran et al. (2008), in 1984 the action plan for BRs indicated that BRs bring balanced relation between conservation and development in addition to its economic and social benefit to local community.

In order to see the implications of UNESCO biosphere reserve programs in YCFBR, going back in history we tracked some experiences of BRs and their trends on forest cover change from some tropical regions. Six BRs are selected as cases based on availability of case studies conducted on biosphere reserves, especially related to implication of the BRs on forest cover change issues. The brief description of the six selected BRs (cases) is presented in the appendix I. Here, summary of all these BRs and their implication on forest cover change are concluded in the table below.

Table 2.Summary of UNESCO biosphere reserve cases from tropical forest areas and the general implication of them on deforestation issues

Cases	BRs	Country	Deforestation Status After designation as WNBR				Comments
			CA	BZ	TZ	LB	
Case 1	Río Plátano	Honduras	I	I	I	I	- The CA experienced the least forest change, followed by the TZ and BZ respectively. No comparison was observed for before and after the BR
Case 2	Calakmul	Mexico	D	D	NA	I	- Transition zone was not included in all studies observed
Case 3	Lore Lindu	Indonesia	I	D	NA	NA	- Deforestation in BZ decreased from 0.79 to 0.68 %, while there was increase in CZ from 0.06 to 0.27 % per year.
Case 4	Dja	Cameroon	D	NA	NA	NA	- No empirical studies were accessed to determine deforestation for other zones
Case 5	Mount Kenya	Kenya	NA	NA	NA	NA	- No empirical studies were accessed to determine deforestation rate for all zones separately. Increase in deforestation rate till late 1990s and improvement for the whole area from 1999 to 2002 was reported
Case 6	Maya	Guatemala	I	I	I	NA	- More deforestation rate was reported for the period 2002-2007 than 1986-2001 for all zones of the BR area

Note: BRs = biosphere reserves; WNWB=World network of biosphere reserve; CZ=core area; TZ= transition zone and BZ=buffer zone; I=increase; D=decrease; NA= Unknown due to no information was accessed.

In conclusion, most studies discussed thus far have focussed on comparison of deforestation rates inside and outside the BR zones. Whilst protected areas in the BR may reduce the rate of deforestation relative to their surroundings (case 1, case 2), other protected forest may still be cleared at high rates (case 3, case 6). Similarly, although buffer zones are aimed to reduce deforestation rates in the core and bridge conservation objective with sustainable development in the transition zone, they might not eliminate deforestation and in some cases the total area of forest loss can still be very high (case 1; case 6). Although, little information exist to see the relation of the leakage belts from the BR zones, few studies indicated that deforestation inside protected areas is simply displaced to surrounding areas (case 1, case 2). This may cause reduction in carbon as result of success in conservation in protected area or the BR area to be offset by an increase in deforestation outside the BR area, indicating unsuccessful of the MaB and REDD+ objectives.

4.1.2.3. Deforestation Facts and Cause in Ethiopia

Concerning changes in forest cover, FAO estimated that Ethiopia lost an average of 141,000 hectares of forest per year between 1990 and 2000 with an average annual deforestation rate of 0.97%. Between 2005 and 2010, the rate of forest change increased by 1.11 % per annum. In total, between 1990 and 2005, Ethiopia lost 14.0% of its forest cover, or around 2,114,000 hectares (FAO 2010). Measuring the total rate of habitat conversion (defined as change in forest area plus change in woodland area minus net plantation expansion) for the 1990-2005 intervals, FAO also estimated that Ethiopia lost 3.6% of its forest and woodland habitat.

Table 3.Trend in extent of forest in Ethiopia from 1990 to 2010

	Forest cover (1000 ha)				**Annual change rate**					
					1990-2000		2000-2005		2005-2010	
year	1990	2000	2005	2010	1000 ha/yr.	%	1000 ha/yr.	%	1000 ha/yr.	%
Trend	15 114	13,705	13 000	12 296	-141	-0.97	-141	-1.05	-141	-1.11

Source: FAO (2010)

Similarly, as described under section 2.3.2 several studies reported different results during their forest resource assessment of Ethiopia. The most prominent cause was conversion of forest to agricultural land, as agriculture land requirement is high than forestry and followed by fuel wood consumption and logging (FDRE 2011a, b). Accordingly, the impact of this deforestation driver is set to increase in a ‘business as usual’ growth path in Ethiopia.

4.2 UNESCO Biosphere Reserves in Ethiopia

This section presents role of forest BR in Ethiopia in general and Yayu coffee forest BR in particular based on interview undertaken with expertise/officials and households (in integration with Yayu BR nomination form. The goals of the BR management plan and functions BR zonation are discussed here.

4.2.1 Biosphere reserve role and in-situ realities in Ethiopia

Related to the BR in the context of forest and its role, all organizations have different but the same contextual meaning. According to IBC of Ethiopia BR is "a conservation approach that aimed to conserve forest through participation of local communities, categorizing the forest section in to use and conservation zones spatially". Similarly, ECFF and OFWE stated that, "BR is conservation and development tool". Yayu coffee forest was designated as a UNESCO BR in order to conserve and sustainably use the wild populations of Arabica coffee and protect these threatened forest biodiversity". Based on this BR context forest management plan was designed to monitor and conserve these threatened Afromontane forest vegetation types.

Accordingly, inclusion of Yayu forest into WNBRs has many objectives and roles than pre-biosphere reserve, including certification of coffee producers which help them to improve their quality of coffee production and forest resources, conservation of forest biodiversity of the area and manage adjacent forest covers, reconcile conservation with sustainable use of forest resources through logistic support, reduce global climate change impacts through carbon sequestration, generate sustainable finance that can boost the livelihood of local communities while generating income for the government, and expanding buffer zone outwards into the transition area doubling its current size and production within ten years. However, the implementation of these objectives was at early stage.

Coffee production contribute a tremendous amount to the foreign exchange currency as a main cash crop to the country, apart it serves as a means of livelihood for local people and plays a vital role in their socio-economic values (Expertise view during interview). Expertise indicated that involving the local community living next to the forest and their consultation from initial stage to implementation of the BR was carried before and after the BR programme. Currently there was on-going activities in which local people are directly and indirectly involving in. These include forest management by farmers to enhance coffee productivity, planting coffee with shade trees which enable gradual expansion of the buffer zone into the more intensively managed transition area and involving local people to generate income through eco-tourism and other harmonious activities with forest resources.

Revealing the wide importance of BR on forest cover and biodiversity of the area, ECFF depicted that the involvement of local community was limited to some districts in the previous three years. Local people's participation was not equally distributed across all zones and districts. To overcome these problems different management designs were planned to implement the BR together with national and international organizations. The plan was to reach all local communities to benefit them from boosting their agricultural production to carbon credit financing-through forest conservation activities. Currently, where there is endorsement (e.g. in Yayu and Hurumu districts and limited areas of buffer zone) farmers have been trained and equipped with basic skills on forest condition assessment, monitoring and management in order to certify their semi-coffee forest plots.


Sor water fall


Coffea arabica


Home of wild animals

Figure 10 some potential eco-tourism areas in the BR and Leakage belt zones observed during the field work campaign. These and other economic potential sites were considered as development plan in the study site to generate income through eco-tourism reducing agricultural expansion to forest land.

4.2.2 Biosphere reserve functions and zonation: guiding principles in Yayu BR

As pointed during interview, BRs aim is to achieve integrated management of ecosystems by putting in place planning schemes which integrate conservation and development through appropriate zonation. Such land use classification helps to ensure that each BR can effectively fulfil the three basic functions. In complement to Seville strategy and MAP the three basic functions of YCFBR are (i) Conservation - that contribute to the conservation of intact and undisturbed forests with wild coffea arabica populations which are genetically diverse and unique, (ii) development - to foster economic and human development which are socio-culturally and ecologically sustainable, through increasing more coffee production and other forest related products and (iii) logistic Support - to provide support for research, monitoring, education and information exchange locally, nationally and globally. To carry out these functions, physically the BR contain three interrelated zones: the core area, the buffer zone, and a transition zone.

Table 4. Summary of YCFBR conservation and management plan in each BR zones

Zone	Conservation and Management plan
Core Area	Goal: Conservation of Biodiversity ▪ Involve in protection of natural forest and coffee gene reserve areas ▪ Involving local communities in monitoring of intact forest biodiversity ▪ Developing eco-tourism and research
Buffer Zone	Goal: Guarantee protection of core area through sustainable use and management of coffee forests ▪ sustained management of forest for non-timber forest products ▪ Enhance experimental research to boost coffee and non-timber semi forest products
Transitional Zone	Goal: Implementation of sustainable development projects ▪ Involve all stakeholders to work together in order to manage and use the area in a sustainable way.

Generally, from different UNESCO BR guiding principles and interview result of organization it can be concluded that, there is a need to shift towards a more integrated zoning functions. Transition area, in addition to the development function, can also consider conservation goals and. Buffer zones can also have an important connectivity function in a larger spatial context as they connect biodiversity components within core areas with those in transition areas. Equally the core area, in addition to its conservation function, contributes to a range of ecosystem services as development functions that can be calculated in economic terms (e.g. carbon sequestration).

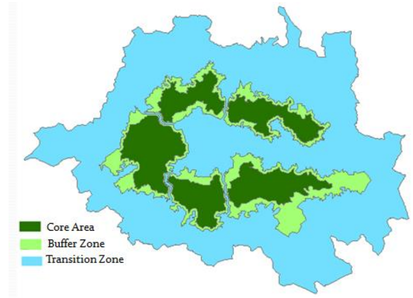


Figure 11. YCFBR zonation and its functions. Core area is where monitoring and research activities are carried out. Buffer zone is where education, training and research are practiced and the transition zone is where integrated land use and settlement exist. More details on Appendix II.

Related to the effectiveness of the BR programme both ECFF and MoST revealed that due to financial constraints and short history of the BR, the management plan was not effectively implemented according to UNESCO BR guidelines. The project was mainly financed by Centre for Development and Research (ZEF) in Germany and supported by Ethiopian Government organizations to achieve this objective. This hinders to widely involve local community and prevent biodiversity loss due to deforestation and forest degradation from the root". However, the strategy was being developed to support in-situ conservation of wild coffee and other forest biodiversity and implementation is going on. Improving income generation through coffee management and plantation outside the coffee forest conservation area was an example.

In order to solve the, problem, for instance, MoST jointly signed an official memorandum of understanding or a "tripartite agreement" with UNESCO's MaB program in Ethiopia and Nature and Biodiversity Conservation Union (NABU) - a Germany based NGO in 2009. The agreement has a total of 11 articles describing functions, roles and responsibilities of each contracting party in order to achieve the Common goal of the BRs. As stated on article one the contracting parties will work together in the area of protection of biodiversity and the sustainable use of natural resources. On article two they agreed to act within a framework of the UNESCO MaB programme, promoting the implementation of the BR program and utilize it as a tool for sustainable development, biodiversity conservation and Climate change mitigation.

The overall interview result on YCFBR zonation shows that it was aimed i) to protect and manage intact forest biodiversity and undisturbed wild coffea arabica populations and preserve their genetic species, ii) to balance conservation with sustainable use of natural resources, through participation and benefits of local communities, tailoring scientific research to resolve natural resource use problems, iii) to undertake BR functions considering the land for which it is best suitable for and increase land capability in carbon sequestration. iv) to ensure that natural resources of the BR required for life (i.e. land, water, air) are managed sustainably and equitably balancing the relationship between man and his environment. To achieve these objectives two broad policy programmes CRGE and R-PP were designed at national level to follow a green growth path that fosters development protecting forest and reducing deforestation from forestry sector in support of REDD.

4.2.3 Farmers' perception on the biosphere reserve concept and forest cover change

The quantitative analysis of qualitative data showing the local households' perception on BR concept and the status of the forest cover loss in six districts was presented in Table 5. The overall result revealed that significantly large proportion of the respondents perceived that there was a decline in forest cover in these districts (except for Yayu and Hurumu) before BR programme. About 74 % of respondents felt that the forest resources of the area was declining (medium to high), while only 26 % believed that forest cover loss was less before the BR designation. According to respondents' point of view, the reason for high forest cover loss was largely as a result of agricultural land expansion which was observed in all zones except for core area. While, over 40.42 % believed that there was low forest cover loss after the BR program, indicating the declining of forest disturbances compared to before the BR implementation. About 45 % of the respondents indicated medium forest cover loss after the area was designated as BR programme and about 15 % still perceived increase in deforestation rate in some parts of the study site.

Table 5.Respondents perception on the status of forest covers loss in YCFBR and the leakage belt since 2000 (10 years before and 3 years after the BR). Assignment of respondents view in each category to translate qualitative data to quantitative analysis was based on their relative response during interview

Districts	Forest loss before BR designation						Forest loss after BR designation					
	high		Medium		low		High		Medium		low	
	No	%	No	%	No	%	No	%	No	%	No	%
Alegesachi	2	4.26	2	4.26	1	2.13	2	4.26	1	2.13	2	4.26
Bilo-Napa	4	8.51	4	8.51	1	2.13	2	4.26	4	8.51	3	6.38
Doreni	5	10.64	3	6.38	2	4.26	1	2.13	6	12.77	3	6.38
Hurumu	1	2.13	3	6.38	3	6.38	-	2.13	4	8.51	3	4.26
Metu	3	6.38	2	4.26	1	2.13	2	4.26	1	2.13	3	6.38
Yayu	1	2.13	5	10.64	4	8.51	-	2.13	5	10.64	5	8.51
Total	**16**	**34.04**	**17**	**40.43**	**14**	**25.53**	**7**	**14.89**	**21**	**44.68**	**19**	**40.42**

The table clearly indicates the status of forest cover loss in six districts before and after the BR program. There was high to medium forest cover loss in four districts (Alegesachi, Bilo-Napa, Doreni and Metu (leakage zone), while low or medium forest cover loss in Yayu and Hurumu districts before the BR. Even, after the BR respondents in these two districts perceived that there was gradual decline of forest cover loss or as it remain low during the interview. There is still some disturbance of forest in Metu, Algesachi and Bilo-Napa districts according respondents point of view after the BR designation.

4.3 Observing forest cover change dynamics in Yayu coffee forest biosphere reserve

This section deals with the forest cover change dynamics observed from multi-temporal Landsat imagery in integration with field collected data. Other open data sources like google earth imagery were also used to pinpoint forest cover loss due to deforestation in the study site using visual assessment. Mean NDVI profile of the three BR zones, forest cover map, monitoring forest cover change dynamics and disturbance detection using BFAST monitor and integrated with field survey results are presented subsequently in the following subsections (4.3.1, 4.3.2, 4.3.3 and 4.3.4), respectively.

4.3.1 Landsat multi-temporal NDVI profile

We analysed the trend in NDVI, using irregular Landsat time series data. Calculating the mean NDVI for each zone in the BR was carried out to create temporal Landsat NDVI time series per BR zones for the period 2005 to 2013. The result for nine years trend shows that NDVI has consistency in core and buffer zones of the BR and more inconsistency in transition zone of the BR which is under intensive human use and where land use related problems are clearly seen as discussed under section 4.2.2.

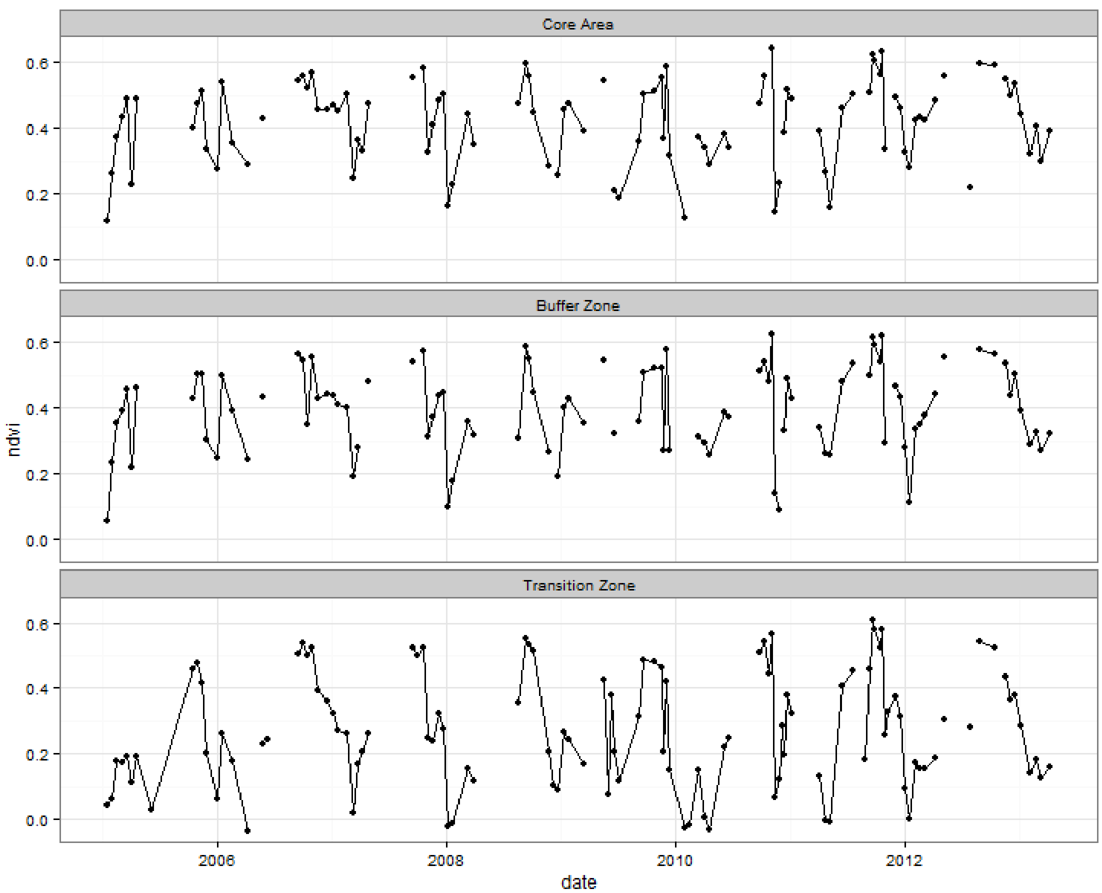


Figure 12.Mean NDVI time series from 2005 to 2013 for YCFBR zones namely core area, buffer zone and transition zone. The time series was mean of all pixels for core and buffer zone, while it was small portion of transition zone due to difficulty of processing mean NDVI of all pixels (computer memory) for

the whole transition area. Mean NDVI was calculated per biosphere reserve zones per time step based on availability of data in each year.

The total mean NDVI values for these zones were compared on annual basis to identify those areas exhibiting greater than specified threshold values (decrease in NDVI) and this might indicate land cover conversion areas. Accordingly, more negative NDVI trends were observed in transition zone which can be due to forest disturbance or related land use problems as observed from visit during field work and Landsat time series image analysis.

From this result we can deduce that transition zone has lower mean NDVI value compared to core and buffer zones respectively (Figure 12). Furthermore, the standard deviation of NDVI value of the three zones in each time step shows that transition zone has high standard deviation (SD = 1.13), while core (SD = 0.67) and followed closely by buffer zone(SD = 0.82) for the same scene in 2005. Reproducibility to another sample location for transition zone show similar structure of mean NDVI profile (Figure 37 on Appendix III). This shows that the transition zone has mixed land use types having dynamic phenologies (e.g. annual change in greening of crops). However, core area having intact forest and Buffer zone consisting semi coffee forest has less difference in NDVI profile as can be observed from the figure.

4.3.2 Forest cover map of Yayu coffee forest biosphere reserve

To calculate the deforestation rates and compare forest disturbances between BR zones and the leakage belt which was observed from Landsat time series, the reference forest cover data have been mapped from year 2005 image. Figure below shows forest cover map of the BR area.

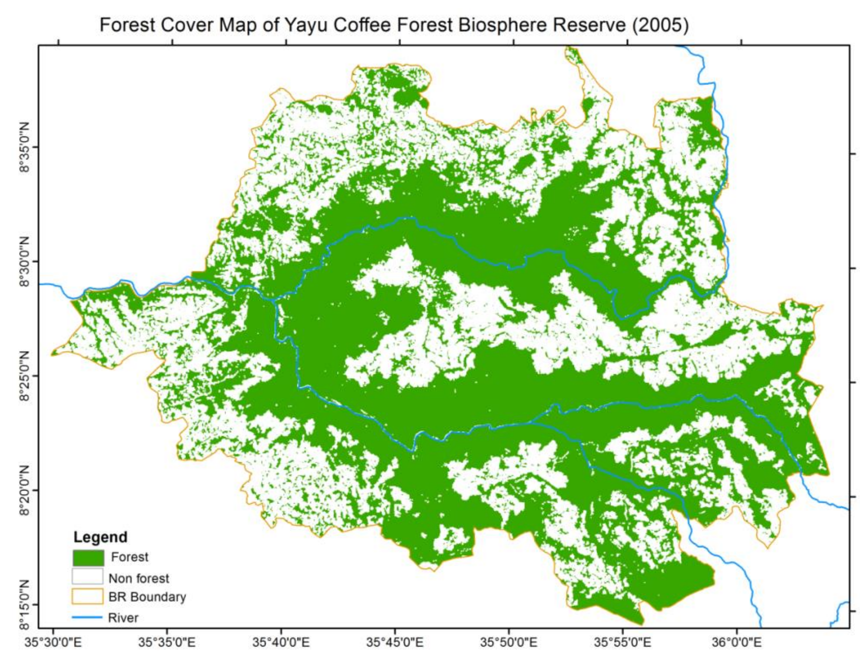


Figure 13. Forest cover map of Yayu Coffee forest biosphere reserve. The figure was generated based on random forest classification algorithm from 2005 single layer Landsat image

Forest area map derived from year 2005 image shows that 58 % (97,053 ha) of total BR area was covered with forest. With respect to the BR zones the core area, buffer zone and transition zone in order are covered by 97.5 % (27, 618.75 ha), 89.52 % (18,798.57 ha) and 43.04 % (50,636.79 ha) of each total land area. The leakage belt has almost similar forest cover with transition zone accounting 44.17 % of land area. In fact the whole core area was covered with forest, while the water running through it might share 2.5 % .FAO estimated forest cover in Ethiopia 13,000,000 ha for year 2005. Based on this data source the BR area and the leakage belt in total shares 2.45 % forest cover of the country by the year 2005.

4.3.3 Monitoring of forest cover change dynamics

A generic change detection approach was used to detect and characterise forest cover disturbance using the proposed BFAST monitor. BFAST change magnitudes with in two interval monitoring period (2005-2009 and 2009-1013) have been used to assess forest cover changes. Our BFAST monitor result shows that NDVI magnitude change varies between highly positive (0.93296) to very low (-0.9473) magnitude intervals in the second monitoring period, and from 0.684907 to -0.73152 in the first monitoring period. Pixels with high negative magnitude change are attributed to forest disturbances, particularly clear cutting and low magnitude changes can represent forest degradation. By combining the two BFAST change magnitude values as described under section 3.3.6, pixels with change magnitude values less than determined threshold value of -0.030, have been considered as deforestation.

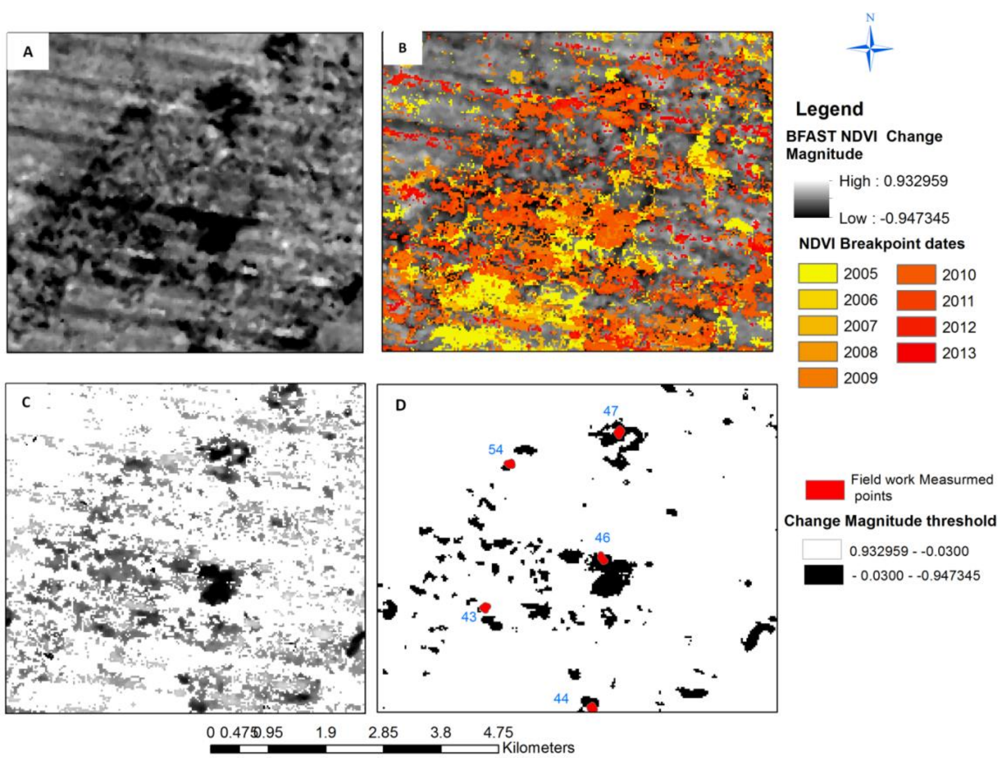


Figure 14.Results of BFAST monitor (2005-2013) on Landsat NDVI image time series and the way we identified deforestation in the whole study area. A) BFAST monitor overall NDVI change magnitude, B) breakpoints detected by year for both monitoring periods overlaid with change magnitude, c) extracted

change magnitudes of the monitoring period overlapped with detected breakpoints in B, where white indicates that no disturbance is detected. The analysis of deforestation D) was restricted to areas identified by threshold (less than -0.03) as an example overlaid with field measured sample point 43, 44, 46, 47 and 54 (red colour). Pixels in black are most negative change magnitudes for the detected breaks, while pixels in white colour are masked pixels based on the NDVI change magnitude threshold determined to identify deforestation areas.

This was based on the combined effect of; i) Change magnitude and breakpoints detected in each year with BFAST monitor, ii) field data we have collected from fifty sample plots and ten sample points taken from historical Google earth imagery. As can be observed from Figure Figure 14D, the data was collected using ODK overlaps with the BFAST monitor high negative change magnitude.

BFAST detected breakpoints were large, however, were still crucial and played key role in deforestation detection. For example, out of breakpoints observed in 2005 i.e. 924669 cells (83, 220 ha of land) for the whole study sites including leakage zone, we also observed high deforestation rate (2289.6 ha). The reason for high rate of breakpoint was related actual disturbance as well as false break due to phenological changes and data gaps

4.3.4 Forest cover disturbance detection by BFAST monitor in integration with field survey and other data sources

4.3.4.1 BFAST monitor change magnitude and forest disturbance

Most negative change magnitude of BFAST monitor results used for monitoring of forest cover disturbance showed that deforestation in all BR zone and its leakage detected from Landsat imagery varies in space and time. Spatially more deforestation was observed in the leakage zone and the transition zone than core area and buffer zone with over all forest cover loss 6.05% and 3.66% of forest cover areas, respectively, for the study time. With time the year 2010 has more deforestation rate in both areas, accounting 1.07% forest cover (1035.81 ha) in the BR area and 1.23% of forest cover (2711.79 ha) in leakage belt (Table 8 on Appendix III).

4.3.4.2 Integration of BFSAT monitor change magnitude and ODK data

The most negative change magnitude with breakpoints derived from BFAST monitor were compared with other land cover changes observed from historical high resolution imagery (Google earth) and field work measurement using ODK collect. Out of 50 sample points measured using ODK collect by the help of preliminary BFAST change magnitudes, 46 of them still overlap after BFAST monitor for the whole study site was applied, revealing true occurrence of deforestation in space (Figure 14 and Figure 15).

Moreover, ODK data was collected to check whether the detected changes in the location observed from preliminary BFAST monitor result were really deforestation or not. The result revel that only 4% (2 observations out of 50) were resulted in misclassification of non-forest as there was regeneration of forests in the site at the present. According to respondents in the area, there was occurrence of deforestation in the past, but now regenerating has occurred due to protection provided by the government. The BFAST monitors for these points also indicate no disturbance since 2005.

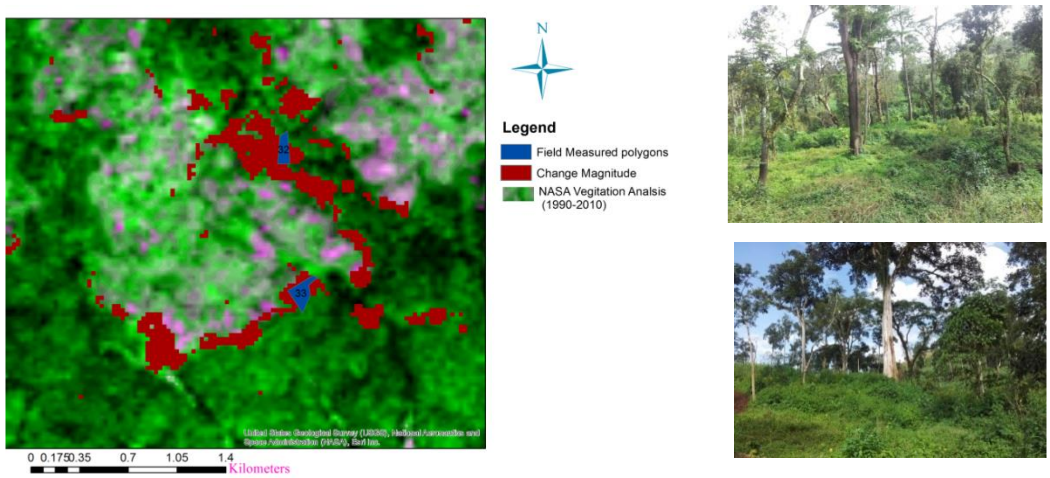


Figure 15.Results of BFAST monitor change magnitude with most negative value (under defined threshold) showing hotspot of deforestation (red colour) overlaid with global 30 meter resolution Landsat imagery from 1990-2010 with band combination of 5, 4 and 3 (left picture as base map). Source of base image: ESRI online image service

The right pictures are field images taken using ODK collect for the corresponding field measured polygons 32 and 33 (blue colour overlaying change magnitude on the left image). The base map for Change magnitude shows the area was covered with forest till 2010. BFAST monitor detected break in NDVI in 2010 for the two sample points. See BFAST monitor plots Figure 41 on Appendix IV.

Using stable historical data as a training period (2000 to 2005), the break dates and magnitude of change indicating positive or negative of the breaks were derived using BFAST monitor. However, as result of variation in spatial pattern of NDVI change magnitudes and breaks points detected, only change magnitudes which overlay with breakpoints were selected as illustrated in methodology part. By assessing the stability of the historical data the break points in NDVI were identified indicating deforestation.

Forest cover loss associated with most negative change magnitudes and breakpoints date were also checked by qualitative visual analysis through high resolution historical imagery (for locations having historical imagery) for sample points collected using ODK incorporating expert knowledge and field observation. Figure Figure 16 was an indication of when BFAST monitor change magnitude for breakpoints detected overlap with historical imagery showing stable history period and detection of forest cover loss with time. On the change magnitude plot (FigureFigure 16) the location indicated by A has -0.2232 change magnitude value. Assessment of historical time series imagery for this location shows that the area was stable till 2/6/2010 and disturbance occurred afterwards which really complement with break dates we have observed from BFAST monitoring (Figure 41 plot 61 on Appendix IV).

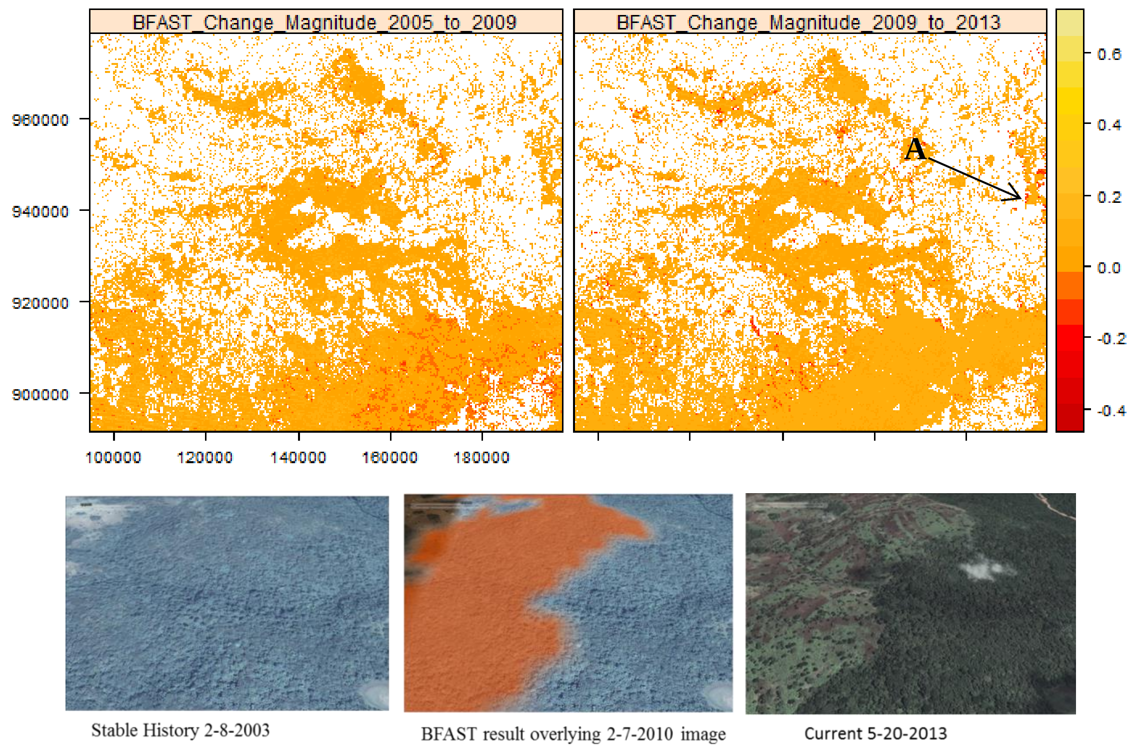


Figure 16. Maps of magnitude of NDVI change in the period 2005-2009 (upper left) and 2009-2013 (upper right) for the whole study area. And historical imagery (Google earth 2003, 2010 and 2013) indicating stable history period (2003 to 2010) and time of breakpoint after 2010 for the area experiencing extensive forest disturbance (last right plot) corresponding to high negative change magnitude observed during the second disturbance monitoring period (at point A) at 8°31'15" N and 36°12'52" E location in the study site. Most lower values with red colour on change magnitude plot shows deforested areas, while low magnitude breakpoints with negative values of orange colour might be associated with forest degradation and others were associated with no change. The white area for both change magnitude plots indicates non-forest pixels prior to 2005.

4.3.4.3 Forest cover loss detection for single sample points

The result of BFAST monitor outcome are magnitude of change with positive or negative value and breakpoints if there was detection during the monitoring period. From 50 disturbance monitoring samples collected using ODK collect still disturbance was detected in 46 sample areas showing breakpoints with negative change magnitude. Two sample points indicate no breakpoints with positive change magnitude supporting the regeneration of forest patches with coffee that observed during field work. However, two areas have no break points having positive and negative values close to zero since 2005. Zooming back in time with less dense historical data for the start of monitoring period (year 2003) we have observed breakpoint in 2004 with negative change magnitude for the first sample (Figure 41 sample 9) that has positive value in our monitoring period 2005-2013.

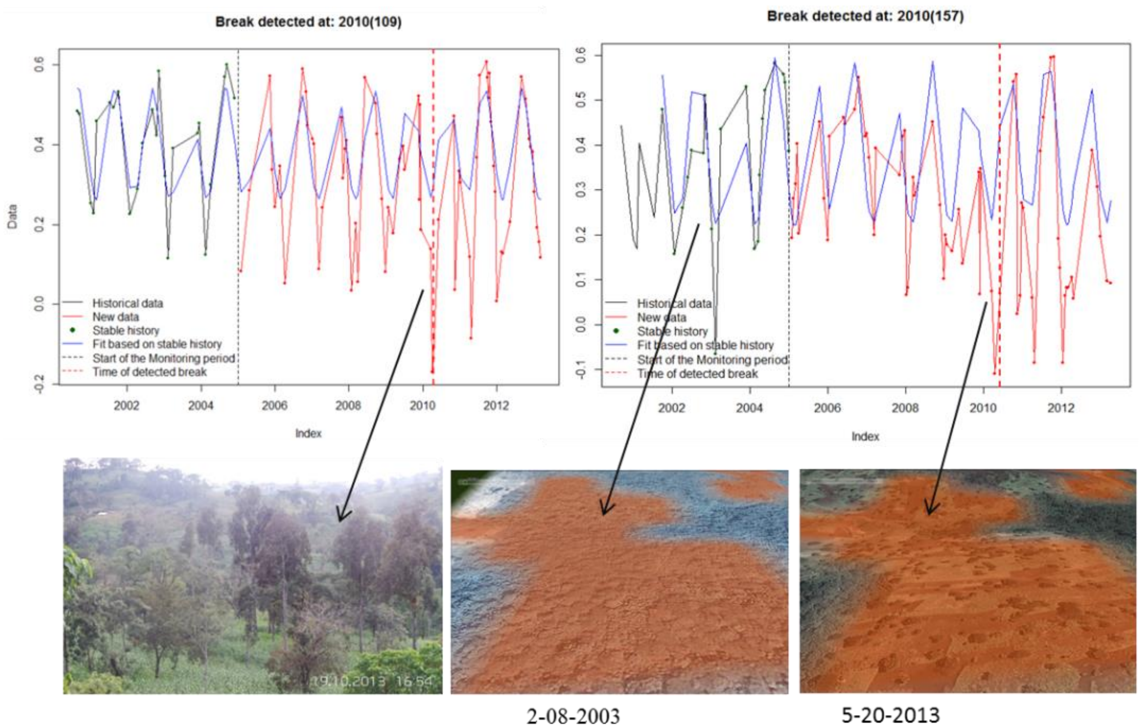


Figure 17. BFAST monitor outcome examples representing ODK data (sample point 32 on upper left BFAST monitor plot) and sample digitized from Google earth imagery (upper right BFAST plot), both indicating breakpoints in 2010. The lower left picture was photograph taken during field work representing breakpoint on upper left BFAST monitor plot. The lower right indicate forest disturbance from Google imagery overlaying BFAST monitor result (red) and complementing time of break observed from BFAST monitor plot (upper right). Spanning back in time on high resolution historical imagery there was stable history of data from February 8, 2003 to February 7, 2010 for the lower middle and right images.

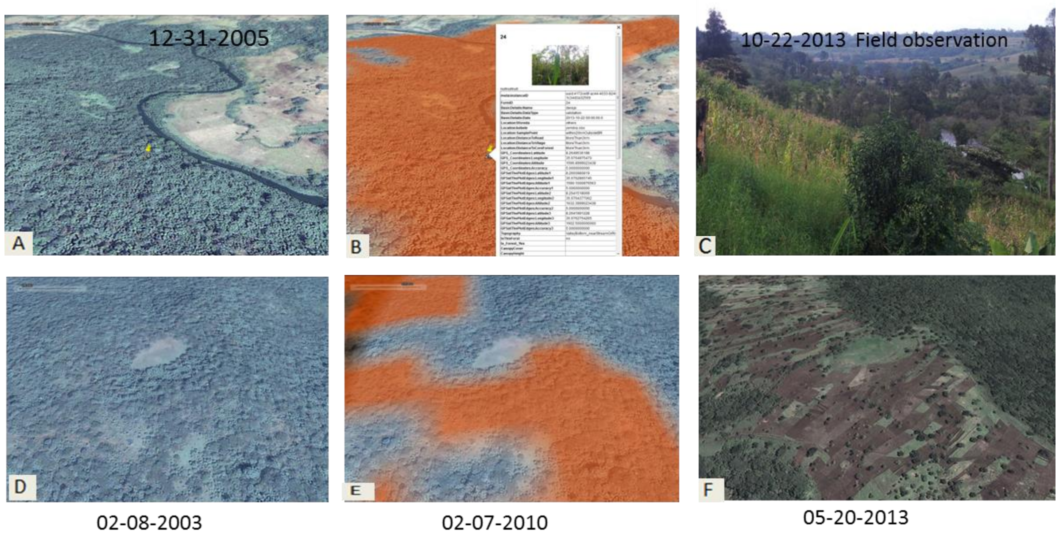
4.4 Validation of change results

Change dynamics due to deforestation observed from Landsat multi-temporal imagery using BFAST monitor is validated based on area and time of deforestation. Section 4.4.1presents validation result of the dynamics in deforestation spatially. Section 4.4.2 deal with the disturbance date result observed from BFAST monitor and ODK collected households' data.

4.4.1 Spatial precision (deforested area)

4.4.1.1 BFAST change magnitude result with historical imagery and field observation

Spanning back in history using Google earth historical imagery the deforestation rate observed from NDVI change magnitude was validated. However, due to limitation of this data source for the study site, four years have been selected based on the availability of the imagery to validate deforestation observed from BFAST result based on ODK data collected from the field (Figure 18).



Sample point	Historical Imagery (HI)				FO or/and HI	Classes
	2001	2003	2005	2010	2013	
1	U	F	U	U	N	Deforestation
19	F	U	F	U	N	Deforestation
20	F	U	F	U	N	Deforestation
23	U	U	N	U	N	Unknown
24	U	U	N	F	N	Deforestation
25	U	U	N	U	F	Regeneration
36	U	U	N	U	N	Unknown
44	F	F	U	U	N	Deforestation
62	U	F	F	U	N	Deforestation
70	F	U	U	U	N	Deforestation

U=unknown, F=forest, N= no forest, FO= Field Observation, HI=Historical imagery

Figure 18.Validation of deforested areas observed based on BFAST change magnitude result using ODK collect and Google earth imagery visually (A to F)

The left figures (A and D) indicate stable historical Google earth imagery showing existence of forest in 2005 upper (A) and in 2003 (D). The middle figures represent BFAST change magnitude result overlaid on google earth image (red colour) indicating disturbance of forest in the area and the metadata on the image B was field information collected for sample point 24 verifying the area as non-forest with tagged image on the ODK data (see also Table 9 and Figure 41 corresponding to sample ID=24). The right images were field observation photograph taken during field work (C) and example of deforested area observed from Google earth image samples (F). The table under the figure indicate an example (10 plots out of 60) of individual observations for each sample point and final forest cover change class for each plot following the image presented above as an example. Green cells indicate forest corresponding to the time assessed or observed.

Change classes: (a) Deforestation - all areas observed as forest, for example in 2003 and 2010 (lower left and middle picture) and 2005 (upper left) and non-forest in 2013 from historical high resolution imagery (lower right) and field observation using ODK collect (upper right picture). (b) Regeneration - all areas observed as unknown or forest from first historical imagery, for example, sample point 25 in 2001 no-forest in 2005 from the same source and then returned to secondary forest (regeneration) as observed from field work in 2013. (C) Unknown - for all areas which has no source of information and no-forest from field during field work. Household information on the disturbance date was not included in this part.

Accordingly, 32 sample points (28 from ODK data and 4 from Google earth samples) were deforested , 2 sample points were regenerating and 26 sample points were still unknown due to lack of historical google earth imagery. However, except the two sample points identified as regeneration, field work data using ODK showed no forest for the rest field collected data. These two areas are now regenerating, while there was disturbance in the past years as understood from local communities and BFAST result.

4.4.1.1 Area of deforestation

Twenty-eight sample points out of 50 collected during the field work has historical imagery showing the existence of forest in the area when overlaid with BFAST monitor result at different time. The comparison of deforestation observed during the field work with corresponding samples measured on Google earth was presented below. Area of deforestation observed using ODK was 236 ha, i.e. about 7 ha greater than area of deforestation measured using integration of BFAST result and google earth imagery.

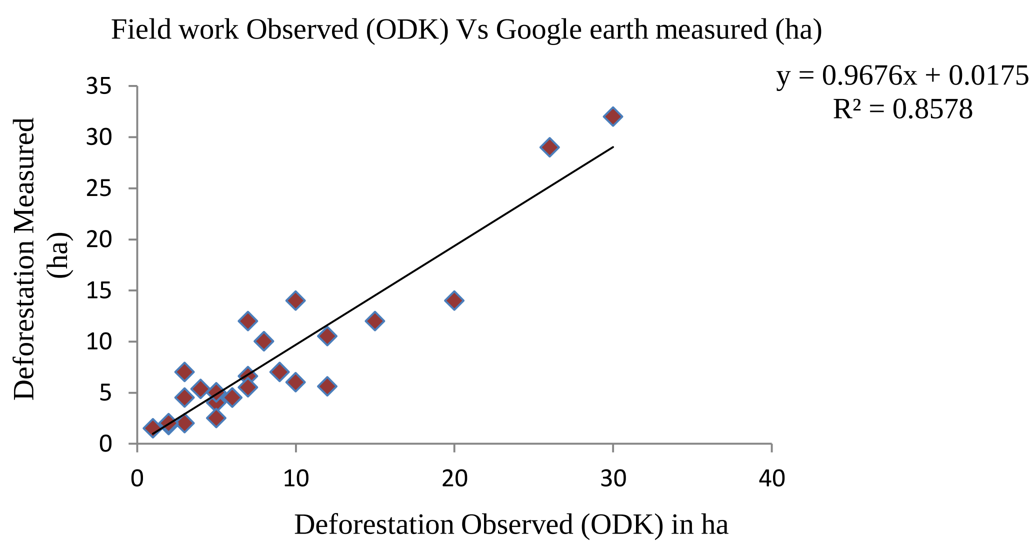


Figure 19 Area of deforestation observed during the field work compared with area deforestation measured using BFAST result overlay on historical Google earth imagery

In general the model shows that area of deforestation measured using BFAST result and estimated deforestation during field work are almost close to the 1:1 line with R^2=0.86 which means that the measured values are comparable to the observed value and real existence of deforestation.

4.4.2 Temporal precision (time of deforestation)

Time of breakpoint detected using BFAST monitor corresponding to each sample point disturbance time collected from local community during the field work were compared. This was to evaluate how the data obtained from households in the study site correspond with our BFAST monitor result. The result showed that the data obtained from local community lag with 3.5 years behind the BFAST result on average.

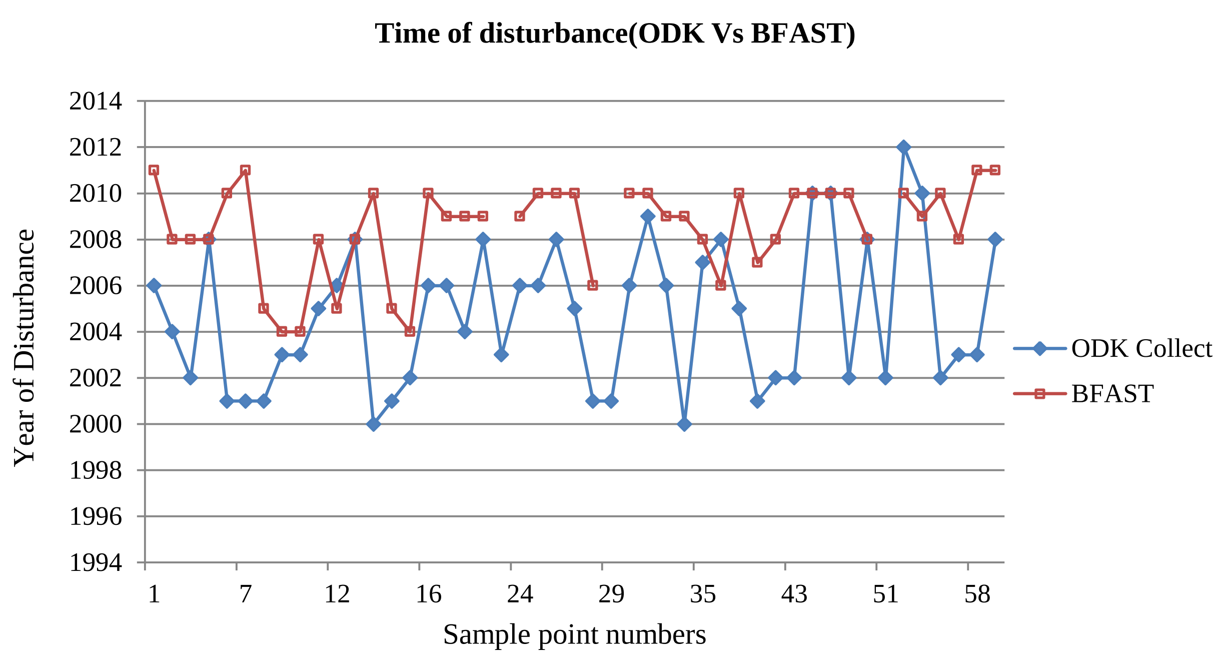


Figure 20 Time variation between field observations from interview result using ODK collect and with BFAST monitor breakpoints observed for each sample point. The gap on the BFAST monitor result indicate that no breaks are detected for the corresponding field work (sample point 25, 29 and 51)

4.5 Impact of Yayu Coffee Forest BR on deforestation rates

This section employs impact of UNESCO biosphere reserve in spatial and time domains. Pixel based results derived from multi-temporal Landsat datasets using BFAST monitor are presented in the subsequent subsections. The first subsection presents spatial variation of deforestation inside the BR zones. Biosphere reserve zones deforestation rate in time, impact of the BR to the leakage belt and the general forest cover loss trend observed are presented in section 4.5.2, 4.5.3 and 4.5.4 respectively.

4.5.1 Impact of biosphere reserve zonation on deforestation rates

4.5.1.1 Spatial deforestation rates (inside zones)

We used forest map area shown on Figure 13 as a reference to tabulate the area of forest disturbance in each BR zones. Accordingly, based on the proportion of forest cover in each zone in 2005, gross deforestation was calculated and presented. Gross deforestation calculated was the proportion of an original quantity of forested area that was converted to non-forest over monitoring period without examining for net deforestation i.e. the balance of both forest losses (deforestation) and forest gains.

Table 6. Gross deforestation rate of the BR zones

Zone	Land area(ha)	Forest area		Total forest cover loss (2005 to 2013)		
		Hectares	% land area	Cell numbers	Area (ha)	% forest area loss
Core Area	28326	27618.8	97.5	243	21.87	0.08
Buffer Zone	21000	18798.6	89.52	2965	266.58	1.42
Transition Zone	117687	50636.8	43.03	20605	1854.45	3.66
Total BR**	167013	97053	58.11	23813	2142.9	2.21
Leakage belt	500605	221140.3	44.17	148648	13378.32	6.05

Note: ** is cumulative effect of core zone, buffer zone and transition zone of the BRs.

4.5.1.2 *Spatial pattern of forest cover loss for the entire biosphere reserve*

The spatial distribution of forest cover loss due to deforestation in the whole BR area was shown below

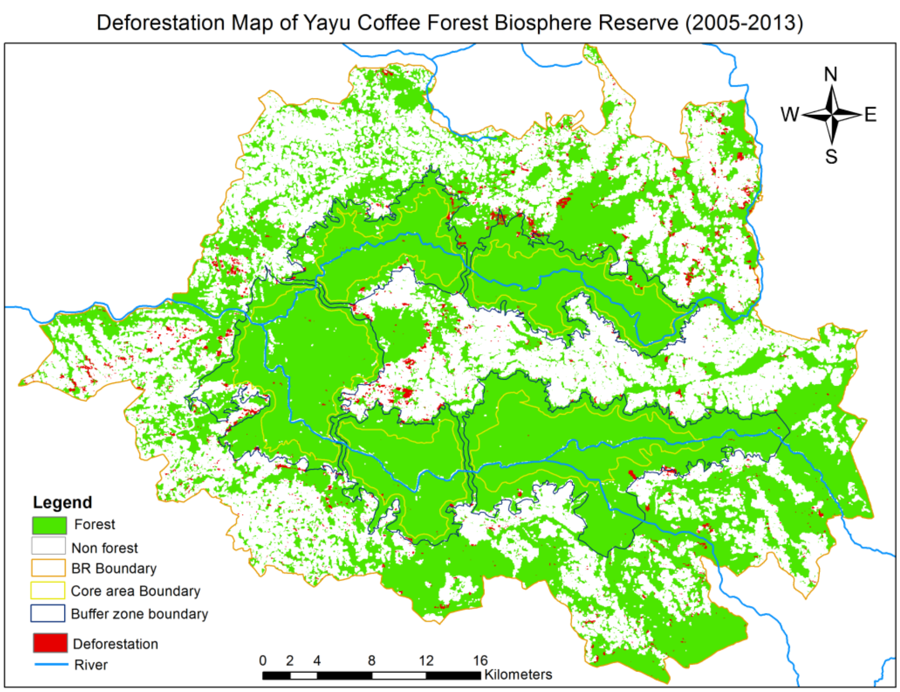


Figure 21.Spatial distributions of forest cover loss in the whole BR area. The red pixels are deforestation areas, green pixels indicate forest cover areas and the white represents non forest areas of the BR.

Results from change detection analysis using BFAST monitor indicate that over 2,143 ha (2.21 % of forest cover) of forest were cleared during the monitoring period (2005-2013) in the BR area. The most hotspots of forest clearing were occurred in the transition zone of the BR, especially along the North-western margin of Alge-Sachi district. In support of the research question one section 4.2.3, visual inspection of the result and remote sensing result with buffer ring of 2 km zone from road showed the most affected areas were relatively far from accessibility of roads where there was low or no awareness about BR.

4.5.1.3 Relative comparison of the internal zones of the biosphere reserve

As motioned in the first section of this report, the zones of the BR area boundaries were obtained from ECFF and were drawn based on a participatory mapping. These zones represent planning for land use management, apart from their importance to protect biodiversity in the BR area. One major objective of this analysis was to compare the rates of deforestation between the BR zones. There was more illustration of pixel based relative comparison of forest cover loss in hectares(ha) on Table 6 and percentage of forest cleared for each BR zones and the total BR area relative to their forest cover areas (in 2005) before and after BR implementation on Figure 22.

The result indicated that, transition zone was the place where all population of the BR inhabited and multiple land use type was practiced and experienced over 3.66% of forest area deforestation, i.e. about 1854.45 ha of forest cover were lost during study time. The Buffer zone of the BR area where there was human influence mainly for coffee production stands second experiencing 1.42% forest area (about 266.58 ha of forest) disappeared due to deforestation in the same period. In both transition and buffer zones, deforestation rate was declining after the area was registered as WNBR, although they showed very high rate of deforestation rate in 2009 and 2010 than any other time observed in the area. Land use practices in these zones differ, but so too does in population. In transition zone, where there was intensive agriculture and multiple land use practices were taking place, fluctuation in rate of deforestation noticeably observed than other two zones. Since all population are inhabited in the transition zone of the BR, increase in the house hold size (as stated by respondents during interview) gave more pressure to forest conversion in the transition zone and the buffer zone relative to the core area.

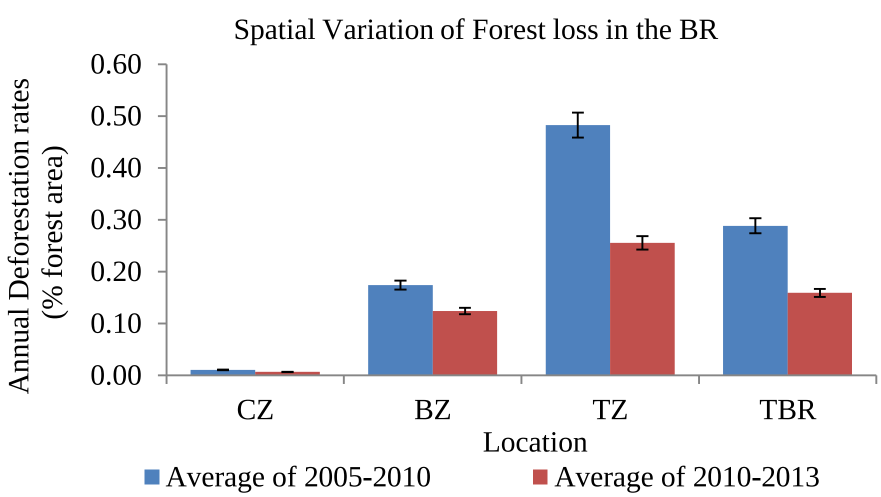


Figure 22.Spatial variation of percent forest cover loss with error bars (5% CI) in the three BR zones core area (CZ), buffer zone (BZ) and transition zone (TZ)) giving emphasis to before and after the BR

designation. Total loss of forest in the whole biosphere reserve (TBR) area was also displayed to show the cumulative effect. The figure was mined from combination of NDVI breakpoints and most negative change magnitude of Landsat imagery for the study site between 2005 and 2013. Deforested areas observed from Landsat scenes pixel by pixel for both site were averaged to their forest cover area.

In general the relative deforestation rate of the BR zones was determined through BFAST monitoring approach and revealed that core zone of the BR experienced low deforestation as expected, while transition zone area show large variability than others followed by buffer zone.

4.5.2 Impact of the biosphere reserve over time

4.5.2.1 Annual deforestation rates

Annual forest cover loss rates across the BR over the study period (2005-2013) were estimated 238 ha per annum.The historical time series of deforestation for BR area remained relatively stable from 2005 to 2008. The highest peak of deforestation was occurred in 2010 (1035.8 ha) followed by 2009 (448.29 ha), and the smallest deforested area was detected in 2013 (22.23 ha) followed by 2007 (25.29 ha) of forest cover loss (see also Table 8 on Appendix III).

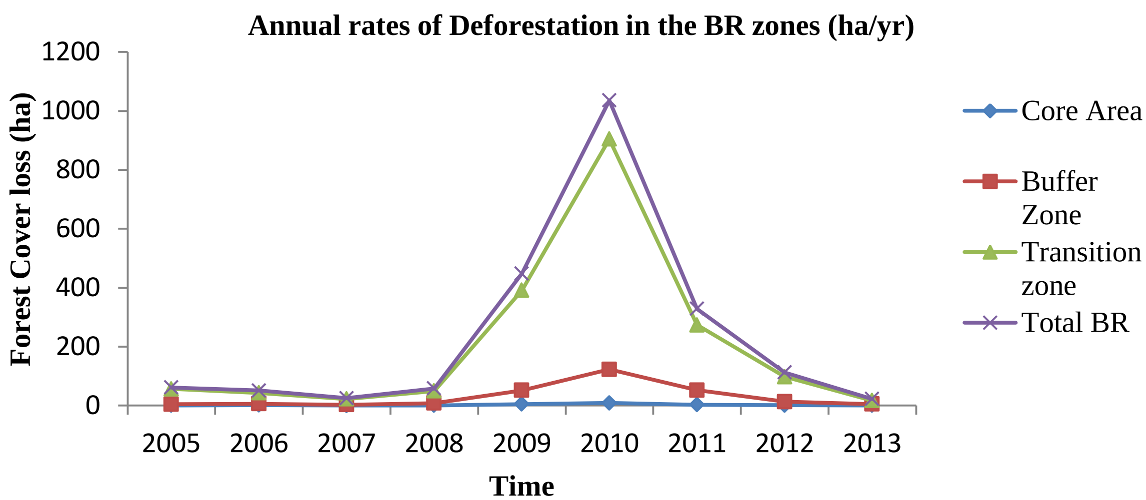


Figure 23.Rate of deforestation in the biosphere zones in temporal domain (ha/year)

4.5.2.2 Before and after the biosphere reserve implementation

The historical time series of deforestation remained relatively stable from 2005 to 2008 and becomes high during 2009 and 2010, making average annual forest cover loss from 2005 to 2010 a tendency of high rates of forest destruction (average of 280 ha per year i.e. 0.29 % of forest cover for the whole BR area). Over the past three years, a noticeable progress has been made in reducing the rate of deforestation compared with before and during the nomination period, particularly in transition zone of the BR area.

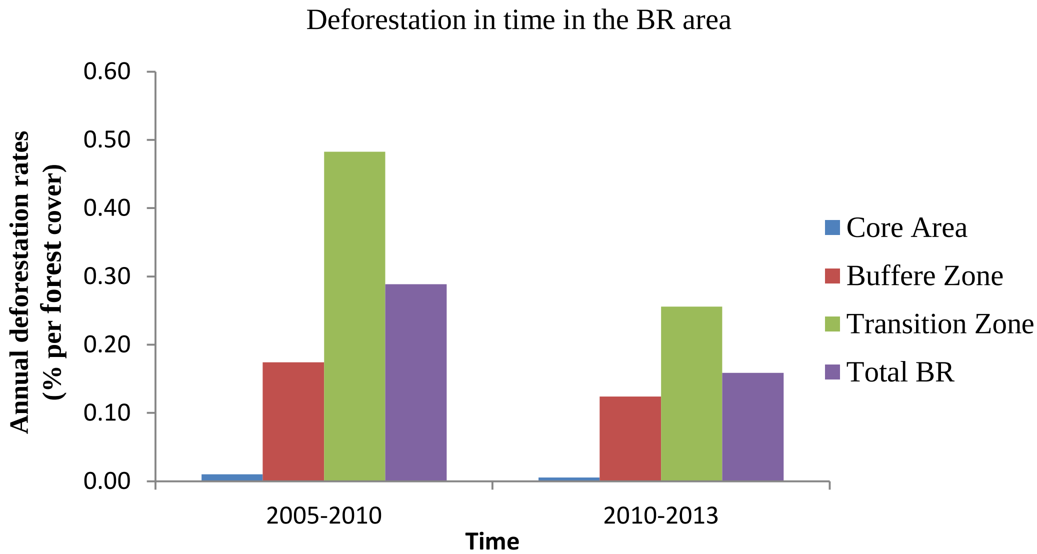


Figure 24.Annual percentage of deforestation in YCFBR before (2005-2010) and after (2010-2013) the implementation of the UNESCO MaB programme

Figure 24 indicate that there was decrease in forest cover loss in the BR area from 0.29% (280 ha) before the BR program to 0.16% (154.29 ha) after the BR implementation. The figure also inferred that forests cover loss in the BR area has notably showed decrease from 2011 to 2013 when compared with deforestation during nomination period (2009-2010).

4.5.3 Leakage analysis: differences in space and time between leakage belt and BR area

4.5.3.1 Relative comparison of deforestation inside the BR and the Leakage Belt

Forest cover loss between the two areas was mapped to evaluate the effectiveness of the BR and its implication on the surrounding forest covered areas. The rates of forest cover loss between the leakage belt and BR area was compared based on pixel by pixel deforestation estimation. In order to see the effect of BR on the leakage zone, we looked back to before the BR registration and the base line reference was set. Accordingly, deforested cells for both sites in the two time domains were calculated, before the BR as base reference line and after BR implementation for comparison. The overall results of this analysis showed that 13,378.32 ha (6.05 %) of the forested area was cleared during the study periods in the leakage belt and 2.21% of forest area in the BR (2143 ha).

The hotspots of deforestation in the BR were more restricted to the transition zone of the BR, particularly north-eastern part of the study area. On the other hand, deforestation hotspot of the leakage belt was mostly concentrated in the south and southwest parts of the study site. Based on respondents view during the field work, the reason for more deforestation in Southwest of the leakage belt (particularly in 2005) was attributed to farm land expansion in the edge of the forest

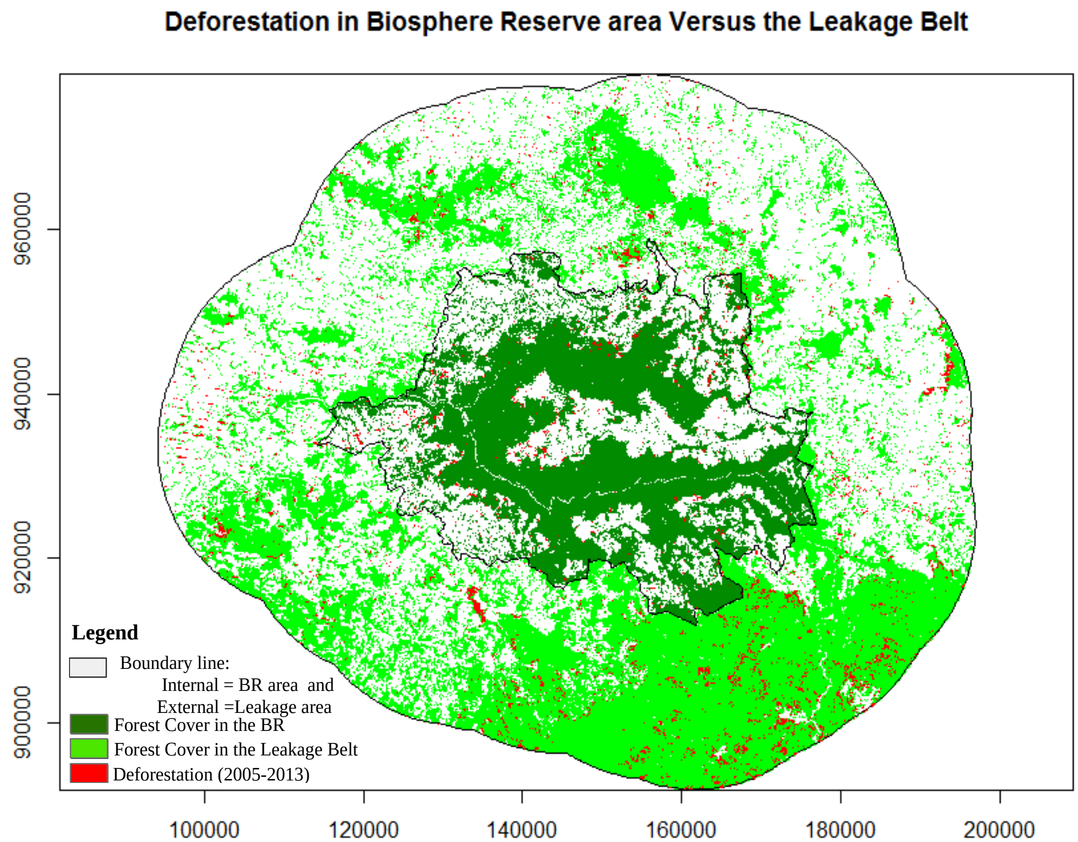


Figure 25.Comparative map of deforestation rate inside the BR area and 20 km buffer outside the BR area (Leakage belt). The white background is non-forest cover areas

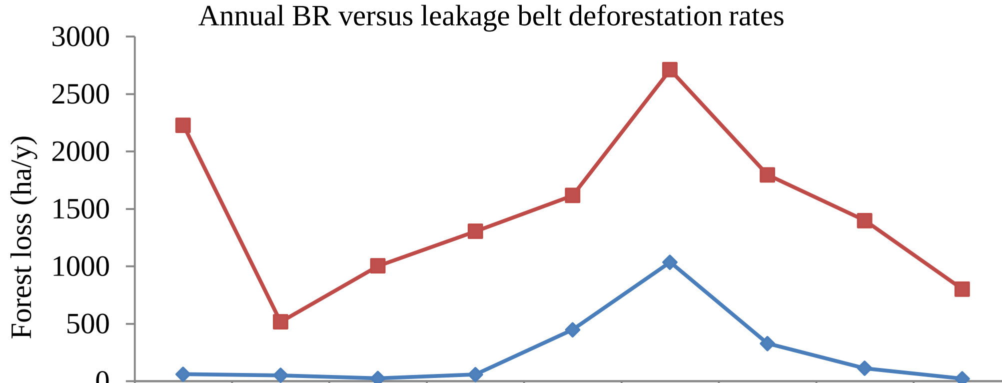
4.5.3.2 Overtime difference in deforestation

Following similar deforestation trend of the BR area, in the year 2010 there was high deforestation in the leakage belt accounting 2711.79 ha of forest cove loss, and the smallest deforestation rate observed was in 2006 (516.51 ha) followed by 2013 recording 801.72 ha forest cover loss.

Rates of deforestation before and after the BR implementation vary in both sites, where high annual rate of deforestation was observed before the BR programme relatively. After 2010, there was a notable tendency towards a drop in deforestation rate in both areas with slight variation between the two areas for three consecutive years. Annual rate of deforestation varied from 0.29% (280 ha) in the BR and 0.71% (1563.58 ha) in the leakage zone before the BR programme to 0.16 (154.29 ha) and 0.60% (1332.27 ha) after the BR programme. Compared to before the BR programme the drop in deforestation rate was about 125.72 ha (0.13%) and 231.31 ha (0.11%) per year forest area loss in the BR area and leakage belt respectively.

This suggests at least three possible facts. First, that the BR zone may have been effective in reducing agricultural expansion and other forest cover loss drivers after its implementation. Secondly, a rate of deforestation in the leakage belt was greater than the rates found in any of the reserve’s zones in the two time periods. Thirdly, the BR area seems to have had some measure of success in stemming deforestation.

There was variation in rate of deforestation in both sites. However, due to the decline of deforestation rate in both sites after the BR implementation deforestation rate estimated does not indicate deforestation relocation or displacement, but can be used to estimate its possible trend in the future based on current rate of deforestation.



	2005	2006	2007	2008	2009	2010	2011	2012	2013
Total BR	61.47	50.94	25.29	58.23	448.29	1035.81	328.14	112.5	22.23
LZ	2228.13	516.51	1003.23	1305.45	1616.4	2711.79	1796.94	1398.15	801.72

Figure 26.Temporal comparison of deforestation between the BR and the Leakage belt. The red trend line indicates deforestation in the leakage belt, while the blue line shows deforestation in the BR area.

Generally, the direction of forest cover loss before and after the implementation of the BR programme in in YCFBR and the leakage belt area was illustrated in Figure 24. As a trend line on the Figure indicates, there was decline in deforestation after BR program in both sites with slight variation between the two sites. This shows absence of leakage of deforestation and carbon emissions from restricted BR area to the unrestricted leakage belt.

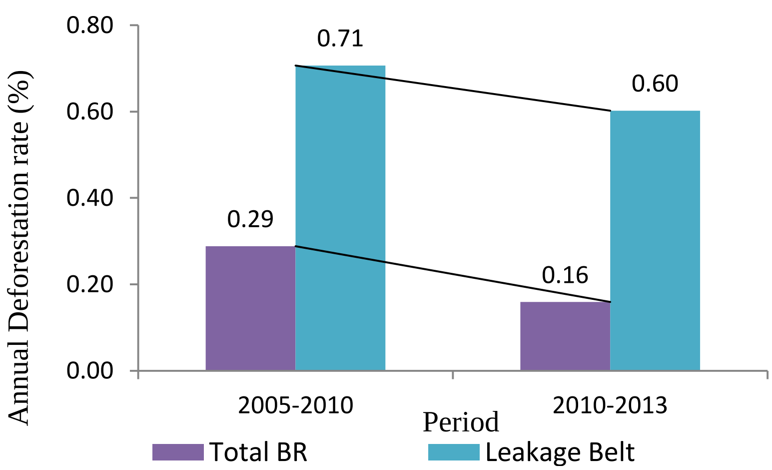


Figure 27.Annual percentage of deforestation in YCFBR and leakage belt before and after the implementation of the UNESCO MaB programme. Percentage of deforestation before the BR was used as base line reference for comparison of leakage belt with BR area after the BR implementation.

4.5.4 Forest cover change trend during the whole study period

Relatively large portion of forest loss was observed before the BR designation with variation of at least 114.95 hectares in transition zone and 9.42 hectares in buffer zone annually than the later period. The annual forest cover loss observed for the whole BR area 238 ha (0.25%) deforestation in the given time period was match lower than 1.1 % annual rate of FAO estimates, for the country of Ethiopia between 2005 and 2010. The rate of deforestation in the BR showed as the area experienced low rate of forest clearing compared to the national rate, even before the registration (2005-2010). The years with most negative change magnitudes were 2005 and 2008 to 2010, where all of them are recorded before the BR registration. While the general trend of the last three years shows that there was gradual declining in deforestation rate after the BR registration as MaB programme.

The leakage belt has similar structure with the BR area except for year 2005, where farm land expansion to the edge was reported as main drivers. However, there was uncertainty attached to cloud cover for deforestation rate observed in the centre of the forest in southwest part of leakage belt. The general trend of deforestation rate in the leakage belt was higher than the BR area.

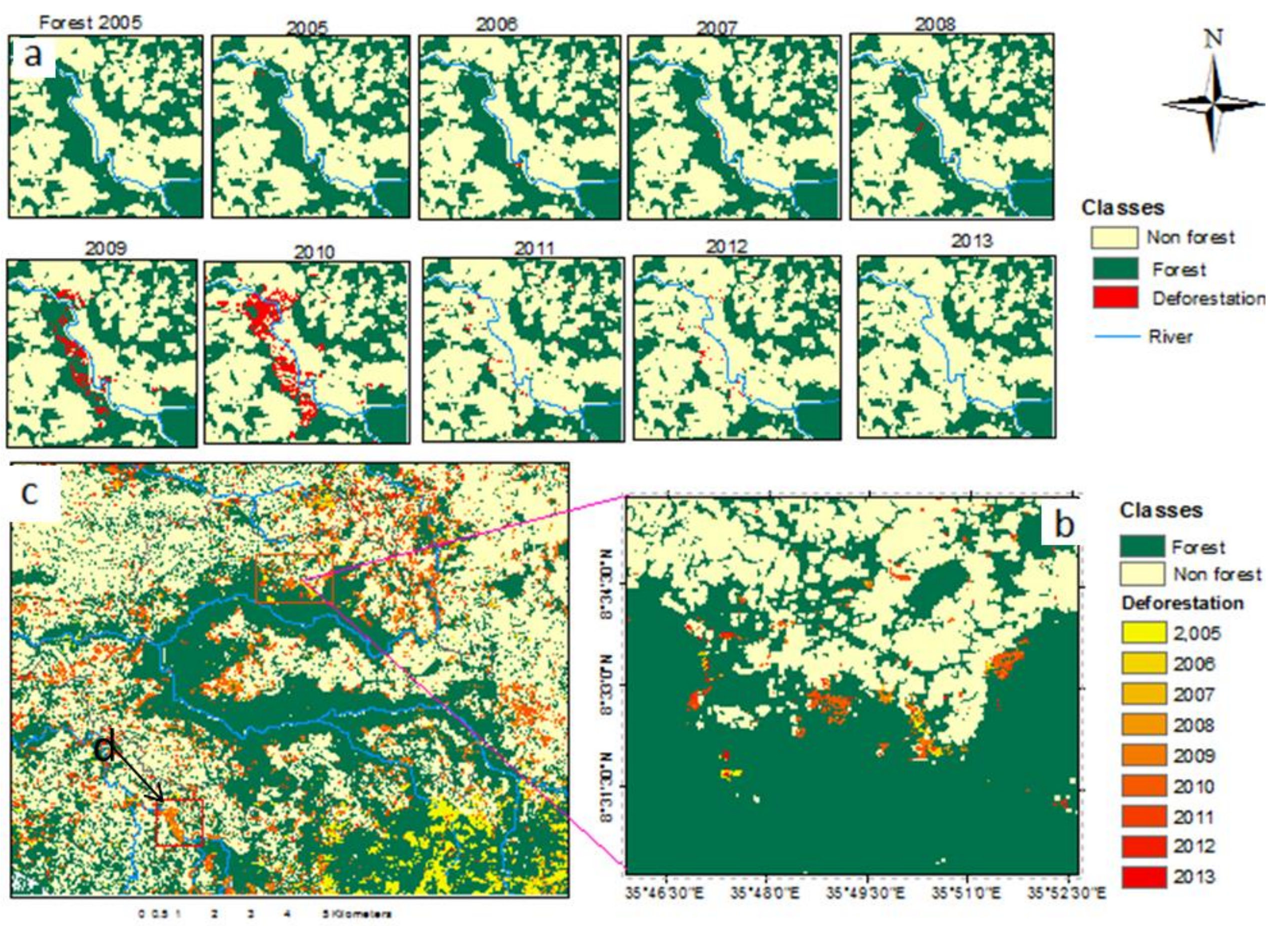


Figure 28.Example of annual relative deforestation per pixel from 2005 to 2013, obtained from temporal series of Landsat images using BFAST monitor methodology (a) representing small area (d) on the entire image (c).

In order to estimate deforestation rate, the forest covered area was mapped at the beginning of year 2005 (the start of BFAST monitoring time) as base for reference. All this information was produced for the entire BR area and the leakage belt. These annual maps were used to produce deforestation maps (Figure 25b) and to calculate annual percentage rate of forest cover lost (magnitude of deforestation) in each time step.

In conclusion, most forest cover change trajectories observed over 2005-2013 were relatively occurred outside the BR boundaries. Landsat image analysis using BFAST monitoring showed that relatively forest cover loss in both BR area and the leakage belt has declining since the establishment of the BR, indicating the BR progrss at reducing deforestation rates.

4.6 Drivers of forest cover change in Yayu coffee forest biosphere reserve

The drivers of deforestation observed from ODK collect is presented in this section. We have considered different factors to assess the causes of deforestation inside and around the BR area. Accordingly, the results of this finding are presented based on some physical and socio economic factors collected using ODK collect and integration of some statistical outputs from remote sensing part. Socio economic drivers as a proximate cause and physical factors as underlying drivers of forest cover change are presented under (4.6.1 and 4.6.2) subsections. While, evidences observed during the field work is discussed under 4.6.3.

4.6.1 Socioeconomic factors

A spatial analysis of forest cover from the observed and interviewed data showed that deforestation patterns vary across the BR and its leakage. The causes of deforestation in YCFBR and its leakage belt were largely dominated by agriculture and agriculture related land expansion. More than 80% of the ODK collected data shows that herbaceous agricultural crops like maize, teff, millet and sorghum were the most dominate crop types grown in the defrosted area. Most of these crops are annual crops, which must be replanted on a regular basis to sustain farmer’s livelihood. According to respondents view point, under this circumstances soil losses it quality quickly under a regime of annual cropping. Due to this, farmers obliged to clear additional forest lands at the edge rather than using costly fertilizers to sustain their farm land fertility through fallowing.

Conversion of forest land to agricultural land for subsistence crops and improper semi coffee forest management, accounting for 35 and 26 percent share from the total category. While, logging for fire wood and timber harvesting and erosion also share 17% and 12% as deriving force for forest cover loss. Fragmented forest patches in transition zone and leakage belt and forests near clearance edges around buffer zone boundary are more susceptible to an array of human impacts/activities. According to local respondents’ point of view this has been aggravated mostly by two imposing factors. The first and most series underlying factor for forest cover loss in this site is high population pressure in need of more arable land to produce subsistence food crops. This causes local and landless farmer to be pushed in to marginal and forest edges and convert forest land to farmland.

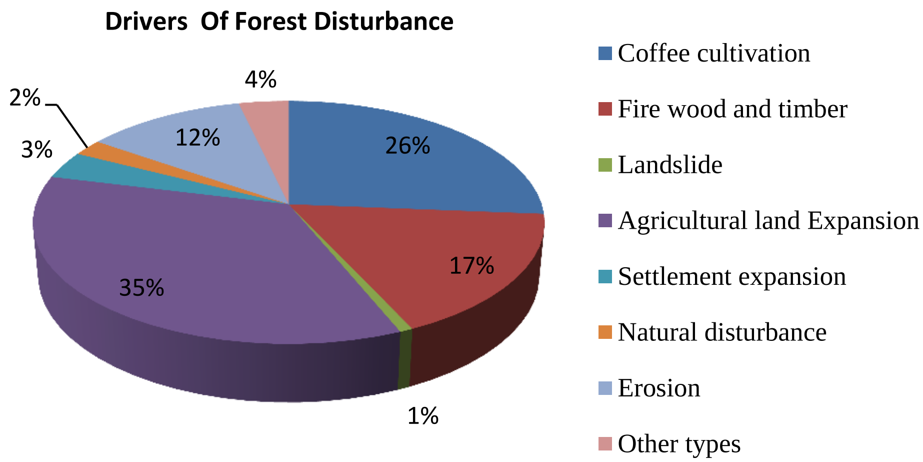


Figure 29.Proximate causes of forest cover loss in YCFBR and surrounding areas

The second problem was improper of coffee management and cultivation by displacing low yield wild coffee population with high yield once. Expansion of coffee growing area together with shade coffee production is important than disturbing understory and forest canopy of original forest coffee areas.

4.6.2 Physical factors

4.6.2.1 Location as underlying drivers of deforestation

Physical factors are integrated to determine their implication on deforestation issues of the BR. The location factor considered were distance to roads, village and core forests. The result of the ODK collected data and statistical analysis of the BFAST monitor result from remote sensing part were complementary on deforestation status, as observed away from road and village networks. Both data sources indicate more deforestation at remote places away from road and market (village) systems. A visual inspection during the field work campaign showed that there was still forest intact nearby the roads, except where some parts of roads are under construction and some received minor maintenance to increase road width. Therefore, these were omitted from the present result. Deforestation linearly increases as distance from nearby roads and village increase to certain kilometre (Figure 27).

However, there was disagreement related to deforestation away from core forest. Remote sensing analysis indicated that deforestation decrease from the edge of buffer zone to certain distance away from core area boundary; while ODK collected data indicate more deforestation in the edge of buffer zone forest and remote areas of transition zone. This may arise from sampling strategy followed during data collection, where most sample points in the buffer zone are not covered due to their inaccessibility and time limit to reach such areas.

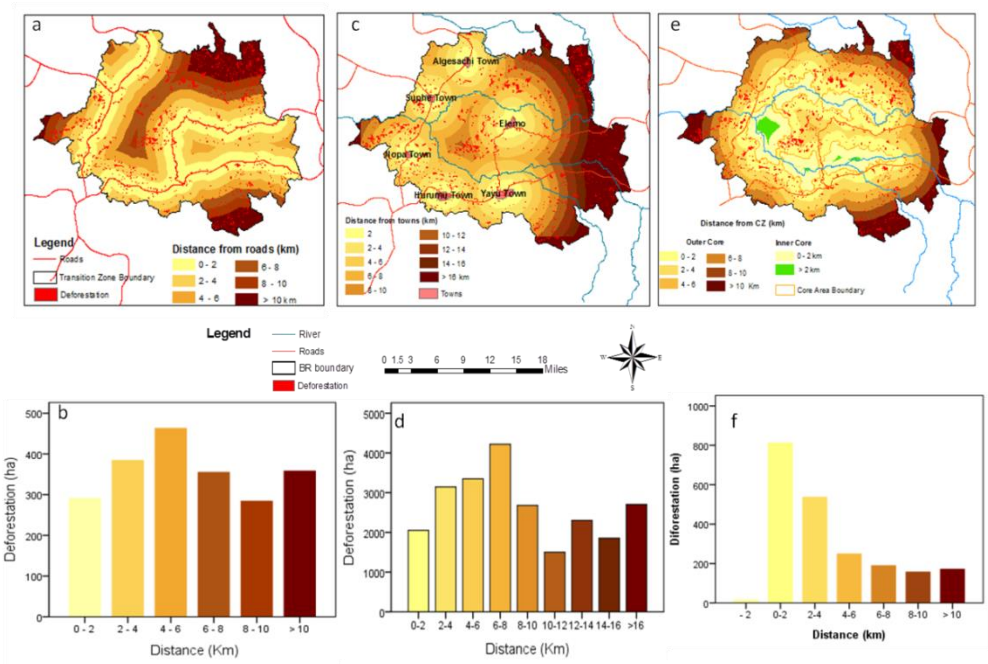


Figure 30.Biophysical factors namely road (a and b), village (c and d) and core area of the BR (e and f) as predictors of deforestation. The bar graphs correspond to the upper deforestation maps and the colour also represents each other. On bar graph 'f' distance with -2 km indicates the inner buffer ring of core area having 20 ha of deforestation out of total (21.87 ha) during the study period and the rest was attributed to green colour. Deforestation rates observed in each buffer ring were presented using bar graphs corresponding to the upper figure in hectares. Source: Partly adapted from Getahun et al. (2013).

Figure 30 infer that relation of deforestation with of distance variables (road, village and core area of forest) varies. Deforestation near road up to 2 km was still relatively low (293 ha) and continued to increase up to 6 km distance accounting 464 ha of deforestation between 4 and 6 km buffer areas. Beyond six km buffer distance deforestation amount seams low, but still high compared to their land area coverage than near road areas. However, as distance from core forest increase deforestation rate drops. Impact of accessibility to village has similar structure with road unless the very high deforested areas were recorded within 6-8 km (415.62) and relatively in remote areas still there was high deforestation rate. However, it was observed that there was more deforestation within 2 km buffer near core forest areas of the BR, 816 ha of forest cover loss from 2005 to 2013 and decrees from buffer zone to transition zone until it picks in remote areas of transition zone again.

Relatively more deforestation occurred at remote places away from road and village and near 2 km buffer area in the forest edge boundary between transition and buffer zone, where semi coffee forest and forest patches dominate. Thus the correlation with the distance variables showed that accessibility to market, road and forest can affect deforestation rate. Though accessibility is a significant parameter to explain the observed deforestation pattern and link with the BR management approaches.

4.6.2.2 Accessibility to forest as underlying drivers of deforestation

To this end it would be significant to see correlation of distance variables with other parameters like local farmers' accessibility to forest and their attitude towards the BR. The result indicates that most farmers (89%) in the Leakage zone has no concept about BR, actually it was outside the BR. Most respondents' in the leakage zone revealed that, there was no restriction to use forest resources (Figure 31). During interview, most respondents indicate that except the fear of their culture and spontaneous observation of government agents no one restrict them from forest accessibility. Moreover, combination of remote sensing information to this ODK data revealed that, there was more deforestation in the leakage belt than the BR area, but showing slight reduction after BR designation.

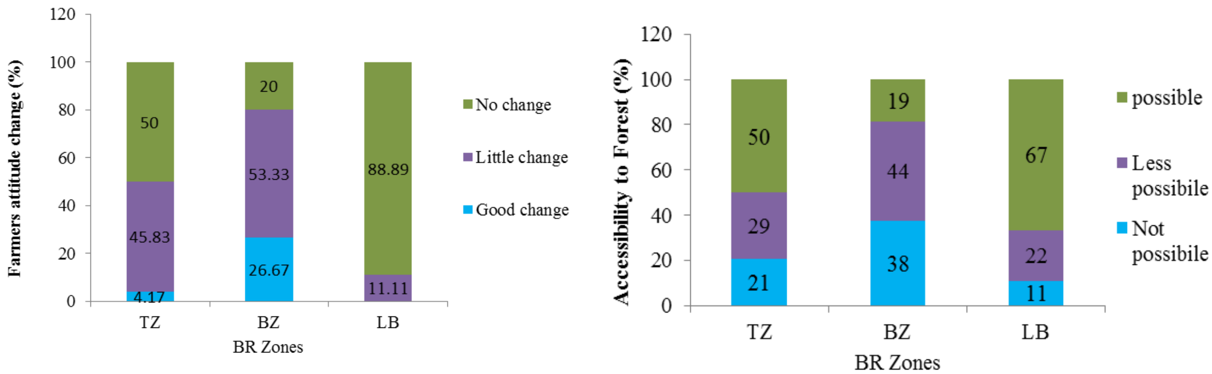


Figure 31.Farmers' attitude change in support of UNESCO BR (left figure) and their accessibility to forest after BR designation (right figure). The TZ, BZ and LB represents transition zone, buffer zone and leakage belt respectively. In this case accessibility of farmer to forest indicates that whether they can use forest resources without any restriction, particularly in relation to BR rules and regulations discussed in section 4.2.2.

In transition zone 40 percent of the interviewed respondents not showed change in their attitude. This was due to BR concept is new for them or they heard but they do not know the objective behind this BR. Only about 60 % of them have little/good change in attitude, indicating less or no possibility of access to forest resources. Comparatively respondents interviewed in buffer zone sample plot has more concept about BR and its rules and regulations, most of them indicating less/no possibility to access BR forest resources.

4.6.3 Evidences behind drivers of forest Cover loss

At meantime of data collection for drivers of forest cover loss, each farmer was asked how the historical forest cover in the area was changed to farm land or other land use types. In addition to the respondent's response, observation was taken based on currently existing situations and image of the area in all directions was recorded. From these evidences we found that clear cutting has intensified forest conversion into agricultural land and selective logging for timber, firewood and house construction contributes the largest share. Coffee plantation and its management which removes undergrowth vegetation and some tree canopies take third rank, although it stands second as a driver of deforestation. Others include grazing, erosion, fire, need of some forest patches for development purpose (e.g. allocation for landless habitants, mining and industry) are the most top evidences observed behind deforestation drivers in the study site (Figure 29).

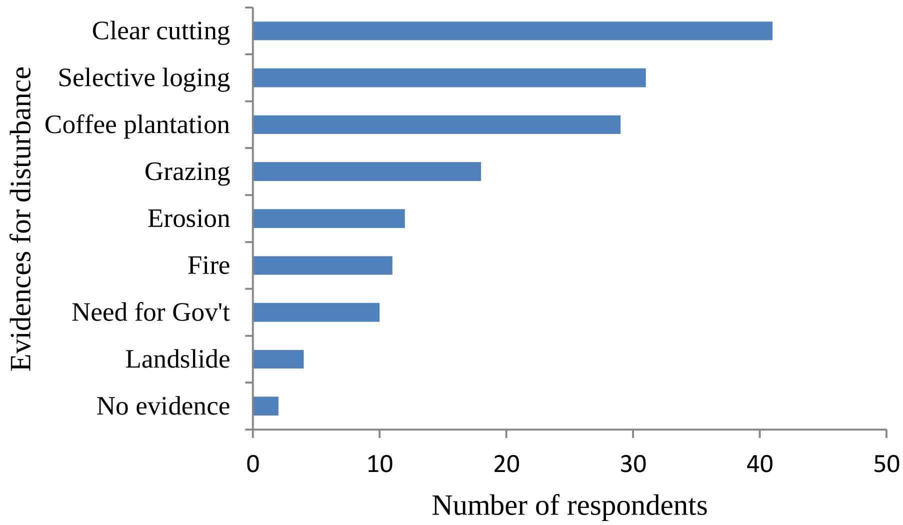


Figure 32.Evidences for forest disturbance observed and responded by local farmers during ODK data collect in the field.

5. Discussion

5.1 Effectiveness of the UNESCO Biosphere Reserve program and objectives

Since the establishment of MaB programme there is an expansion of BRs as WNWBR although biodiversity loss still continues worldwide. According to Mehring (2011) legal protection does not automatically result in effective management and conservation of biodiversity halting deforestation issue. Effectiveness of YCFBR that aims to achieve BR functions through reconciling forest resources use with conservation and sustainable development was discussed below.

5.1.1 Spatial and temporal impact of biosphere reserve in Yayu

The area of deforestation in each zone has been mapped and the annual rate of deforestation between 2005 and 2013 for the BR area and the leakage belt was presented. Overall forest loss was 2142.9 ha in the BR area and 13378.32 ha in the leakage belt between 2005 and 2013. The analysis provided lower rate of deforestation after the BR program than before the BR and also inside the BR than outside the BR areas.

5.1.1.1 Impact within the biosphere reserve

Spatial analysis of deforestation rate inside the BR showed that, there was very less deforestation in core area (0.01%) compared to transition zone (3.66%) and buffer zone (1.42%) areas. However, there are threats due to the combination of factors. i) relatively high deforestation observed at the forest edges of buffer zone particularly during the time of BR designation (Figure 21), ii) expansion of coffee forest in buffer zone area which destroyed understory types and upper forest canopies as observed during the field work. In line with this observation, the study conducted by Wakjira (2010) on deforestation of coffee forest area in South-western Ethiopia, Gole (2003a) on Yayu forest and Senbeta and Denich (2006) on the biodiversity and ecology of Afromontane rainforests including Yayu all pointed that intensive management of forest coffee alters the structure, composition and functions of the original forests changing coffee forest to semi forest coffee. iii) The coal mining, logging and illegal farmland expansion is still in transition and buffer zone which might threaten biodiversity conservation of core area.

The estimates of this study is in close agreement with study conducted in Calakmul BR (Mexico) by Bray (2010), Roy Chowdhury (2006) and Vester et al. (2007) for the whole BR area where low deforestation was observed after BR program (Case 2 under subsection 4.1.2.2 and Appendix I). Similarly, after BR designation, there was more involvement of the government and the NGO in the BR management approach which might bring improvement in the state of forest conservation and reduction of deforestation status in yayu BR than before the BR implementation. Some measures of MaB program currently running in Yayu BR (e.g. coffee forest monitoring, coffee certification, environmental education), was the main reason to show slight decline in deforestation than before the time of BR program. This is in line with previous studies (Betti 2004; Bray 2010; Oke 2009; Vanleeuwe et al. 2003) where all highlighted reduction in forest cover loss and effectiveness of the BR after interventions. However, this result deviate from findings by Mehring (2011) which indicated that increase in deforestation rate inside the core area and decrease in buffer zone highlighting ineffectiveness of buffer zone in protecting core area of Lore Lindu BR in Indonesia. In contrast to this study, our Landsat time series result revealed decline of deforestation both in buffer and transition zone, protecting core area of the BR. In fact, still there was deforestation in Buffer and transition zones due to several push factors discussed under section 4.6.

Despite the considerable temporal fluctuation of deforestation rates in the study site over 2005-2013 (Figure 23), the distribution of deforestation across BR zone remarkably seems stable. For instance, there was less deforestation between 2005 and 2008. However, deforestation rate observed in 2010 and 2009 was 1035.81 ha (1.07 %) and 448.29 ha (0.46 %), respectively, in total accounting 69% (1484.1 ha) of total deforestation rate of all time domains in the BR area. This was the time whereby rapid forest cover loss took place within short period making the rate of deforestation more than threefold as high as that experienced by the area during 2005-2008. This is in line with Takahashi and Todo (2011), where their study indicated that there was an increase in deforestation rate during implementation of community forest management project (Belete-Gera Regional Forest Priority, Ethiopia) than before and after the project implementation.

Forest edges of buffer zone and forest patches in remote areas of the transition were the main target areas for recorded deforestation. Field investigation also revealed that-farm land expansion, coffee management and logging are primary drivers of deforestation in the area aggravated by social and biophysical factors such as increase in household size, accessibility to forest, market and road. Based on interview with some organizations and farmers (at the site level) also showed availability of week forest sector governance, lack of coordination and illegal forest related activities such as logging, fire wood collection and timber harvesting are relatively high in remote areas of the BR which are also underlying causes of the observed deforestation.

Overall, the forest cover loss observed during the study period were not attributed to single variable, rather it is the cumulative effect of proximate causes and underlying drivers (Geist and Lambin 2002; Kissinger et al. 2012). Moreover, the reasons that drive to drastically pick in deforestation during the time of BR designation (in year 2009 and 2010) have got main attention. Our investigation was based on data collected during field work and experiences and findings from different sources. The pick in deforestation observed from dense Landsat time series imagery can be attributed to three interrelated causal factors. These factors are: First, absence or loose forest monitoring policy (regulation) giving emphasis to preparation of BR nomination form and designing the BR area for designation including demarcation of the BR zones during the time.

Secondly, lack of awareness among most local communities about the BR concept and its function as described on UNESCO BR nomination form Article 4.6, particularly these who are far away from road networks. For instance, in an interview with 50 local households 40% in transition zone and 17 % in buffer zone revealed that they have no concept and not aware about BR and its function. Some of them still believe in a possibility to access forest resources without any restriction. Although forest management association have been formed at six districts in which BR fall during nomination period, effective implementation of the concept reached two districts resulted in low deforestation rate record during the study period and also at the time of BR formation (Figure 34). This gap may initiate local community to override forest resources in 2010 to get more farm land at the end of that time.

The third factor was related to farm land expansion and Villagization. According to local respondents view peasants are on the permanent way to keep their existing agricultural land and to expand for additional farm land plots so as to obtain a dignified standard of farm land and to sustain their standard of living before the forest areas become under conservation control. This was emanated from lack of BR concept or awareness. Particularly, these who are away from government monitoring where pushed in to forest and converted the forest system in to non-forest or semi coffee forest. This is either through expanding excising indigenous farm land in to forest front and/or opening up new semi-coffee forest plantation in the forest areas disturbing the original forest coffee system. The first case was mostly attribute to indigenous farmers who already have land but seek to expand it to sustain their future food security and the drivers of the second cause are mostly attributed to landless peasants and immigrants who are watching for land and do not have other options to sustain their life.

Another most primary force that pushed the local community to the forest goes back to the history of Villagization in Ethiopia. Villagization program was launched to settle farmers within peasant association into one centre. It was began in 1985 and became a nationwide campaign in 1987 (Lorgen 1999). Accordingly between 1985 and 1987 about 11 million farmers were built new house in their new centre with the intension to ease social service and infrastructure provision (Wakjira 2010) in Ethiopia, where Ilubabor zone is one part. During an interview with 50 households, most farmers pointed that before Villagization program most forest edges in buffer zone were covered by garden coffee, settlement and other farm lands, showing as it was their own land. However, after Villagization most old settlement and agricultural land far from the new villages has got time to grow secondary forest contributing to increase in forest patches. The study conducted by Wakjira (2010) also stated that forest fallow increased from 12% in 1973 to 16 % in 1987 in south-western part of coffee growing regions as a result of Villagization. During the mobilization of local community for BR designation, these forest fallows were converted to agricultural land in fear of the area can be protected for conservation. However, exploring additional time series data and verification of this Villagization impact was beyond this study.

Geist and Lambin (2002), stated that institutional factors due to mismanagement in forest sector due to policy loose drive many causes of deforestation in developing countries. Similarly as a result of this historical fact related to Villagization and simultaneously taking loose of policy measures on forest monitoring during the time of the BR designating most indigenous farmers completely converted forest patches in the transition zone and buffer zone in to agricultural land. One of the key issue raised by the respondents were the issue of property right on land and which they want to secure their ownership right on that land. In this line Vyrastekova and Van Soest (2003) indicated that lack of implemented property rights leads to natural resource degradation and habitat destruction which exacerbate biodiversity loss.

5.1.1.2 Impact of the biosphere reserve on the leakage belt

In line with Wade (2010), our finding indicated that areas 20 km outside YCFBR have higher deforestation rate, 6.05 % forest clearance than areas inside the BR area which account 2.21 % forest clearance during the monitoring period 2005 to 2013 (Case 1 under subsection 4.1.2.2 and Appendix I).

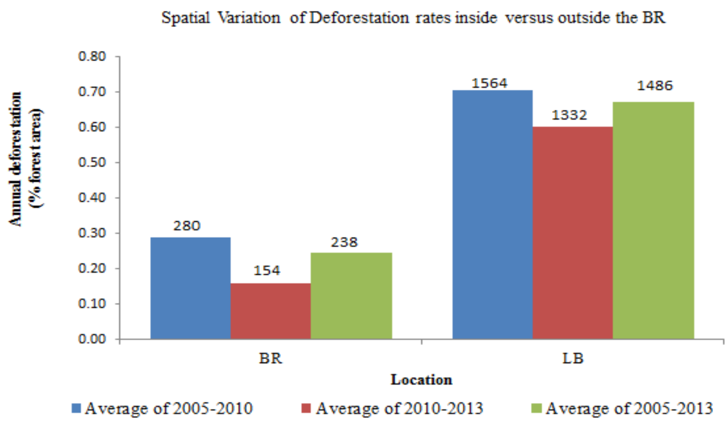


Figure 33.Annual rate of deforestation inside the BR area and in the leakage belt for two time domains (before and after the BR implementation) and for each total site. Numbers tagged on the top of each bar represents average annual deforestation in hectares corresponding to percent annual deforestation in the y-axis.

In contrast with Roy Chowdhury (2006), Vester et al. (2007) and Oliveira et al. (2007), but in agreement with Takahashi and Todo (2011), any significant negative impact and actual dislocation of deforestation to the leakage belt in both time and space as a result of project activities inside the BR was not observed. However, rates of deforestation are still high in the Leakage Belt than the BR area. Two ideas for discrepancies observed between the studies can be mentioned based on our current findings.

First, the designation of yayu BR in the area might be an impact to the slight reduction of deforestation outside the BR boundary in parallel with rapid decline inside the BR area. If permanence of reduction rate in forest cover loss observed after the BR program can be maintained in both areas in the future, MaB and REDD+ programs and activities will become successful in reducing deforestation and forest degradation, which in turn help to reduce carbon emissions by sink and will show complete success of the Yayu BR program. This is in line with (FDRE 2011a, b), supporting Readiness Preparation Proposal (R-PP) for Ethiopia which may lay out a foundation in reducing deforestation and forest degradation (REDD) from forestry sector to achieve middle income status following environmentally sustainable green growth path economy by 2025.

Second, leakage of deforestation might be happened in the future, if permanence of reduction not continued and the slight variation in reduction of deforestation rate observed after BR implementation is becoming wide between the two areas with time. The magnitude of reduction in annual deforestation in both sites relatively varies with more reduction in BR area i.e. from 280 ha (0.29 % forest cover) to 154 ha per annum (0.16 % forest cover) to low reduction in leakage belt i.e. 1563.58 ha (0.71 %) to 1332.27 hectares per annum (0.6% forest cover), Figure 27. Study by Oliveira et al. (2007) on Peruvian Amazon found that as a result of restricting land use in protected area dramatic increase in deforestation rates outside the restricted area or leakage belt was observed. There was two enforcing ideas between our study and study by Oliveira et al. (2007) in Peruvian Amazon. In the study by Oliveira and colleagues, deforestation rates have decreased inside the protected area in parallel with increase outside the boundary. In our case, deforestation rate decreased in both areas but with slight variation. Besides, the observed deforestation rate after BR implementation in the leakage belt was below average annual base line that was observed before the BR implementation. This suggests that there is progress in reducing deforestation in both areas within three years of BR history without dislocation of deforestation to no restricted leakage belt.

Although the general trend in forest cover loss rate after the BR has been lowering both inside and outside the BR relative to before the BR, consideration has to be given to eliminate feature threat of dislocation in deforestation to the surrounding leakage belt. The threats may arise due to the following main factors. First, the rapidly growing population in transition zone and surrounding area (Gole et al. 2009; Ilfata 2008). Transition zone is where all population in the BR inhabited and no settlement is allowed in core and buffer zones according to Yayu BR management plan. From local households' view gradual increasing number of immigrants in BR area combined with low awareness of forest conservation in the leakage belt may aggravate forest impact, further threatening dislocation of deforestation. This is in line with Vlek (2002) who pointed out that spontaneous migration related to coffee production and other socio-economic and political factors leading deforestation in coffee growing regions of south-western Ethiopia.

Second the steadily improving of the current forest management approach in the BR area. Increasing BR management approach to remote area of transition zone can increase restriction of biodiversity loss. In line with Ewers and Rodrigues (2008) this allows more access of forest resources in remote areas of the landscape where still forest management and monitoring approaches are rare and the local community has more accessibility to forest resources without any restriction. For example, as shown on Figure 29, about 89% of respondents in the leakage zone have no idea about the BR and its purpose and more than 67% of them still believe in accessibility to forest.

5.1.2 Impact of community participation in the BR management approach

Perceptions of rural farmers with regards to the BR, and particularly to forests differ among farmers as observed in the present study, which varies according to their socioeconomic situations. This is in agreement with previous study by Dolisca et al. (2007). This cause variation in communities' involvement on forest conservation and management across BR area. For instance, some farmers have a concern about the degree of deforestation of the reserve and still prefer government and NGO intervention to strongly putting in place environmental policies for management of the BR area. They also prefer that, the state and UNESCO biosphere program should pursue conservation program that will strength their involvement and stabilize local communities' relation with environment. Others still have not more information about the BR and are more concerned about the economic and social benefits of the Reserve, especially about sustainability of their livelihood as observed from their attitude during the interview.

In line with study conducted in Maya BR (Guatemala) by Hughell and Butterfield (2008), where government and non-government organizations promote environmental awareness to local community low deforestation rate was observed after BR program. The interview and house hold survey result of YCFBR revealed that local communities in the two districts (Yayu and Hurumu) were well informed about the ecological importance of BR compared with other districts. The interview also revealed that their participation since the BR nomination was high as compared with pre- BR time. Before the BR program most part of buffer zone and core area were under yayu participatory forest management (Appendix II), where these two districts were included in this forest management approach. The low deforestation rates observed in these areas could be an outcome of involvement of the local community in land and coffee forest conservation initiatives through environmental education programs. Particularly the impact was clearly seen in the year 2010 when other districts registered more than 60 % of their total deforestation rate (Table 5 and Figure 34). The outcome obtained from remote sensing data result also complements with the benchmark we have set from organizational interview and the local respondents view.

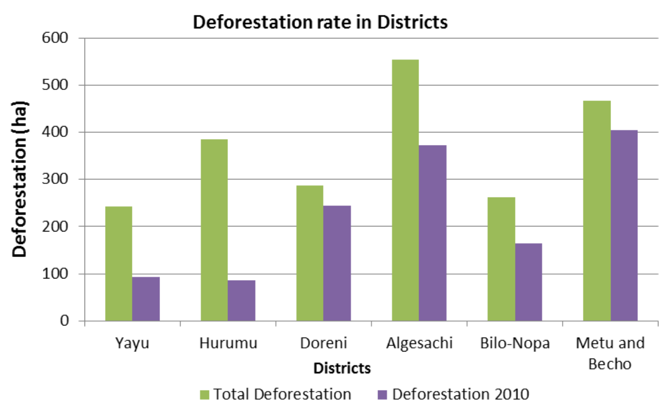


Figure 34.Participating local community for YCFBR nomination left picture) and an example of deforestation rate observed in districts (right figure). The first 5 districts are in the BR area and the remaining one is from Leakage Belt. Source of picture: (Gole et al. 2009)

On the other hand, as observed from field interview there was insufficient attention given by the government, non-government and the public to remote areas of the study sites to tackle deterioration on forest resources. Relatively more deforestation was also observed in remote areas where less integration with market and road networks available. In remote areas the farmers feel no fear for institutional and government policy to convert the land to agricultural land. Most deforestation and forest degradation are running illegally. Involvement of local community at each level is important for successful BR conservation and management. Fritz-Vietta and Stoll-Kleemann (2008) from a case study on Mananara-

Nord BR in Madagascar and Mehring (2011) from the case study on Lore Lindu BR in Indonesia concluded the importance of community participation for the success of BR approach. Similarly, Roy Chowdhury (2006) on Calakmul Biosphere Reserve (Mexico) revealed that underscoring the environmental importance of local communities around the boundary of BR can also recall deforestation to the leakage belt area. Taken together these implies that involving local community at each level and place is an important issue in minimizing discrepancies in BR concept and forest loss impacts that mainly occurred due lack of awareness and responsiveness.

5.1.3 Yayu BR linked with REDD+ activities

The role of forest BR is crucial to increase carbon sequestration through reducing the impact of deforestation. Our present result showed the progress made in reducing deforestation. The result supported the CRGE strategy of Ethiopia developed to reduce emission from forestry sector through REDD+ activates. This is in line with Gullison et al. (2007), stating the role of reducing deforestation can result in increased carbon storage. ,Continuing with this progress can also strength implementation of REDD, creating conducive environment for sustainable green growth path development option.

However, this requires to strongly halt irregular deforestation and forest degradation activities practiced by the rural community. Keeping deforestation rate below the current forest cover loss reduction rate level need integrated sustainable conservation and development across both BR zones and its leakages area . Field observation and respondents' response revealed that some local communities need to sustain their livelihoods. More than 80% of deforestation in the area is caused by seeking land for farm land, improper coffee management and collecting fire wood and timber. Providing economic incentives according to REDD+ forest monitoring strategy for the maintenance of forest cover can help local community to avoid forest loss drivers and its negative impacts like carbon emission meeting the requirement for sustainable development with green growth path option. As an example involving and providing the local community to use energy efficient technologies like cook stoves can reduce amount of forest destruction due to firewood. Promoting the role of land use and forest coffee management to forest dependent local communities through voluntary carbon programme of REDD+ activities can enhance carbon sequestration reducing impact of deforestation and forest degradation.

5.1.4 Biosphere reserve effectiveness with regard to MaB program, REDD+ and Climate Resilient Green Economy initiative

Successful implementation of REDD+ activities and MaB program require reduction in deforestation rate through implementation of BR management plans. Evaluation of YCFBR effectiveness in reducing deforestation relative to before the BR and implementation of the BR conservation was presented in the Table.7, guided with the bench marks as outlined in section 4.1.

Table.7. Identified findings on the realization of BR conservation and management plans on deforestation

Strategy	Bench marks	Finding identified
Seville Strategy and Madrid Action Plan of MaB program	Decreasing intensity of land use proximity to the core areas	BFAST monitor showed very low deforestation rate in core area of the BR and deforestation rate increase towards transition zone, in complement with mean NDVI trend observed for the three zones.
	Goal 1**:** Use BR for conservation of biodiversity	Intact forest in the core area was secured. But forest edges adjacent to buffer zone and forest patches in transition zone were not completely secured.
	Goal 2**:** Utilize BR models of land management and approaches to sustainable development	Alternative income generations were accepted. Plant seedling stations for expansion of coffee genetics and other forest biodiversity were already open for local farmers, although managing BR approach to sustainable development was at early stage
	Goal 3:Use BRs for research, monitoring, education and training	Environmental education related to forest resource monitoring, forest coffee conservation, planting and certification was reached to some local communities.
	Goal 4:Implementation of the BR concept	BR zonation was completely implemented, while participation and involvement of local community on the BR concept was mostly restricted to some districts and around road networks.
	Action 2 target 12**:** zonation – linking functions to space	Progress has been made in conservation and knowledge generation, while sustainable use of resources through integrated zonation and collaborative management still has limitation.
REDD+ forest monitoring	Reduce emission from deforestation and forest degradation	Annual rate of deforestation decreased from 0.29% before the BR programme to 0.16% after the BR programme in BR area and 0.71% to 0.6% in the leakage belt
	Tackle leakage of deforestation	There was no actual leakage of deforestation. Rather, slight reduction of deforestation outside the BR boundary was observed.

These findings are in disagreement with findings of Mehring (2011) where the author identified weaknesses in the implementation of buffer zone function to protect the core area. While we have identified that there was appropriate implementation of the three BR zones and there increasing intensity of land use and management intervention away from core areas. Less intensity of land use around the core area was the main reason of low deforestation in our study case. However, our finding is in partial agreement with Mehring (2011) in community participation, that our study found strong involvement in some districts and around road and village centres and low involvement in remote areas. The cause of high deforestation in remote area in our case is also due to low community participation and high intensity of land use in transition zone. The managers of Yayu BR, particularly ECFF stated that they has recognized the limitation in community involvement and thus started to reconcile functions of the BR program with local community.

Generally, from our analysis it can be summarized that Yayu BR established on June 2010, has shown some measure of success in stemming deforestation rate compared to before the BR program. The reasons for progress are: 1) one reason might be an effort made by Yayu BR managers to involve some local communities in the BR management approach after the designation. For example, 83% and 60% of local communities in buffer zone and the transition zone in order are aware about the BR concept after the BR designation, although more discrepancies were observed before and during the BR implementation. Realization of the local realities of forest dependent peoples and linking them with coffee forest monitoring and environmental education approach is one progress in reduction of deforestation in some parts of the BR area. 2) Reduction and absence of leakage in deforestation which in turn reduce carbon emissions. 3) Field work investigation also revealed that before implementation of the BR program expanding farmland and coffee plantation to the forest patches particularly in transition zone, where the area was not part of Yayu forest priority area was mostly left to the judgment of local community. After the BR implementation the three zones of the BR were clearly defined and the border between forest lands and farm lands was marked by paint by cooperative action of Environment and coffee Forest Forum, Oromia Forest Wildlife Enterprise and the local peoples.

Furthermore, efforts done to reduce carbon emissions from forestry sector at this individual BR level is important and is an exemplary foundation for the green growth path economy designed at national level. Ethiopia has planned to divert current economic development running through Business as usual scenario to climate resilient green growth path (FDRE 2011a, b), to achieve middle-income status by 2025. One important pillar is through implementation of REDD from forestry sector and enabling carbon stocks. The finding we obtained from remote sensing data and we verified through field work data also showed the progress made by MaB and REDD+ program implementations and acceptance of these goals at local scale to reduce deforestation and forest degradation. Therefore, although some limitations are there (e.g. integration of conservation with sustainable use, involving local community at all local districts) the framework of the UNESCO MaB programme and REDD+ designed at national level to promote sustainable development, biodiversity conservation and Climate change mitigation shows a promising step in our case study site, Yayu coffee Forest Biosphere Reserve.

5.2 Potential error sources of the forest change analysis

Forest cover change analysis is important in understanding impacts of forest loss on climate and environment in general. We have detected deforestation using the BFAST monitor algorithm in combination with ODK based collected field work measurements. The suitability and limitation of the applied methods for forest cover change analysis in the present study is discussed below.

5.2.1 Data availability and potential errors in BFAST monitor analysis

The aim of this study was to explore all available time series Landsat datasets in order to detect reliable forest cover changes. However, it was challenging to obtain dense Landsat time series data without gaps The main reason was difficulty to get full scenes in time series covering the whole study area mainly due to lack of cloud free observations and Landsat 7 ETM+ Scan line corrector (SLC-off) data gaps. For instance, the statistical break points detected by BFAST monitor for the study period before we have applied change magnitude threshold and field work data was large. However, this does not necessarily mean that the deforestation rate in the area was high. This might be because of large cloud cover and Landsat 7 ETM+ Scan line corrector (SLC-off) data gaps observed. For instance, as computed from 190 Landsat scenes to calculate mean NDVI (i.e. 31 ETM+ SLC_on, 140 SLC_off and 19 TM) especially in the border of the image each pixel losses 31 to 63 percent data in the time series (Figure 38 Appendix III). In line with this Mas (1999) indicated that high existence of cloud cover in tropical forest regions results in a lack of imagery at regular time interval. Study by Herold (2009) also revealed that Ethiopia has 40 to 50% mean annual cloud cover which lowers the amount of information (data) obtained from Landsat imagery.

The gap observed in the profile might challenge the chance of obtaining full information from temporal profile of Landsat images. This is in line with DeVries et al. (2013b), where they indicated high positive relation between more availability of time series data and the result. For instance, in our result most Western and South western borders of the study site has more data gaps (Figure 38). This can result in uncertainty (false breaks) attached our estimates of deforestation inside and outside BR area, particularly in the border of the image.

Moreover, BFAST monitor is more sensitive to detect breakpoints due to phenological changes-changes due to periodic agricultural crop life cycle following season's internal variations in climate. This can emanate if there was misclassification of non-forest pixels to forest during forest masking (DeVries et al. 2013b) and/or due to low availability of stable historical data for that pixel which result in false break during monitoring. Previous work by Verbesselt et al. (2010b) using BFAST revealed that BFAST detects timing of phenological changes within time series accounting for abrupt disturbances. During winter season most agricultural lands become devoid of plants and susceptible to BFAST monitor showing false positive break detection (Figure 35). Although BFAST monitor was robust method to detect disturbances without the need of threshold and deal with data gaps in analysing satellite image time series, additional high resolution images from other sensor are important. This can further complement such investigation in tropical montane coffee forest regions where seasonal fluctuation of agricultural land is high (personal observation and experience).

Leagend

Image	Imagery date	land use	description
a	04-03-2005	Agricultural	No break (true positive)
b	19-04-2010	Agricultural	False break
c	16-02-2005	Forest	True positive
d	19-06-2009	No forest	True break

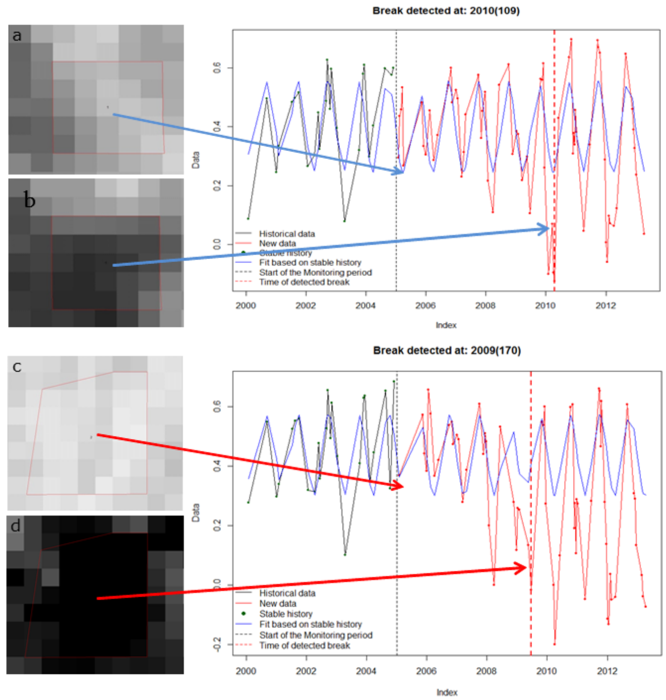


Figure 35.Real positive BFAST monitor breakpoint detected on lower BFAST monitor plot (indicating deforestation in central image (d) in 2009) and false positive breakpoint detected in 2010 on the upper figure while the area was agricultural land with no forest cover (b). Inspecting the single NDVI layer corresponding to the monitoring period in 2005 (layer a and c) and breakpoint dates detected on the two BFAST monitor plots (b and c) we identified agricultural land for the upper plot in 2005 (layer a) and forest during the same year for the lower plot (layer c) from Google earth imagery. Points at the centre of NDVI layers (a and b) were at the same location representing upper right BFAST monitor plot and as is the lower two NDVI images (c and d) representing lower right BFAST monitor plot. More description on legend.

5.2.2 Potential errors from ODK data and BFAST monitor analysis

Our analysis points to gap between BFAST monitor and ODK collected data observed in the present study. One limitation of BFAST monitor is that it does not directly provide information on the causes of forest disturbance (Verbesselt et al. 2012) compared with other change forest detection methods. However, identifying drivers of disturbance is an important notion in REDD+ forest monitoring activities to reduce carbon emissions related to forest driver activities. In the present study we demonstrated integration of ground data using Open Data Kit (ODK) in order to get topical information which helped us to identify these drivers and describe data obtained from remote sensing domain. The accuracy of estimating forest disturbance between BFAST monitor and ODK collected data from interviewing of local farmers was assessed to verify whether or not a disturbance is occurring and the timing and causes of this disturbance during the monitoring period.

Accordingly, our validation result illustrated two major important concepts related to either change or no change and the timing of change.

1) Our result confirmed that there was high relation with more than 97 % agreement between the two methods showing forest loss as a result of deforestation in the area. Only one sample point was not detected with BFAST monitor from ODK collected sample points in the monitoring period, except for two sample areas identified as regeneration. Moreover, the area change was in agreement between the two i.e. estimated field work observation (from 28 sample) and measured from BFAST monitor result showed a strong correlation R^2=0.86 (Figure 19). According to field work data from 50 respondents, 96 percent of them also reveal the occurrence of deforestation. However, the result may still have limitation due to lack of high resolution Google earth imagery to visually inspect, measure and verify the area of change for ODK collected from 22 sample points.

2) We have interviewed local farmers to pick the time of disturbance if they respond and agree on occurrence of deforestation (Figure 20). We also assessed time of disturbance using BFAST monitoring for each sample point based on data collected during the field work. These were then compared with time of forest disturbance obtained from local farmers and BFAST monitor for each single polygon central pixel checking the reliability of our result in time. Unfortunately, we have observed an average of three and half years' time lag of local farmers from BFAST monitor detected breakpoints. This can originated from both ODK collected data from the respondents and BFAST monitor result.

Lag of time with respect to local farmers might arise as a result of two main factors. The first factor was related to respondents land tenure insecurity and economic interest. Based on the field work interview we perceived that most local farmers were reluctant due to they believe that reporting exact time of forest disturbance can negatively impact their economic values and social security. Some of them still worry that the government can take over the land if they report disturbance date in near time since most of them have no ownership guarantee on the land and forest, particularly where deforestation happened. Oromia Rural Land Use and Administration Proclamation No. 130 /2007 state that "any person who is found using the land not given to him legally shall be obliged to leave the land without any condition and also be subject to penalty in accordance with the law". Some forest managers and district level development agents during the field work also revealed that farmers, particularly these in deforested site are reluctant in fear of government land policy besides their economic interest. The second factor arises unintentionally, due to lack of educational awareness to exactly report date of deforestation occurrence. From our field work experience, particularly at the first glance, most farmers link the deforestation time with occurrence of situations and what they have experienced with (e.g. government election period, during the time of...). This can also leads to misreport on the time of deforestation.

Mismatch of deforestation time might also emanate from BFAST monitor breakpoint dates. The reason behind was that BFAST monitor provides a single break date information for the whole monitoring period. For example, if there is more than one disturbance in the time interval, BFAST monitor reports the first as breakpoint dates and ignores the rest. As an example, setting two different starting date of the monitoring period (2005 and 2009) for one single pixel of field work polygon (e.g. sample pint 34) we observed two different breakpoints. The year 2009 was reported as breakpoint when 2005 was set as start of monitoring time, and 2010 as breakpoint when 2009 was set as start of monitoring time with -0.102 and -0.077 magnitude of change respectively (Appendix IV- sample 34). This is in line with study conducted by Meñaca (2012) indicating limitation of BFAST monitor methods. This suggests that further work is required to see the reliability of this issue and forward possible solutions.

Moreover, mismatch of deforestation date can also arise due to different concept in deforestation between farmers and the satellite data. Satellite data shows date of disturbance when the forest is cleared and the canopy structure does not exist. Farmer might think when the disturbance of the under canopy started by slashing which slowly develops in to deforestation after some time interval.

With regard to this BFAST monitor and ODK data, 1) integration of high resolution sensors from spot and Landsat 8- Landsat Data Continuity Mission (Irons et al. 2012) could be more robust for reliable deforestation and forest degradation estimation. This can also solve the problem of sufficient data limitation in time series and allow visual interpretation of satellite images besides computer assisted analysis of the original digital data to inspect area and type of forest change. 2) As used in this study ODK collected forest monitoring data showed a key role in providing complete history of forest cover loss processes from ground measurement to satellite data thresholding and interpretation. Besides, tracking change areas with photographic evidence and GPS location, recording and retrieving forest driver information through interview and integrating the data with real time BFAST monitoring were some important products of ODK collected field work data as observed in this study. However, the ODK collect data we demonstrated is for one time domain, only answer the study objectives. In line with (Pratihast et al. 2012) continuity mission using mobile based in-situ local expert forest monitoring is important to timely collect and report forest disturbances and to support REDD+ activities in the same study area.

5.2.3 Complementarity of ODK collected field data and remote sensing data

Remotely sensed Landsat data can detect changes due to complete clearance of forest cover over wide area and over time. Moreover it can provide biomass estimation, especially it is more crucial in areas with complex forest stand structures and environmental conditions (Lu 2006). However, understanding and identifying major forest cover change drivers like logging due to firewood collection and timber harvesting and coffee management which destroys under canopy cover and disturb the structure of forest is challenging using remote sensing data and BFAST monitor results alone. This can produce uncertainties attached to estimation of carbon from deforestation and forest degradation in support of REDD+ activities. However, ODK data can detect these changes due to its flexibility of collecting data from under canopy forests, although it has limitation to cover wide areas at limited time interval. Moreover the integration of remotely sensed satellite data source and mobile based ground data collection can help to pinpoint carbon emission due to deforestation and forest degradation.

Figure 36.Timber logging (left) and understory slashing for coffee management (right) figure. This can be easily detected with ODK collect.

5.3 Future research needs

A further extension of this study is to assess the permanence of forest monitoring using high resolution images like Landsat 8 and Spot with increased and continuous spatiotemporal ground data. This can provide adequate evidence on the impact of the programme. Monitoring carbon emission with regard to degradation, biomass and canopy cover is not discussed in this thesis due to time and other resource constraints. However, this helps to inform more details on the impact of BR on deforestation and forest degradation. Adequate time and space dimension allows to understand a detailed variations and changes in forest disturbances for the variables measured. Forest disturbances can also change due to the overtime change in demographic and socio-economic characteristics of the households which requires continuity in assessing the extent to which such factors determine the outcome variables. In addition, an extension of this study can be comprehensively help to assess the effect of the UNESCO BR on other components of the environment including mitigating natural resource degradation and biodiversity loss.

Another area of consideration emanates from the fact that various countries including Ethiopia included the UNESCO BR programme in their development plans. For instance, based on MaB programme and REDD+ activities, Ethiopia has designed R-PP and the Climate Resilient Green Economy (CRGE) path. This is a foundation for the country’s vision to be one of the middle income nations in 2025. However, empirical studies that fine-tune these programmes in local context helps to provide evidence for workable frame to guide these activities.

6. Conclusions

In this section, conclusion of the main findings identified related to forest cover change of the study area has been made based on the theoretical framework that guides the research. It also addresses each research questions formulated at the beginning of the study to examine impact of BR on forest cover change.

Some UNESCO biosphere reserves in tropical regions show success in reducing deforestation rate inside the area after implementation while deforestation still continued to increase in untreated areas. Variation in implementation of the biosphere reserve concept, rules and regulations to the ground as stated in Seville strategy and Madrid action plan was the main reason for the difference. The resulted deforestation pattern inside Yayu coffee forest biosphere reserve area is quite similar to other biosphere reserves like Calakmul biosphere reserve in Mexico in reducing deforestation rate after biosphere reserve implementation. However, it differ from the other tropical biosphere reserve areas such as Rio platano in Honduras and Maya biosphere reserve in Guatemala where deforestation rate continue to increase after implementation of the biosphere reserve program.

In this study, spatial deforestation rates were evidenced from Landsat time series data using BFAST monitor in integration with ODK collected field work analysis, revealing that a promising step in reducing deforestation rates after the intervention of UNESCO biosphere reserve program in Yayu coffee forest biosphere reserve. Overall, calculation of deforestation rates before and after the establishment of BR program showed a decline with 0.13 % i.e. from 0.29 % before the BR implementation to 0.16 % per year after the biosphere reserve programme. Regarding zonation, forest cover loss is declined both in transition and buffer zones from 0.48 to 0.26 % in transition zone and from 0.17 to 0.12 % per year in the Buffer zone, staying core area of the biosphere reserve unattached in both time domains with 0.01 percent per year of forest cover loss. These findings are not in line with some of the earlier studies that reported that deforestation rate in South-western Ethiopia has continued.

The results of the time series trend in deforestation rate indicate that deforestation was high during the time of biosphere reserve designation than it does before and after the establishment. This is attributed to loose of forest monitoring regulation, intent of local people to get more farmland at the end of the time and land ownership rights related to villagizaion program. However, after implementation of the BR program, deforestation in both the BR area and the leakage belt decreased substantially with different rate than the time when there is no biosphere reserve program, even if deforestation is not eliminated in both cases. The rate in the leakage belt is slightly reduced with 0.11 % (231.3 ha) per annum compared to the BR area. This might be due to the variation in efforts made in implementing the goals and objectives of the BR program and REDD+ forest monitoring activities in the area after biosphere reserve implementation.

Evaluation of Yayu coffee forest biosphere reserve in reducing deforestation rate relative to before implementation of biosphere reserve conservation and management plans has shown progress in reducing deforestation rate. This was attributed to more efforts done in implementing the goals and objectives of the BR program and REDD+ activities even though this is not consistently without limitation. Some measures of progress include the relatively low annual deforestation rate observed after BR implementation in comparison with before the BR implementation in both BR area and the leakage belt, effective implementation of the three zones of the BR and the demarcation of borders between farmland and forest land, numerous activities by government and non-government organizations to promote environmental education and coffee forest monitoring approach. Furthermore, with current remote sensing time series analysis dislocation of deforestation due to restricted use in BR area to unrestricted leakage belt was not observed. This is due to the fact that the average annual deforestation rate observed after biosphere reserve is below the base line reference observed before the biosphere reserve implementation.

Socio-economic factor like farmland expansion, lack of operational forest coffee management and logging were observed as the primary drivers of deforestation in the study area. Increase in population pressure from the increased household size, landless peasants and immigrants from other part of the places related to coffee production and resettlement program are the main stressors of deforestation rate observed in in the area. In addition, biophysical factors like accessibility to road, village centre and core area of the BR were indicated to pose significant effect on deforestation pattern. Areas away from road and village networks are under stress of deforestation due to more susceptibility of forest edges and patches in these areas for self-subsistent and landless peasants seeking for farmland in such a less forest monitoring regulations area.

If permanence of reduction rate in forest cover loss observed after the BR program can be maintained in both areas in the future, MaB and REDD+ programmes and activities will become more successful in reducing deforestation and forest degradation. This in turn help to reduce carbon emissions by sink and will show complete success of the Yayu Biosphere reserve program laying the foundation for the countries green growth path development strategy.

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Appendixes

Appendix I. Description of implication of UNESCO BR on some selected cases from tropical Regions

Case 1: Río Plátano Biosphere Reserve: Honduras.

Río Plátano Biosphere Reserve has been UNESCO BR (since 1980) and World Heritage site (since 1982). A total of 525,000 hectares of tropical forest in North-eastern Honduras was designated as Rio Platano Biosphere Reserve to protect the largest intact lowland tropical and pine forests with in Honduras. The reserve was placed on the List of World Heritage in danger in 1996 (Wade 2010). The study on Evaluation of Deforestation in the BR from 1985 and 2002 using Landsat image pointed that Buffer zone has high deforestation rate than transition and core area accounting 16%, 6% and 1% respectively. The analysis also indicate that areas 5 km outside the BR have higher deforestation rate (22 % forest clearance) than areas 5 km inside the biosphere reserve which account 18% forest clearance. Hence, the official designation of the BR to protect and conserve biodiversity not halted deforestation within the protected area. Lack of implementing monitoring activities within the forest as a result of colonization of the forest by poor Hondurans seeking for land, lumbering, shifting cultivation, fuel wood collection and grazing are reported as drivers of deforestation.

Case 2: Calakmul Biosphere Reserve: Mexico

It is the largest forest reserve in Mexico comprising 723, 185 hectares of protected land and with almost 23, 740 inhabitants (2000) in its buffer zone. Land cover change trajectory study under taken by Roy Chowdhury (2006) on Calakmul BR between core and buffer zones of the reserves using remote sensing and spatial modelling shows effectiveness of reserves and other state policy instruments in protecting forests. The reserve has had some measure of success in stemming deforestation; due to management personnel of the Biosphere reserve recognize the ecological importance of surrounding communities. According to this study out of the 421 km^2 deforested forests over the period (1987–1996), only 7% occurred in the reserve's buffer zone and 3% in its core area. Similarly, study conducted by Vester et al. (2007) on Land use change around protected areas of Southern Yucatan and Calakmul BR from 1987 to 2000 stated that rate of deforestation was 0.2% showing decline at the last six years of that period. Similar case study, Bray (2010) indicated protected areas in Mexico seem to be reducing deforestation rate as in Calakmul region after the establishment of the Biosphere Reserves. However, analysis of the spatial patterns and trajectories of land change over 1987–1996 underscores the environmental importance of ejidos that lie outside the reserve's boundaries recalling deforestation outside the BR boundaries.

Case 3: Lore Lindu Biosphere Reserve: Indonesia

Lore Lindu BR (designated as WNBR in 1977) is one of the largest remaining mountainous rain forests in the area, where 90% of the area is montane forest above 1,000 meters altitude (UNESCO 2010b). Study conducted by Mehring (2011) to evaluate effectiveness of the BR buffer zone using an integrative research design show that buffer zone is not effective in reducing deforestation in the core area, rather deforestation rate quadruplicated after management establishment in 1998 in core area. As indicated the deforestation rate in the buffer zone decreased from 0.79 to 0.68% per year after management establishment, while in the core area the deforestation rate increased from 0.06 to 0.27%

per year, exceeding the total deforestation rate of the total area of the by 0.23% per year in the meantime.

Case 4: Dja Biosphere Reserve: Cameroon

Dja BR represents the uppermost north section of the Congo forest basin consisting dense evergreen forest type. It was designated as UNESCO's BR in 1981 (Betti 2004; Oke 2009). Later, it was also declared as World Heritage Site on December 5th 1987. The objective of the study was to examine the impact of deforestation activities on the biosphere reserve and the importance of the reserve to local communities who live around the area. The result showed that the reserve was still 90% untouched, although there are increasing threats due to a combination of deforestation, mining, logging, commercial agriculture activities in the reserve. Also, the importance of the BR to local communities in increasing their household incomes rather than as a means of subsistence was noticed according to this study.

Case 5: Mount Kenya Biosphere Reserve, Kenya

Mount Kenya BR is a belt of moist Afromontane forest. It was recognized as UNESCO BR in 1978 under the MaB to enhance its conservation status and recover it from increasing human pressure. Later after the designation, large human-induced deforestation activity threatened Mount Kenya natural forest, especially in the late 1990s (Kariuki 2006). However, after a number of important policy measures (involving the government, the local community and NGOs) were implemented in the late 1999 and 2000 there was overall improvement in the state of conservation and decline of deforestation status (Vanleeuwe et al. 2003). For example, as ground survey result of the latter case study shows, the number of active logging sites decreased by 88% from 1999 to 2001.

Case 6: Maya Biosphere Reserve, Guatemala

In 1990 the government of Guatemala designated the Maya BR under UNESCO MaB program in order to combine conservation and sustainable use of natural and cultural resources. Using Landsat satellite imagery and GIS based assessment the study conducted by Hughell and Butterfield (2008) compared the three biosphere reserve zones with Forest Stewardship Council (FSC) certified forest concessions in transition zone. Comparison of annual deforestation rates by land use zones in the Maya Biosphere Reserve from 2002 to 2007 indicate that the rate of deforestation in FSC certified area of multiple use zones (0.04%) is much less than non-certified multiple use zone or transition (0.86%), core (0.79%) and buffer zone (2.2%). The study found less deforestation within the FSC certified forest concessions than in the remainder of the transition zone and the overall Maya BR.

Appendix II Description of Yayu coffee forest biosphere reserve zonation

Core area**:** The core area of YCFBR represents intact undisturbed natural forests endowed with high abundance of wild populations of Arabica coffee and high biological diversity (Gole et al. 2009). It consists of five contingent compartments covering 27,733 ha (16.6 % of total BR area) and hence provides appropriate and sufficient surface area to attain the conservation objectives of the reserve. These areas are protected natural forest and coffee gene reserve areas as part of the National Forest Priority Areas and act as reference points on the natural state of the ecosystems. So the main objective of the core area is in-situ conservation of the genetic resources of coffee (populations of Coffee Arabica) and undisturbed natural forest biodiversity.

Buffer zone: contiguous to the core area, it covers 21,552 ha (12.9 % of total BR). It represents managed coffee forests by individual farmers (Gole et al. 2009). Activities are organized so they do not hinder the conservation objectives of the core area, but rather help to protect it (ECFF). For example, sustained management of forest for non-timber forest products (like for coffee, honey and spices production) are allowed. The buffer zone can serve as area for experimental research which can provide ways to manage semi-forest coffee and agricultural land to enhance overall quality of production while conserving forest resources. It is also open for education, training, tourism, and recreation facilities. As stated by ECFF during interview buffer zone is an area in which human use is less intensive than transition zone. Moreover, as it was stated in (UNESCO 2008) role of buffer zone is to minimize negative and external effects of human-induced activities and to guarantee the conservation objectives in the core area.

Most parts of current core and buffer zones of the BR area were under Yayu National Forest Priority Area, protected by two legally binding regulations before the BR designation;

1. Federal Democratic Republic of Ethiopia’s Forest Development, Conservation and Utilization Proclamation 542/2007, and
2. Oromia Forest Proclamation No. 72/2005, even before its designation as BR.

Transition Zone: the large outer area of a reserve occupying 117, 736 ha (70.5 % of the BR area) and it is characterized by multiple land uses. It is where all people in the biosphere reserve live and work, using the natural resources of the area, and is therefore under intensive human use. It is ‘area of cooperation’ , where local communities, conservation agencies, scientists, civil associations, cultural groups, businesses and other stakeholders agree to work together to manage and use the area in a sustainable way and will provide appropriate context for land-use related problem identification (ECFF).

Appendix III Additional Figures and Tables

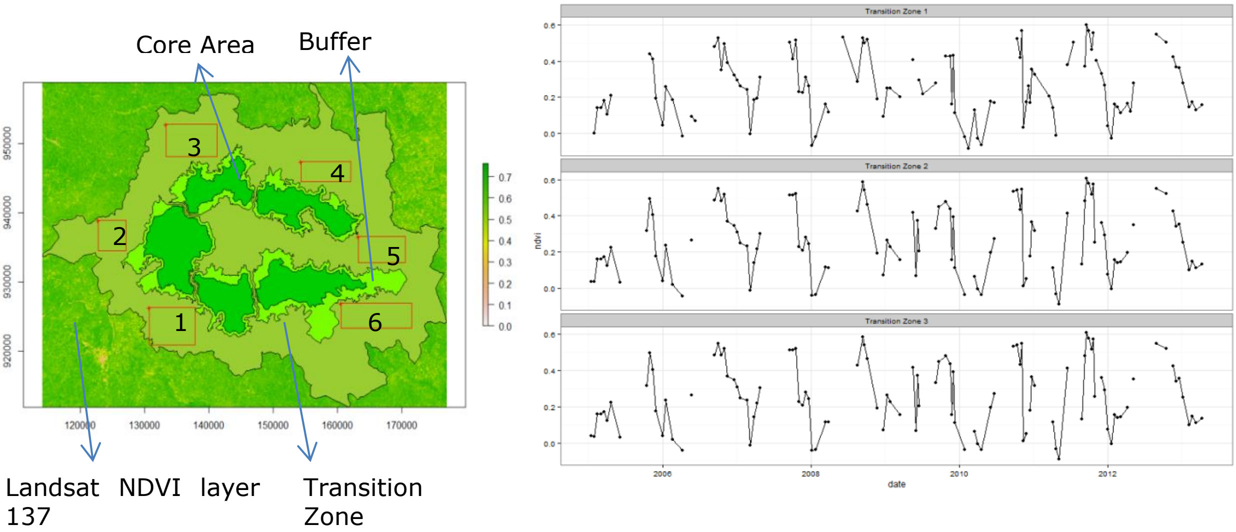


Figure 37 Temporal mean NDVI profile for transition zone (right plot) representing sample polygons; 1, 2 and 3 from the left figure in transition zone. Sample 6 represents the mean NDVI profile in transition zone plotted in the main body of this paper (Figure 12). We take one NDVI layer to select polygon, while the calculated mean NDVI is for the entire layers in the study period.

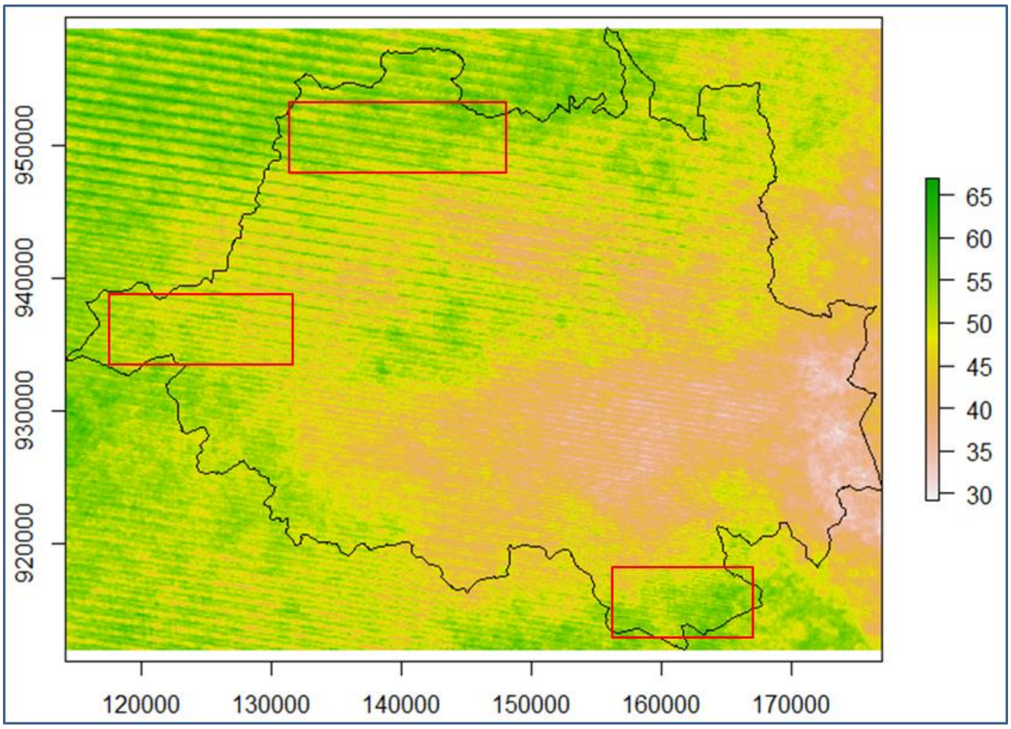


Figure 38 Percent data loss throughout the time series (2000 to 2013) for each pixel in YCFBR and its leakage belt percent data loss are between 31% to 63% for each pixel due to cloud and SLC-off gaps. More data loss was observed in transition zone and leakage belt outside the biosphere reserve as can be observed. For example, most borders of leakage belt and examples with red box in this plot in the BR loss above 50 % data. This can result in more commission error.

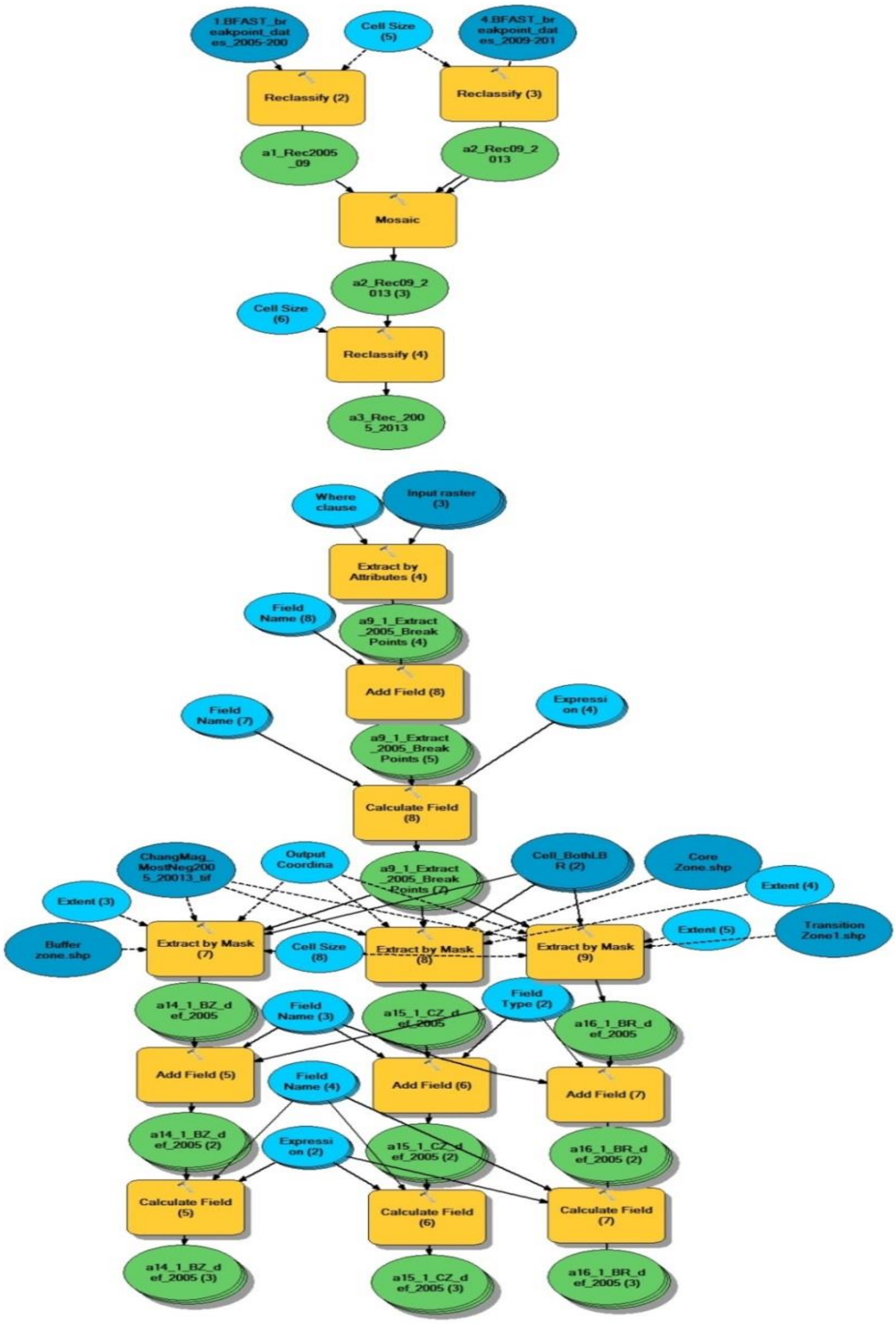


Figure 39 Examples of ArcGIS Models and tools used during post-processing of BFAST change magnitude and Breakpoints to produce maps and to calculate deforestation in all zones of the biosphere reserve and the leakage zone.

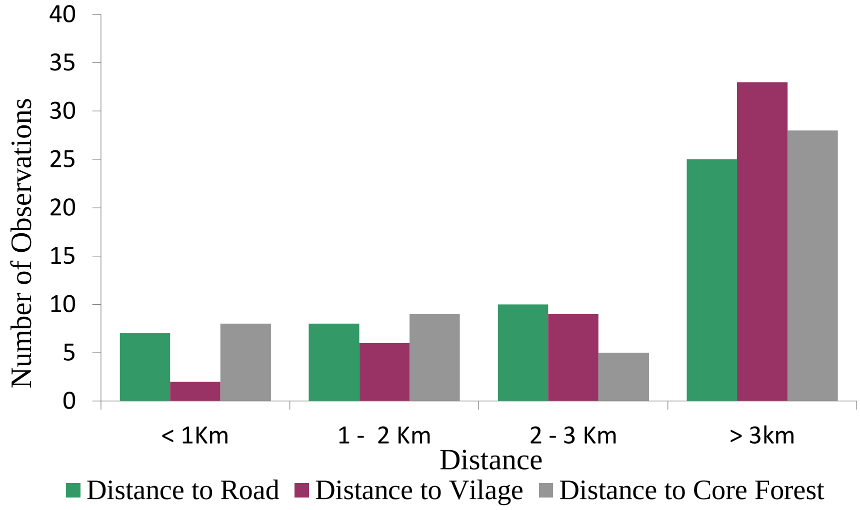


Figure 40 Distance versus deforestation using ODK Collect. The bar graph shows that the relationship between deforested sample points observed from preliminary BFAST Change magnitude with ODK collect from field work.

Table 8.Estimates of annual rates of deforestation detected (ha/year) obtained with dense Landsat time series images for the period of 2005 to 2013

	Biosphere Reserve (BR) Zones					
Year	**CZ**	**BZ**	**TZ**	**Total BR**	**Leakage Zone**	**Total Area loss**
2005	0.45	4.59	56.43	61.47	2228.13	2289.6
2006	1.98	6.21	42.75	50.94	516.51	567.45
2007	0.09	3.06	22.14	25.29	1003.23	1028.52
2008	0.9	8.01	49.32	58.23	1305.45	1363.68
2009	5.13	51.84	391.32	448.29	1616.4	2064.69
2010	8.73	122.85	904.23	1035.81	2711.79	3747.6
2011	2.79	51.93	273.42	328.14	1796.94	2125.08
2012	1.35	13.23	97.92	122.5	1398.15	1510.65
2013	0.45	4.86	16.92	22.23	801.72	823.95
Grand Total	**21.87**	**266.58**	**1854.45**	**2142.9**	**13378.32**	**15521.22**

Note: ** is cumulative effect of core zone, buffer zone and transition zone of the BRs, while, * is the cumulative effect of all biosphere reserve zones and the leakage belt.

Appendix IV BFAST monitors results for single Sample plots and ODK collected disturbance dates

Table 9 BFAST monitor change magnitude and breakpoint dates observed from single pixels and ODK collected date of disturbance and measurements for the same plot area.

FID	Id	BFAST On google earth (ha)	Field work Estimation (ha)	Year of Disturbance (Farmers)	BFAST mon. Break dat.	Ch. Magnit.	Main Driver
1	1	2	3	2006	2011	-0.0687	Coffee cultivation
2	2	No access	3	2004	2008	-0.0642	Farmland expansion
3	3	5	5	2004	2008	-0.1562	Farmland expansion
4	4	4.5	6	2002	2008	-0.1562	Coffee cultivation
5	5	No access	5	2008	2008	-0.0527	Farmland expansion
6	6	5.34	4	2001	2010	-0.0573	Farmland expansion
7	7	No access	6	2001	2011	-0.0562	Coffee cultivation
8	8	No access	8	2001	2005	-0.034	Farmland expansion
9	9	No access	5	2003	2004	-0.0201	Farmland expansion
10	10	5.6	12	2003	2008	-0.1359	Farmland expansion
11	11	5	5	2005	2008	-0.1018	Farmland expansion
12	12	NA	8	2006	2005	-0.0529	Farmland expansion
13	13	10	8	2008	2008	-0.0713	Logging + Farm land
14	14	No access	2	2000	2010	-0.0385	Farm land Expansion
15	15	2	2	2001	2008	-0.0821	Farm land Expansion
16	16	7	9	2006	2010	-0.0089	Coffee Cult.+ Grazing
17	17	1.8	2	2002	2004	-0.012	Farm land + Settlement
18	19	29	26	2006	2009	-0.0939	Farm land Expansion
19	20	32	30	2008	2009	-0.1114	Farm land Expansion
20	23	NA	2	2004	2009	-0.0325	Farm land Expansion
21	24	14	10	2006	2009	-0.0513	Farm land Expansion
22	24 (h.B)	NA	5	2006	2010	-0.1612	Farm land Expansion + Logging
23	24(h.tr)	10	8	2008	2010	-0.0513	Farm land Expansion + erosion + Coffee cultiv.
24	25	REG	REG	2003	REG	0.25	-
25	27	6	10	2005	2010	-0.0209	Coffee Cult. + Erosion
26	28	NA	5	2001	2009	-0.0627	Coffee Cultivation
27	29	No access	5	2001	NA	0.0025	Farm land Expansion
28	31	No access	9	2006	2010	-0.0679	Farm land + Coffee cult.
29	32	12	15	2009	2010	-0.0543	Farm land Exp. + Log.
30	33	No access	6	2006	2010	-0.0183	Farm land Expansion
31	34	No access	4	2000	2009	-0.1022	Farm land Expansion
32	35	No access	5	2007	2008	-0.0195	Farm land Expansion
33	37	No access	5	2008	2006	-0.1066	Settlement + Coffee cult.
34	38	14	20	2005	2010	-0.0504	Farm land + Coffee
35	39	5.5	7	2001	2007	-0.068	Coffee cult. + logging.

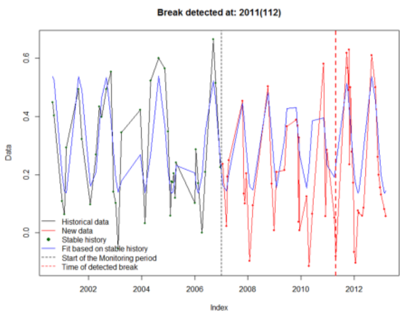
36	40	No access	1.5	2006	2010	-0.1053	Logging
37	41	2.5	5	2002	2008	-0.0325	Coffee Cultivation
38	43	7	3	2002	2010	-0.0864	Farm land Expansion
39	44	6.6	7	2010	2010	-0.1053	Farm land Expansion
40	46	12	7	2010	2010	-0.035	Farm land Expansion
41	47	4	5	2002	2010	-0.1613	Farm land Expansion
42	49	1.5	1	2008	2008	-0.0707	Coffee cultivation
43	50	No access	3	2010	2008	-0.0707	Coffee cultivation
44	51	No access	REG	REG	NA	NA	-
45	53	No access	5	2012	2010	-0.0609	Farm land Expansion
46	54	4.5	6	2010	2009	-0.0675	Farm land + Erosion
47	54(hen)	4.5	3	2002	2010	-0.1029	Farm land + Coffee cultivation
48	57	No access	6	2003	2008	-0.1166	Farm land Expansion
49	60	5	5	2008	2011	-0.0575	Farm land Expansion
50	60	10.5	12	2008	2011	-0.0513	Farm land Expansion
51	61	From Google earth imagery			2010	-0.0835	-
52	63	From Google earth imagery			2010	-0.1243	-
53	101	Agricultural field			NA	NA	-
54	102	Disturbed coffee forest			NA	NA	-
55	103	Degraded forest patch			NA	NA	-
56	104	Forest patch with coffee			NA	NA	-
57	105	Coffee forest with less canopy			NA	NA	-
58	106	Degraded forest patch			NA	NA	-
59	107	Coffee forest			NA	NA	-
60	108	Coffee forest			NA	NA	-

Note: NA= No breakpoints observed hen= Hena kebele in Doreni district REG= regeneration h.b= hurumu district buffer zone, h.tr = Hurumu district transition zone

Sample point and BFAST monitor plot

Sample point and BFAST monitor plot

1



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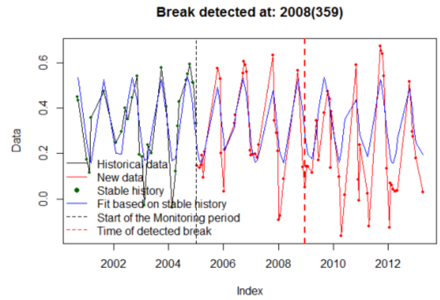

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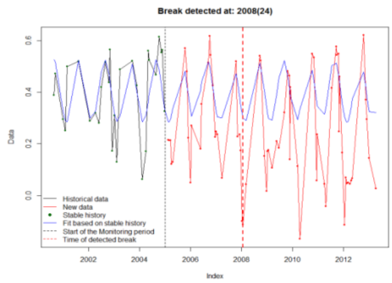

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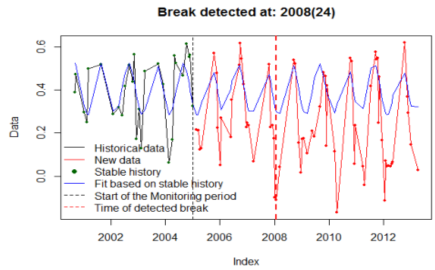

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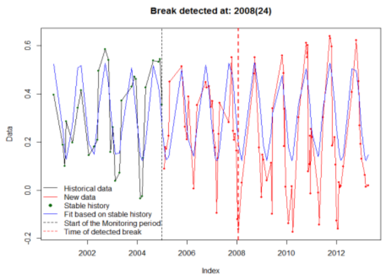

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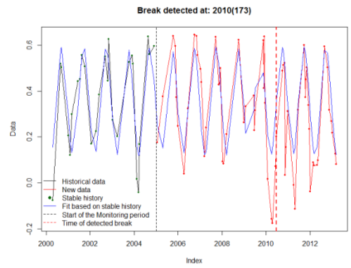

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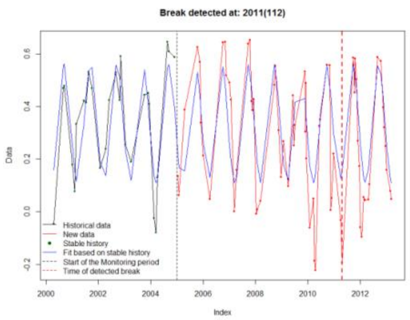

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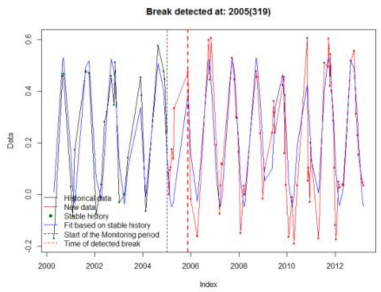

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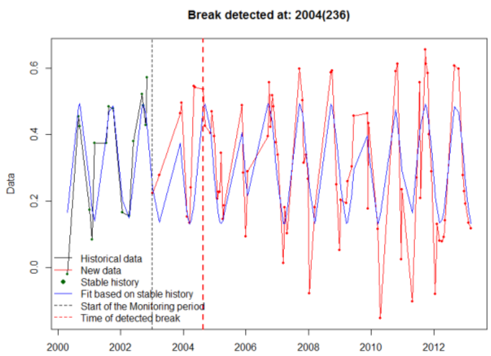

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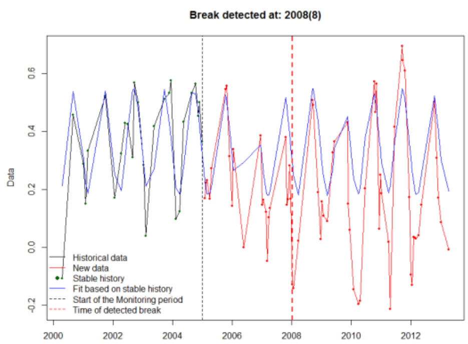

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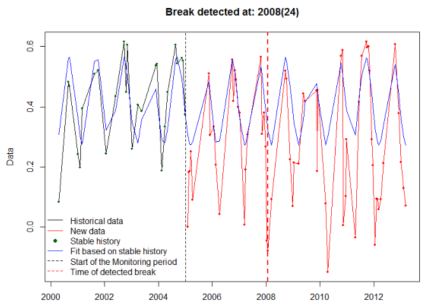

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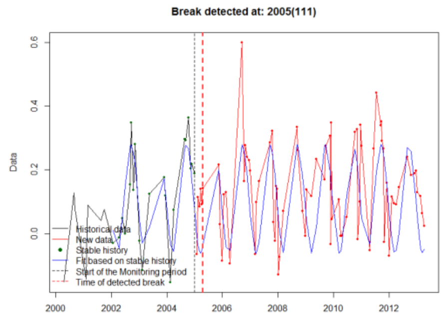

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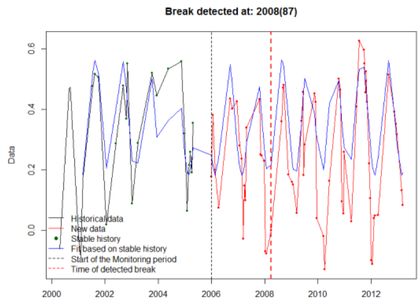

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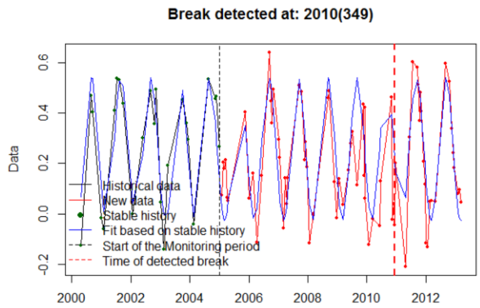

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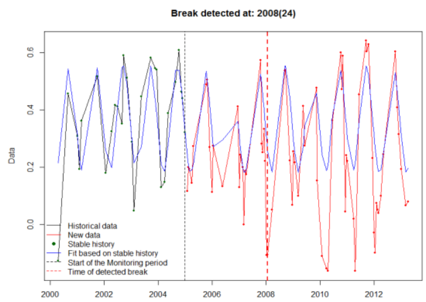

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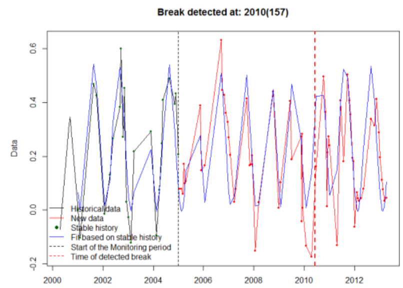

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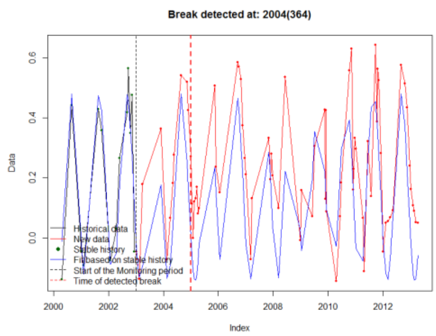

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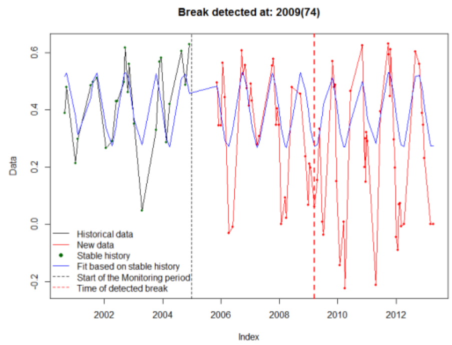

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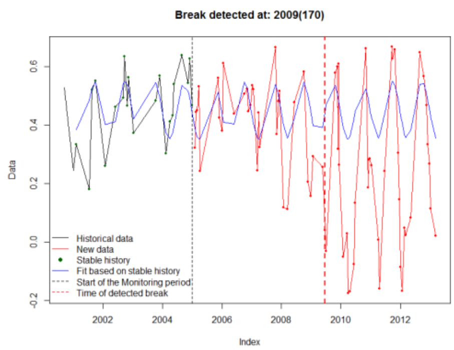

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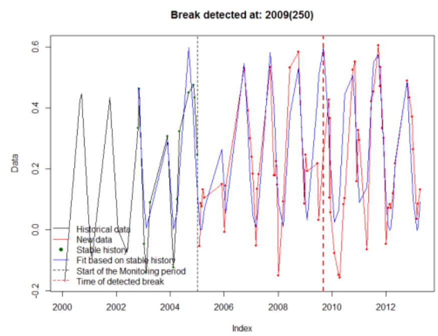

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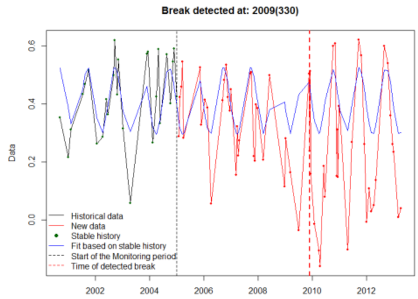
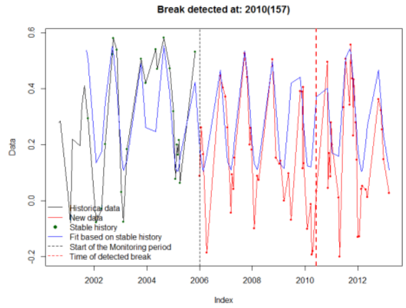
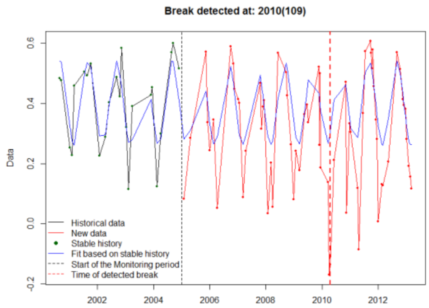


24 (Hurumu transition zone)

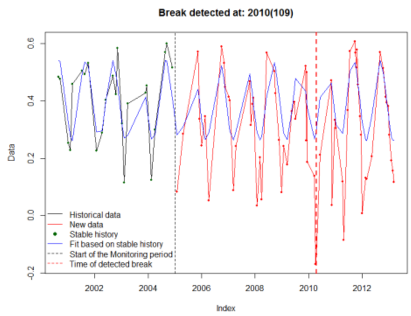


24 (Hurumu buffer)



25

27



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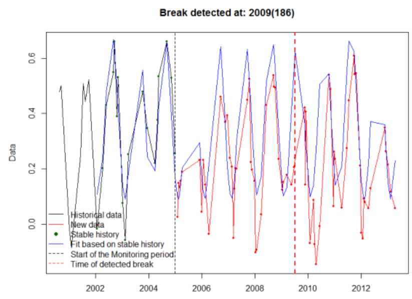

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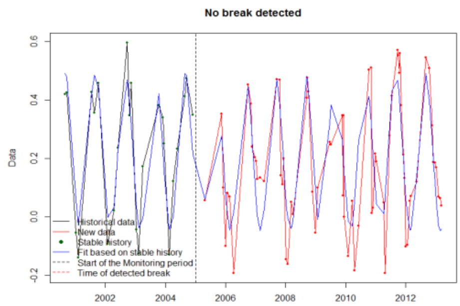

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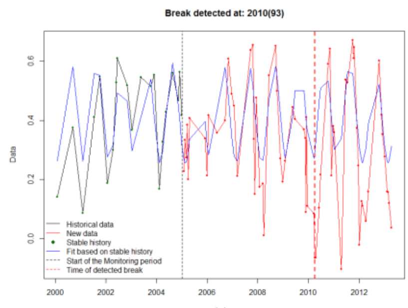

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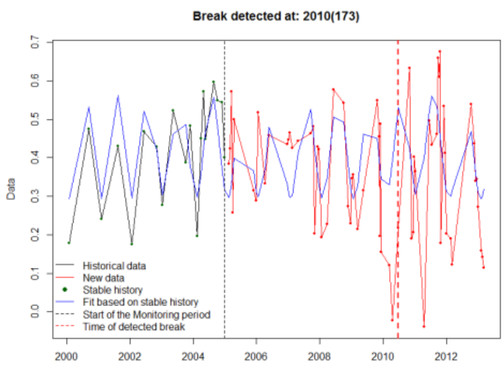

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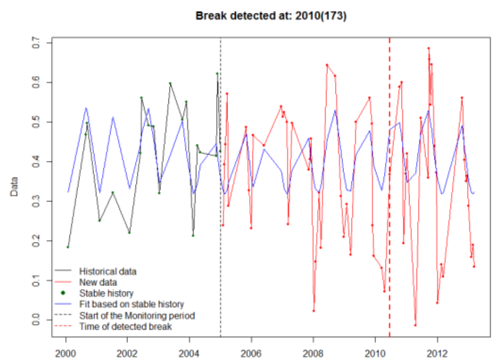

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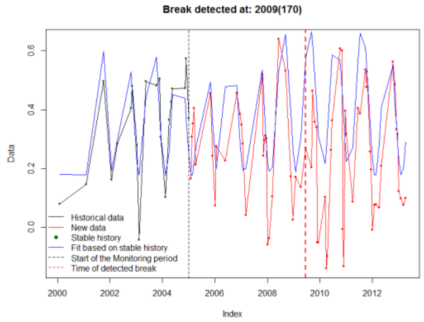

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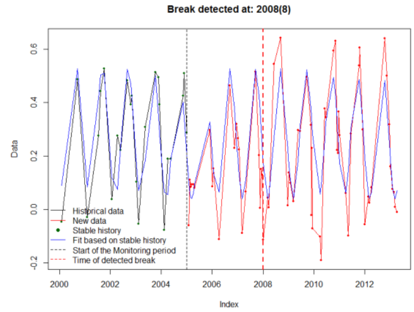

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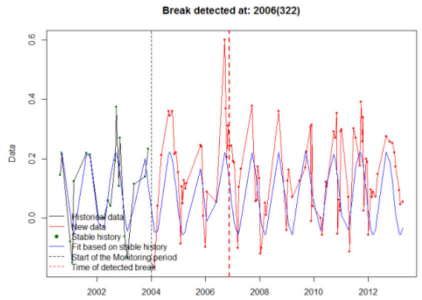

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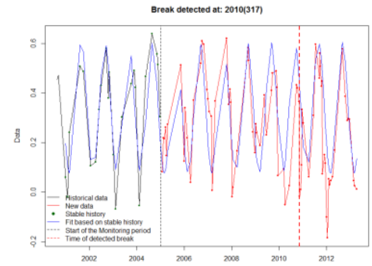

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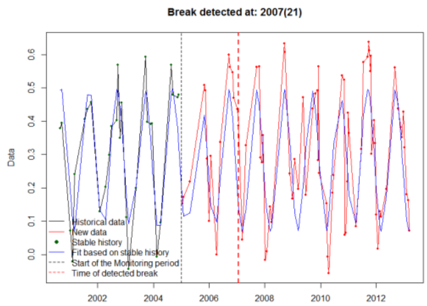

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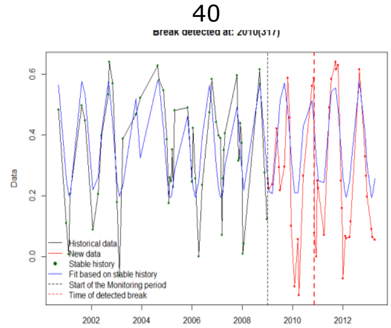

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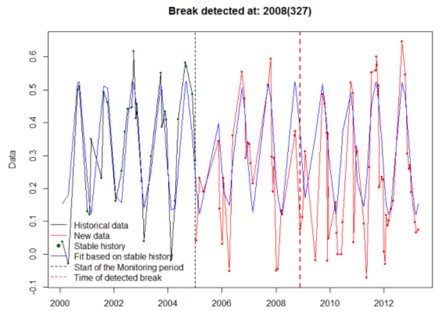

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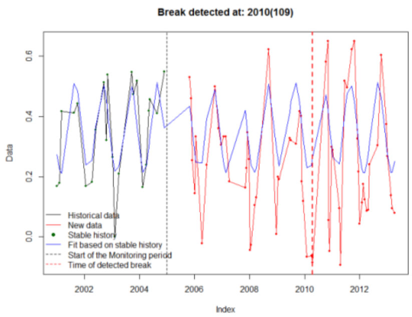

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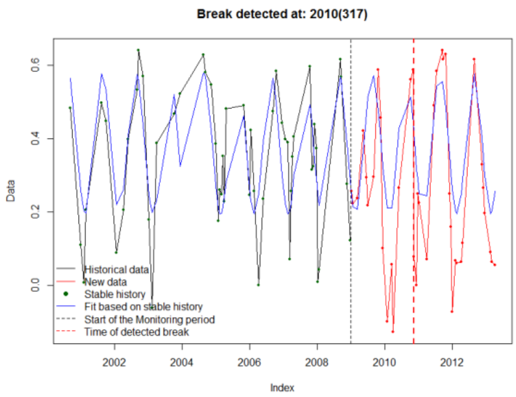

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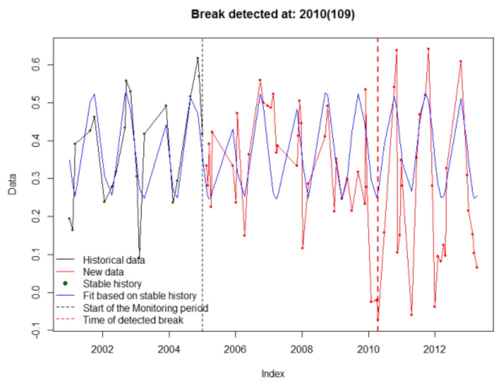

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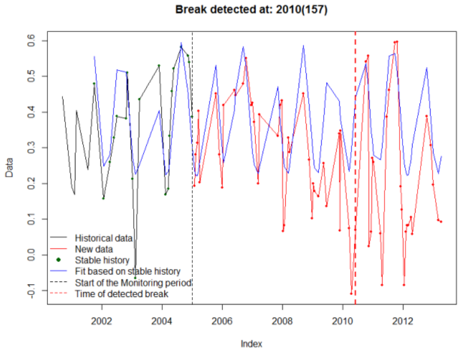

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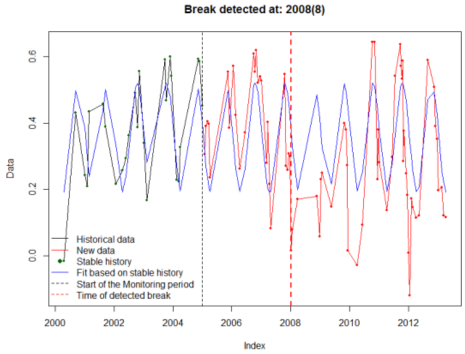

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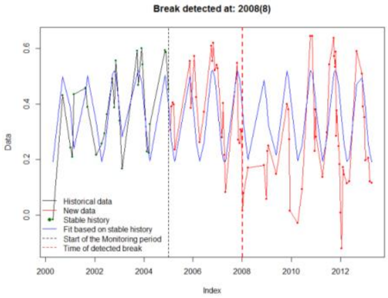

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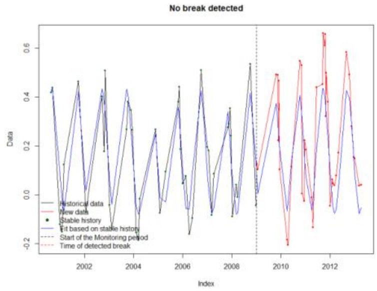

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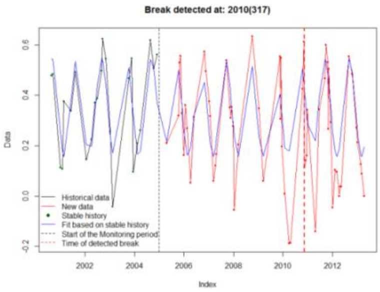

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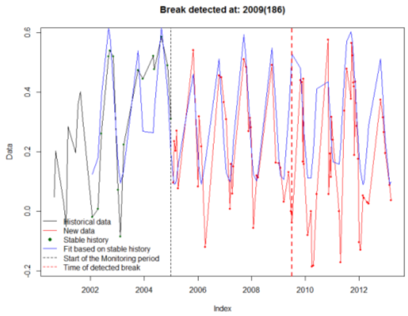
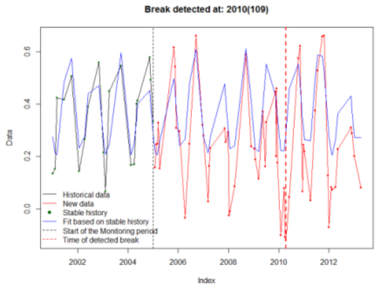


54(doreni-hena)



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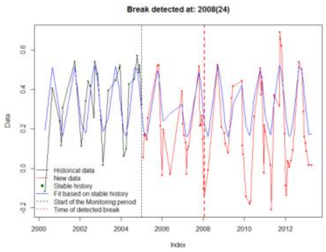
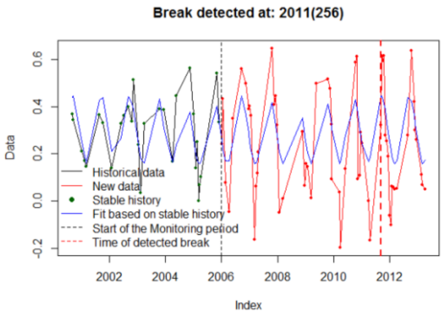
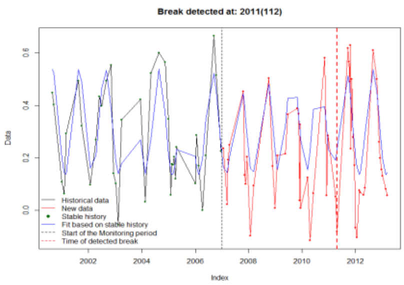


60(Chora district)



61

60(Doreni district)



63

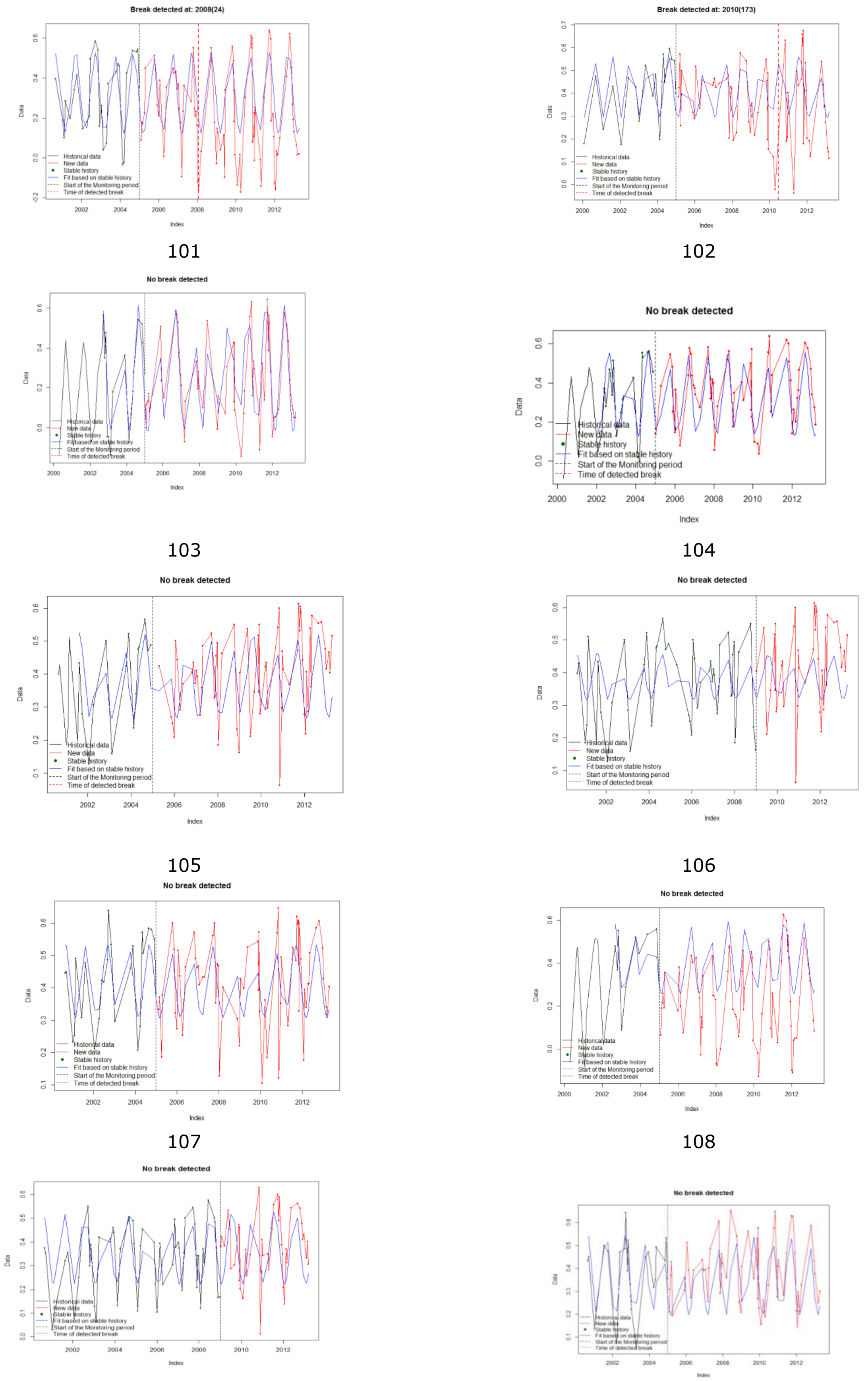


Figure 41. BFAST monitor single pixel breakpoint detection results (Numbers are written at the top)