Murree Hills Forest Monitoring in the Context of Reducing Emission from Deforestation and Forest Degradation (REDD+)

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DEDICATION

I want to dedicate this effort to my beloved parents and respected teachers who gave us motivation and supported this effort morally, economically and technically.

Acknowledgement

All praises and thanks to Almighty Allah, the lord and creator of this universe whose powers and glory all good things are accomplished, He is merciful, compassionate and never spoils ones' efforts. He bestowed on us the ability and an opportunity to work on this project.

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Abstract

Reducing Emissions from Deforestation and Forest Degradation plus (REDD+) is a mechanism to cut down GHG emissions and protect threatened forest ecosystems by involving and making them sustainable forest dependent communities. Forests uptake CO_2 from the air and providing a great service to human kind. Around 33% carbon emissions into the atmosphere are caused by the human activities such as deforestation and degradation of forested land. Changes in land use pattern may release stored carbon into the atmosphere which is a major source of global warming. Pakistan is facing higher deforestation rates due illegal logging, transforming into agricultural land and development of housing societies that had reduced the forest cover from 5 to 2.5 percent. Deforestation in Murree Hill forests was examined/investigated in the context of REDD+ from year 2000 to 2012 employing MODIS vegetation indices (NDVI/EVI), land cover product MCD12Q1 and CO_2 emission inventory. Existing carbon stock data was used to quantify LULUCF emissions based on IPCC guidelines. The findings indicated an increase in vegetation index and an increase of forest cover by 42 percent based on MODIS land cover product. While CO_2 emission data sets: EDGAR (Emission Database for Global Atmospheric Research) and REAS (Regional Emission inventory for Asia) exhibited an increasing trend on contrary to vegetation indices over study area. Also it didn’t not agree with calculated LULUCF emissions. Overall, outcomes of the study suggest that Murree hills forest is a storehouse of CO_2 and it has great potential for REDD+ implementation.

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List of Abbreviations

IPCC	Intergovernmental Panel on Climate Change
GHG	Greenhouse gas
UNFCCC	United Nations Framework Convention on Climate Change
LULUC	Land use and land use change
LULUCF	Land use, land use change and forestry
AFOLU	Agriculture, Forestry and Other Land Use
FAO	Food and Agricultural Organization
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SPOT	Satellite for observation of Earth
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
EDGAR	Emission Database for Global Atmospheric Research
REAS	Regional Emission inventory for ASia
SCIAMACHY	SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY
CDM	Clean Development Mechanism
MRV	Monitoring, reporting and verification
AD	Activity Data
GPG	Good Practice Guidelines

ARL NOAA	Air Resources Laboratory National Oceanic and Atmospheric Administration
SUPARCO	Space and Upper Atmosphere Research Commission
ETM	Enhanced Thematic Mapper
ALGAS	Asia Least-cost Greenhouse Gas Abatement Strategy
INC	Initial National Communication
LCC	Land Cover Classification
WGS	World Geodetic System
UTM	Universal Transverse Mercator
GVM	Global Vegetation Monitoring
OBI	Object Based Image
USGS	US Geological Survey
FRCGC	Frontier Research for Climate and Global Change

Chapter 1

Introduction

1.1 Background

Forest ecosystems play a critical role in the global carbon cycle, sequestering carbon dioxide (CO_2) through photosynthesis and storing carbon in plant biomass above and below-ground and in soil organic matter. In Pakistan, relatively no research has been conducted in forest ecosystems for estimating carbon stocks, carbon sequestration and forest mapping. The aim of this study was to determine REDD+ potential in Murree Hills forest.

Forests cover around 3.8 billion hectares or 30% of total land area of the world (1). They are the most important and productive ecosystem i.e., it may provide a diversity of tangible and non-tangible service for human beings. Forest plays a significant role in maintaining the natural environment such as regulate the hydrological cycle and reduced the soil erosion, regulate the micro-climate (i.e., temperature, relative humidity), harbour biodiversity and store carbon, livelihoods (providing jobs and local employment), water (watershed protection, water flow regulation, rainfall generation), food, nutrient cycling and climate security etc. Standing forest hold a large carbon stock and sequester carbon from the atmosphere (Pagiola et al, 2002). Unfortunately, being highly valuable, the forest cover is decreasing day by day due to human activities such as illegal logging, conversion into agricultural fields and housing societies that ultimately has caused devastating effects on our environment. It has been stated that, around 6.8 million hectares of forest had been lost every year during the 1990 and 2005 (1). It has been stated that the deforestation and degradation of tropical forests may contribute 12–20% of global carbon emissions in the atmosphere (3, 4, 5).

Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to get financial value for the carbon stored in the forest, provide incentives for developing countries in order to halt the deforestation and degradation to reduce the emissions of carbon from forested lands. REDD+ motivated the decision makers of the developing countries to protect the forest and get financial benefits improve the livelihood of forest-dependent communities. In 2008, United Nations initiated the REDD+ program to stop the emissions of carbon stored in the forest of developing through offering financial incentives. This program also targeted stakeholders for their capacity building to implement REDD+ mechanisms.

With a low forest cover of 2.5 percent relative to the international standard of 30 percent, Pakistan has a huge diversity of forests ranging from coastal mangroves to temperate conifer forests. This ecological set up is mainly due to arid and semi-arid climate prevalent in most part of the country. The total area covered by forest is 4.34 million hectares (Mha) or 5 percent. Natural forests account for 4.2 Mha whereas irrigated plantations occupy 103,000 ha. Forest area occupied by Sindh, Baluchistan, Punjab, Khyber Pakhtun (KPK), Azad Kashmir and Northern areas is 0.92, 0.33, 0.69, 1.21, 0.42, and 0.66m ha respectively. It is evident that most of the forests are distributed is in the northern part of the country with 40 percent in KPK, 15.7 percent in Northern Areas and 6.5 percent in Azad Kashmir. The Northern region of Pakistan mainly comprises of Alpine and temperate forests. Forests in Pakistan are diminishing at a rate of 27000 ha/year bringing it down from 5 to 2.5 percent.

Pakistan’s forests can store around 213 million metric tons of carbon. Pakistan is the member of the Coalition of Rainforest Nations and also signatory to the initial REDD+ proposal submitted by the Rainforest Coalition in 2008. To develop REDD+ readiness roadmap Pakistan joined UN-REDD Program in 2011 and has also initiated its REDD+ Preparedness phase, which is a collaboration between Climate Change Division of Pakistan, International Centre for Integrated Mountain Development (ICIMOD) and WWF-Pakistan. It is financially supported by the United Nation Development Program (UNDP) through One UN Joint Program on Environment (JPE).

1.2 Study Area

Murree is an exurb of Islamabad and the administrative centre of Murree Tehsil, in the Punjab province in Pakistan with an area of 37977 ha. It is in a subdivision of Rawalpindi District and includes the parts of the Margalla Hills around Islamabad. It is located on the southern slopes of the Western Himalayan foothills as they ascend north-eastwards at an average altitude of 2,291 meters (7,516 ft).

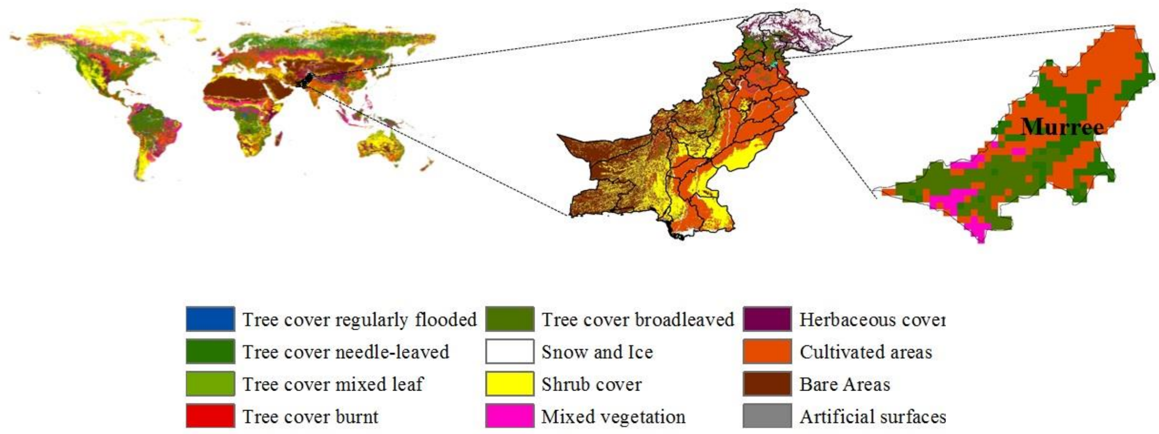

Figure 1: Study area Murree Hills

1.3 Aims and objectives

Objectives of the present study are as follows:

- Extract forest cover of study site
- Identify deforestation pattern over study site
- Monitor CO_2 emissions over study site

Chapter 2

Literature Review

2.1 Green House Gases and there Role in Climate

It has been estimated that 2.1 Gt of carbon which is 17 % of the anthropogenic emissions are resulting due to annual decrease in tropical forest which also pose threat to species [10; 11]. These statistics spectacle why the Land-Use, Land-Use Change and Forestry (LULUCF) sector must not be let of while looking for climate change solution [12]. It has been discussed and studied that tress are best carbon pools which are enough to balance all emissions from industrial sector, and this relatively correct. Though, emissions from deforestations sector is important which need to be reduced and it is a key action to tackle climate change, which not only to store the stocks in forest ecosystem but it will also include the to maintain carbon sink and reservoirs as well [13]. Amount of carbon which can be sequester by adopting programs such as LULUCF practices over first half of the 21st century was 12-15% [14].

2.2 Reducing Emissions from Deforestation and forest Degradation

The term ‘‘reducing emissions from deforestation’’ first needs to be clear up. “Avoided Deforestation” was most commonly used term in this context and this is also assumed that leads to instituting of National Parks or conservation areas to maintain balance. Forest conservation is one of likely best option by which land use changes can be ducked. This can also be stopped by adopting best management or sustainable forest management practise. Many land use practices like shifting cultivation are succeed in reducing emissions from deforestation sector. By designing rules and guidelines we can achieve much better results [15]. Main objective of

REDD+ initivies is to reduce CO2 emissions caused by permanent loss of forest. We need therefore to be anxious with deforested emissions but also considered degradation too; as the REDD + is two dimensional concept. While the Degradation is three dimensional concept which means thinning of forest over large area which have potential threat of permanent loss and this also remove significant amount of Carbon from effected area.

2.3 Atmospheric Abundances and Trends

According to IPCC [16] in 1990 average annual CO2 concentration over the globe was 353 ppmv.While in 1991 increased in annual concentration was observed and set 353 ppmv as a global annual value and recently an increase of 1.8 ppmv/yr is observed. CO2 concentration has increased almost 3 ppmv over South Pole to Arctic basin [17: 18] these depends upon distribution of fossil fuels burning, terrestrial and oceanic sink and sources [16]. Gradual increase in CO2 emissions has been observed over Northern hemisphere. Whereas southern Hemisphere has observed as a major contributor in fossil fuel emission. This may be because of net uptake of oceanic region in Southern hemisphere. Different studies shows that CO2 and its stable isotop are showing regularity in seasonal cycle especially over Northern Hemisphere. Northern Hemisphere, is dominated by the activity of the terrestrial biosphere in the Northern Hemisphere, rather than by seasonal changes in ocean PCO_2 or fossil sources.

2.4 Sources and Sinks for Carbon dioxide

Global Terrestrial ecosystem account almost 60 percent of forested area and soil carbon stock [19]. Major pools for atmospheric carbon on earth are Ocean, Forest and soil which could significantly contribute to decrease global carbon emission and can help to tackle climate change [20; 21; 22].

Plant Biomass store almost 90 percent of the carbon and if we continue cutting of trees this all will be released back in atmosphere and will increase the atmospheric concentration of CO2 [23]. This highlight the importance of forest ecosystem over planet earth and need to enumerate carbon stored in plants.

According to NOAA studies in 2010 an increase in CO_2 concentration has been observed from 315 ppm 91985) to 387.35 ppm in 2009 [24]. Carbon sinks like Oceans and terrestrial ecosystem are playing major role in maintaining CO2 concentration in atmosphere otherwise that cloud be high then it is measured due to increased used use fossil fuel combustion. It has been assessed that 50 % of the carbon store in terrestrial ecosystem located in Northern latitude [25; 26].

Carbon flux within soils contribute to global carbon cycle. CO_2 is part of carbon cycle which involve many process; sinks and sources which exchange carbon between terrestrial, oceanic and atmospheric ecosystem [26; 27; 28]. Transfer of this carbon occur through different biological and geological processes under different climatic conditions and over different time intervals [26; 27].

2.5 Recent Estimates of Deforestation Rates

Deforestation and forest degradation released 1-2,000 Mt C/year during 1990s (IPCC, 2007).

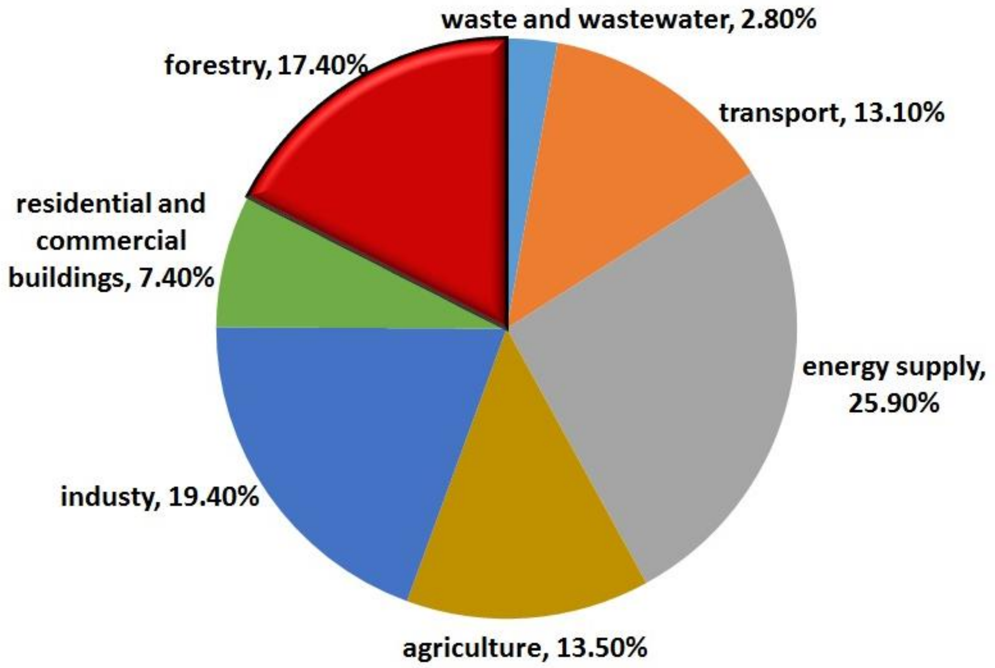

Figure 2: Contribution of deforestation and forest degradation to Global GHG emissions

2.7 REDD+ in Pakistan

Pakistan is the member of the Coalition of Rainforest Nations and also signatory to the initial REDD+ proposal submitted by the Rainforest Coalition in 2008. To develop REDD+ readiness roadmap Pakistan joined UN-REDD Program in 2011 and received Targeted Support funds for this purpose. This fund will eventually lead to development of National Forest Monitoring System. As an initiative to protect its forest resources and gain financial benefits from it Pakistan has launched nationwide unilaterally financed Mega- Carbon sequestration project which will lay a foundation to fulfill REDD+ objectives.

Pakistan has initiated its REDD+ Preparedness Phase which is a collaboration between Climate Change Division of Pakistan, International Centre for Integrated Mountain Development (ICIMOD) and WWF-Pakistan. It is financial supported by

United Nation Development Program (UNDP) through One UN Joint Program on Environment (JPE). This project will go forward with the aim to develop national REDD+ strategy for Pakistan by incorporating the regional experience ICIMOD has gained through REDD+ pilot activities in Nepal and the presence of WWF-Pakistan. Khyber Pakhtunkhwa (KPK) and Gilgit Baltistan have initiated pilot activities related to REDD+.

2.7.1 State of forests in Pakistan

At present forests of Pakistan are suffering from large-scale deforestation and degradation. And it is continuing unprecedentedly by 0.75 per cent per year [25]. In 1992 forested land was 4.242 Mha, which declined to 3.44 million hectares in 2001. Since independence in 1947 61,000 ha of forest land have been converted to some other land use type [11].

The Mangrove forests, in Indus delta, have suffered highest rate of deforestation at 2.3 percent per year, followed by coniferous forests and ravine forests at 1.99 percent and 0.23 percent respectively. On provincial basis the conversion of forest land to non-forest land is highest on Punjab with conversion of 977 ha of land, Sindh with 279, Baluchistan with 137, KP with 100 ha and lastly lowest in AJK 6 ha [26].

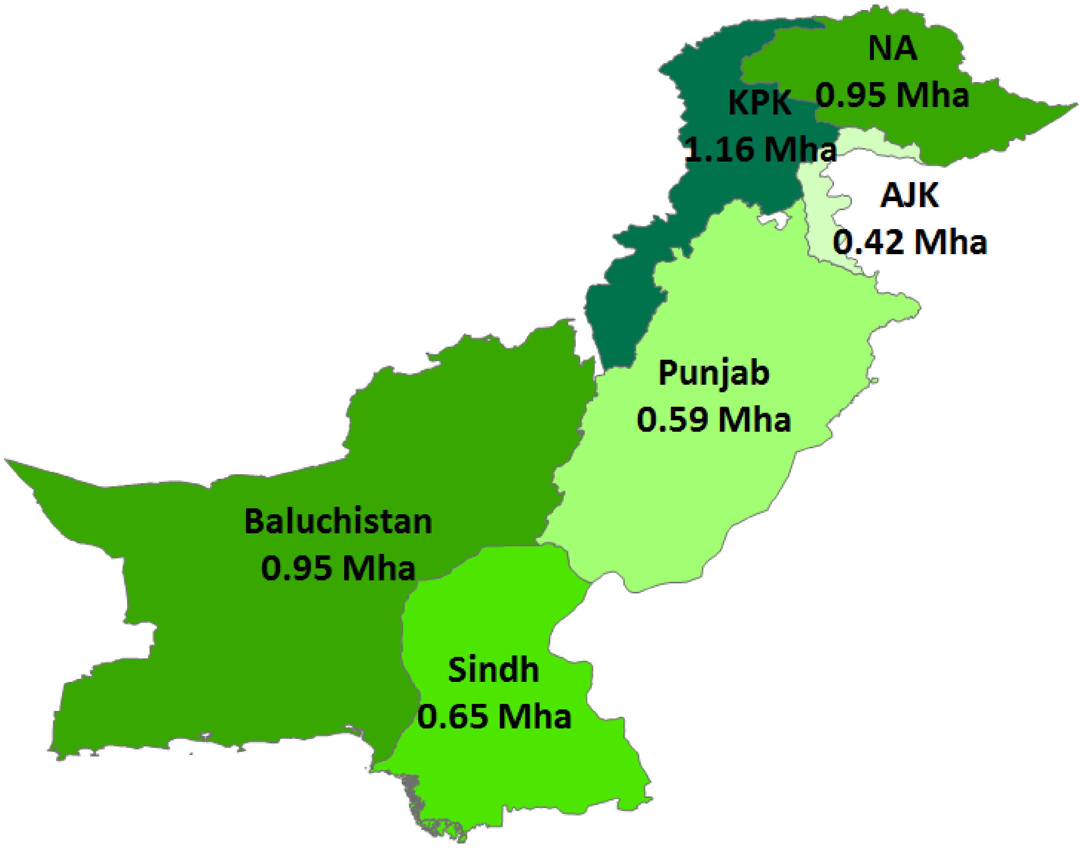

Figure 3: Forest Area Distribution over Pakistan (Forestry statistics of Pakistan, 2004)

On the contrary government statistics show an increase in forest cover by 21.1 percent from 1947 to 1994. This increase is mainly attributed by afforestation and agro-forestry projects and strict control in illegal logging [27].

Some studies have reported significant deforestation mainly contributed by illegal timber extraction. Former Prime Minister of Pakistan lifted the ban from timber transportation which was imposed in the early nineties. As soon as the ban was removed 2.07 million cubic of timber was transported to different parts of the country. Timber mafia also benefitted from this opportunity by chopping trees worth Rs 8 billion [28].

2.7.2 Temperate coniferous forests in Pakistan

These forests, dominant in Pakistan, mostly grow in northern parts of the country at an elevation between 1000 and 3500 meters. They are abundant in places like Mansehra, Dir, Swat, Malakand and Abbottabad districts of KPK and Rawalpindi district of the Punjab. Major species include fir, spruce, deodar, blue pine and chir pine. Coniferous forests as a whole cover 1.93 Mha or 40.92 percent of total forests in Pakistan. Provincial distribution of these forests is highest in KP with 1073000 ha, AJK with 407000 ha, Northern Areas with 285000 ha, Baluchistan with 116000 ha and Punjab with 49000 ha [29]. They play an important role in timber provision, protection of land and soil on steep mountain slopes, supply of fuel wood and non-wood products, medicinal plants, livestock grazing and as well as support the habitat of wildlife species. Some of the coniferous forests types are [30]

Himalayan moist temperate forests

These forests, with limited undergrowth, includes evergreen and deciduous species. They grow at elevations between 1500 and 3000. Specie distribution is based on lower an duper zone these forest. Dominant species in the lower zone are Cedrus deodara, Pinus wallichiana, Picea smithiana and Abies pindrow (Partal) while Abies pindrow and Q. semecarpifolia are overriding in higher region.

Himalayan dry temperate forests

These types of forest consist of evergreen forest including open scrub brushwood, while some of area also show presence of coniferous and broad leaved species. This kind of species are most common at North West side of the study area and extended though the length of the area. Main Species are dry zone deodar, Pinus gerardiana (Chalghoza) and/or Quercus ilex. Blue pine are mostly dominated at inner trak region of the forest while locally found species also exist there which are ; Juniperus macropoda (Abhal, Shupa, Shur) and some Picea smithiana.

Sub-alpine forests

Sub alpine forest species like evergreen conifers and broad leaved trees mostly found in lower canopy side, typically along with deciduous shrubby undergrowth of Viburnum (Guch), Salix (Willow, Bed). Such type of forest almost found in throughout Himalayas range at range of 3350 meter. Common species of these forest types are; Abies spectabilis and Betula utilis (Birch, Bhuj). High level pine are mostly occurred at burnt sides and landslips.

Alpine scrub

This category mainly includes shrub formations 1 to 2 meter high but extending up to 150 meters. These forests are characterized by Salix, Lonicera (Phut), Berberis (Sumbul, Sumblue), Cotoneaster with Juniperus and occasionally Rhododendron or Ephedra (Asmania).

2.7.3 Forest mapping in Pakistan

To assess a country’s potential for REDD+, historic pattern in forest cover and related CO_2 emissions have to be quantified. This will give a trend of possible future emissions if deforestation prevails. The use of remote sensing is a suitable method because satellites record the earth’s land cover over the past decades. This data is archived and can be analysed of past changes in forest cover indicating the deforestation trends. There has to be a LULUC database in place for developing temporal and spatial records and assessing its variation over the years. In Pakistan forest cover assessment has been carried out on city or district level. Space and Upper Atmosphere Research Commission (SUPARCO) has carried out studies to assess the forest resources of Pakistan. Some of their research activities include mapping land cover of Swat, exploring the pattern of irrigated plantations in Changa Manga and mapping the Mangrove forest along the coastal areas and the Indus delta.

Siddiqui et al [31] evaluated the distribution of the Riverine forests along the river Indus plains. The results indicated 1042 ha loss of Riverine forests per year with a total loss of about 21,590 ha during the study's temporal coverage from1977 to 1998. In a similar study by Habibullah et al [32] temporal changes in Riverine forest cover of Sindh between 1979 and 2009 were identified. Land cover of study area was classified in to: forests, grassland/agricultural land, dry land/land use and water. By comparing land cover maps the annual ratio of depletion of forests came out to be 9.0%, with a total loss of 85% of forest cover from 1979 to 2009.

Assessing the decline of Coniferous forests in all provinces of Pakistan was done by Ahmad et al [33] using GIS applications. Their study, which showed an overall decrease in forests, detected forest cover change from 1992 to 2010.

A study in 2005 carried out by Ali et al [34] determined the change in forest cover in Basho valley by comparing Landsat images of 1976 and 2002. They also tried to determine the causes of forest loss with the help of surveys, workshops and interviews with forest department, forest contractors, Basho Development Organization and the local community. According to their results the major contributing factor towards deforestation is mismanagement of forest department and illegal harvesting instead of over population.

Forest cover assessment of Ayubia National park has been carried out by Abbas et al [35] using high resolution imagery of Quick bird. Their study was successful in classifying land cover of Ayubia National Park into the following classes: conifer forest, conifer forest (shadowed), mix forest grasses, build up area and bare rocks/soil. The area covered by Coniferous forest, as calculated in this particular study, came out to be 2100 ha.

Rizwan et al [36] by using GIS techniques and Landsat Enhanced Thematic Mapper (ETM) extracted the forest cover of Toba Tek Singh, district of Punjab. Comparison made between the official forest area allotted to forest departments and the actual area covered by forests showed that the actual forest area (2140 ha) is less than the allotted area (5896 ha). Abbas et al [37] assessed the distribution of mangrove forests along Makran coast of the Baluchistan Province and the entire Indus Delta within the Sindh Province. The study used images of ALOS-AVNIR-2, with a resolution of 10 m, for the year 2009. Multi-scale Object Based Image Analysis showed that mangrove cover spread to an area of 98,128 ha in Pakistan. Land cover maps developed had the following classes: dense mangrove, medium mangrove, sparse mangrove, algae, saltbush/ grasses, mudflats and water.

2.7.4 Biomass and carbon stock measurements in Pakistan

Forest carbon assessment and forest inventorying is one of the prime requirements of implementing forest monitoring and MRV system. Pakistan lacks in complete and accurate statistics on carbon stock values, growing stocks and standing volume of its forests. The only available carbon stock data for Pakistan is that collected by of Food and Agricultural Organization (FAO) and through local research.

According to FAO [19] the total biomass of forests in Pakistan, including living and dead wood, is 573 million metric tons (Mmt). Nizami et al [38] carried out carbon stock assessment of the sub-tropical pine forests in Murree, Pakistan. In another study by Raqeeb et al [39] growing stock volume of temperate forest in Gilgit Baltistan, Pakistan was estimated. The study also tried to determine the relation between height and volume with respect to diameter of the dominant species. Kanwar and Ahmad [40] estimated carbon potential for total forests of Pakistan to be 389 mega tons.

2.8 GHG Emission Inventory of Pakistan

Being signatory to Kyoto protocol and UNFCCC Pakistan is obligated to submit national GHG report to UNFCCC after every two years. Pakistan's last GHG inventory, Initial National Communication (INC) developed for 1993-94, was submitted to UNFCCC in 2003. The inventory covers major sectors like energy, transport and LULUCF. In the forestry sector the CO_2 emissions reported are for changes in forest carbon stock. Total carbon uptake was estimated as 11,451 kt (kilotons)**,** while annual carbon release was 13,231 kt. Net carbon release thus comes out to be 1780 kt, which translated into net emissions of 6527Gg (giga grams) of carbon dioxide [41].

According to the results of a GHG inventory developed by Khan et al [42] with temporal coverage from July 2007 to June 2008 the total carbon uptake was 87,284 Gg. With annual carbon release estimated as 18,730 Gg, net CO_2 up-take came out to be 68,676 Gg. Outcomes of both inventories were achieved using Revised IPCC Guidelines of 1996 for National Greenhouse Gas Inventories.

Emission inventory record maintained by EDGAR and REAS are in the form of gridded data. The gridded data can be used to generate spatial and temporal maps of GHG flux in tons. Moreover data used to develop maps holds information of total carbon dioxide emissions and emissions sector wise as well. Ample gridded data is available over Pakistan; however the mapping of carbon dioxide is still in developmental stages.

2.9 Quantifying emissions (emission factors) from LULUCF

2.9.1 Gross and net emissions

Carbon emissions contributed by deforestation and forest degradation can be estimated from gross or net changes in carbon stocks. Gross emissions assumes removal of trees and any other vegetation type resulting in emission of total carbon. However net emissions takes in to account the carbon sequestered by the vegetation replacing forests. As illustrated in figure 6 carbon sequestered in the replacing land use is 60 t therefore net emissions are 90 t (150 – 60). But if this 60 t is not considered then the gross emissions would be 150 t of carbon. This phenomena has to be kept in mind when reporting net emissions from LULUCF.

Emission Factors

Three important aspects of Emissions Factors are [43]:

Gases

Emissions and removals various from land conversions are calculated based on the differences in initial and final carbon stocks of the land cover type. Although non CO_2 gases are also emitted but from REDD+ perspective CO_2 is considered. Moreover these emissions are reported as CO_2 tons per hectare.

Pools

Carbon pools in a forest are:

- Aboveground Biomass
- Belowground Biomass
- Dead Wood
- Litter
- Soil

Tiers

Tiers are the assessment of Emission Factors/ changes in carbon stocks in the designated carbon pools of a forest with different levels of certainty. There are three tiers:

Tier 1 approach does not requires fresh data collection or ground based measurements for carbon stock assessment. Standard values for biomass or tree volume can be used from IPCC Agriculture, Forestry and Other Land Use (AFOLU) report. Using this approach will lead to results having low certainty with error range ~ +/- 30-70 percent. Furthermore Tier 1 estimates provide poor resolution of forest biomass varying at sub-nationally level.

Tier 2 is an improved version of Tier 1 such that emphasizes on using data specific for that country like national reports and inventories. Another advantage of Tier 2 over Tier 1, which assumes total emission of carbon, is the accounting of carbon being transferred from woody biomass to litter. Following this approach will make Emissions Factors more reliable.

Tier 3 approach is quite accurate as it quantifies Emission Factors based on periodic carbon stock assessments including carbon exchange between different carbon pools.

2.9.2.1 Quantifying CO_2

The IPCC AFOLU provides details on how CO2 emissions can be estimated. There are two ways to estimating CO2 emissions [43]:

Stock difference approach

This method is based on the difference between carbon stocks at two time spans within a particular carbon pool. This method can be applied practiced data derived from any Tier level. In the case of deforestation, where total loss of carbon stock is assumed and only gross emissions are considered, data for initial carbon stock is sufficient. Whereas for degradation carbon stock for both time periods has to be known as net emissions have to be calculated. Following equations are used in stock difference approach to estimate CO2 emissions:

Deforestation

$$CO_2 \textit{ emissions/year} = \textit{Area deforested/year} \times \textit{C stock of forest}$$

Degradation

$$CO_2 \textit{ emission/year} = \textit{Area degraded/year} \times (\textit{C stock non-degraded forest} - \textit{C stock degraded forest})$$

Gain-loss approach

To use gain loss method for emission calculation by deforestation data derived from Tier 3 approach has to be used. Tier 1 and 2 approach would be inapplicable. On the other hand gain loss method is quite useful to calculate emissions from degradation using data derived from any level of Tier. Loss in biomass will be determined using data of timber harvest, fuel wood harvest and litter. Gain in biomass would be recorded upon forest regeneration.

2.10 Satellite forest monitoring in the context of REDD+

To keep track of REDD+ activities, remote sensing has been widely used as an observational tool [44]. Remotely sensed data, satellite and LIDAR, provides historic time series, based on which future deforestation patterns can be modelled. Besides remote sensing ground based measurements, for carbon stock assessment, are equally essential for forest monitoring and accounting for changes in carbon stock [45].

Chapter 3

Materials and Methods

3.1 Methodology

Overall Methodology is adopted for this research is presented in figure 6. Various type of datasets and software packages are used to study the change in forest cover of Murree Hills, Pakistan (figure 4) and CO_2 emissions (figure 5).

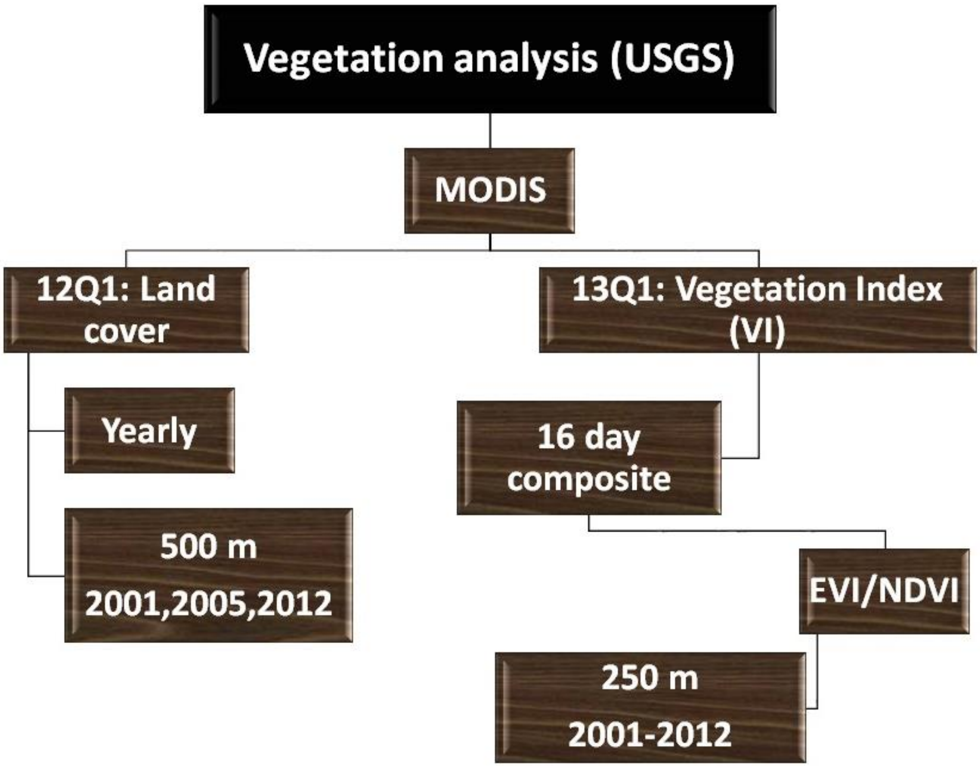

Figure 4: Datasets for forest cover assessment

There are two type of datasets are used in MOD13Q1 and MOD12Q1. MOD12Q1 is Land cover product which is globally available and was extracted on study area and processed on ArcGIS 10.2.

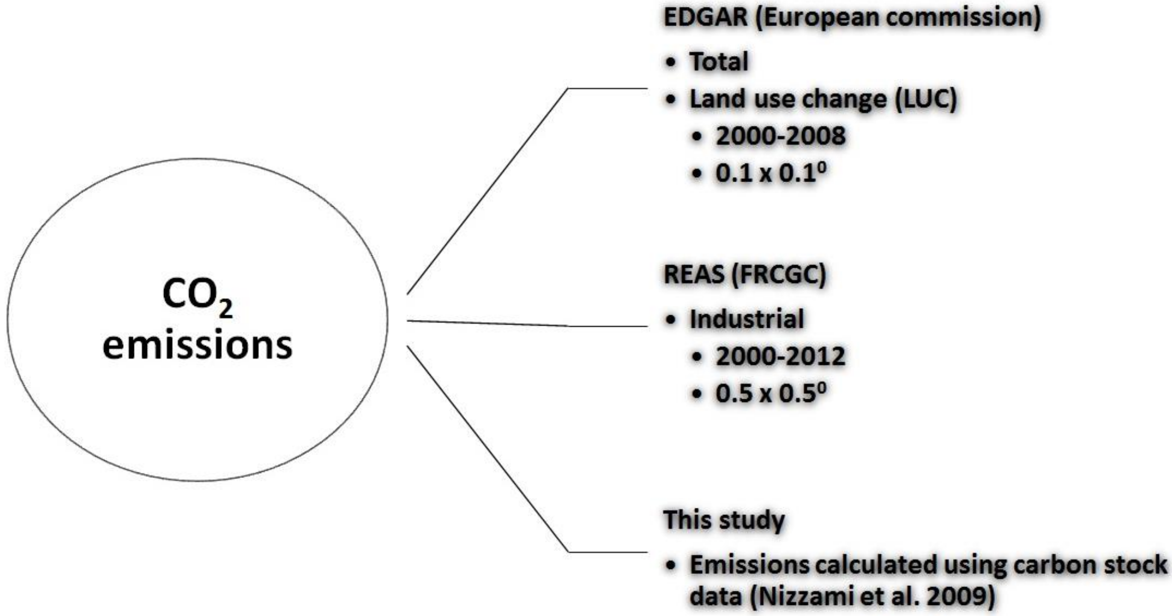

Figure 5: Datasets for CO_2 analysis

3.2 Satellite Data Analysis

Changes in vegetation cover were analysed using data recorded by MODIS on-board Terra platform. MODIS product downloaded for years between 2001 and 2012, was 13Q1 Vegetation Indices (VI) and 12Q1 land cover product with tile number h24v05. MODIS products are in HDF-EOS (Hierarchical Data Format for NASA's Earth Observing System) with Sinusoidal projection. To extract information over Murree using shapefile, the tiles had to re-projected to WGS-84 using ArcMap v10.2.

MOD13Q1 dataset provides two VI layers: Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI). The first one represents the continuity with the Advanced Very High Resolution Radiometer (AVHRR) mission; the second one is a newer VI, which is known to be able to account for both background and aerosol effects (7, 8). Vegetation indices (NDVI & EVI) are key products to monitor changes in vegetation over the globe. Then data is used by different models as an input data and analysis done to monitor changes on hydrological and biogeochemical cycle at global and regional level. MODIS products were obtained from the Land Processes Distributed Active Archive Centre (LP DAAC).

Table 1: Specifications of MODIS sensor

Properties	MODIS Terra/Aqua
Spatial resolution	250 x 250 m to 5600 m x 5600 m
Swath width	2330 km
Temporal resolution	5 minutes to annual
Temporal coverage	2000 to present
Red and NIR bands	1 & 2 620-670nm & 840-880nm
Spectral range	36 bands (0.405 to 14.385 µm)
*Data Quality assessment	89.32 % accurate (NDVI) 98.11% accurate (EVI) 74.8% accurate (Land cover)

**(http://landval.gsfc.nasa.gov/ProductStatus.php?ProductID=MOD13Q1&MCD12Q1)*

Since Murree is towards north of the country where temperatures are quite low and summer time is ideal to study the vegetation due to vigorous growth and less snow cover. Therefore MODIS vegetation index was used only for the month of June. Yearly spatial maps of mixed forests (needleleaf/broadleaf) were developed for the years 2001, 2005 and 2012, along with NDVI and EVI spatial trend. Time series for NDVI and EVI were also developed over Murree Hills. Forest area was calculated using Eq.1.

$$\textit{Forest covered Area} = (\textit{No of pixels with Forests})\ (\textit{Area of one pixel}) \qquad \textit{Eq. (1)}$$

3.3 Emission Inventory Data

The yearly inventory data on Global CO_2 emission of EDGAR (European Union) and REAS (FRCGC) were downloaded and extracted over the study site by using ArcMap v10.2. Followed by this time series were developed to depict temporal trends of CO2 emissions over Murree hills. EDGAR datasets downloaded were total emissions and land use change (LUC) emissions.

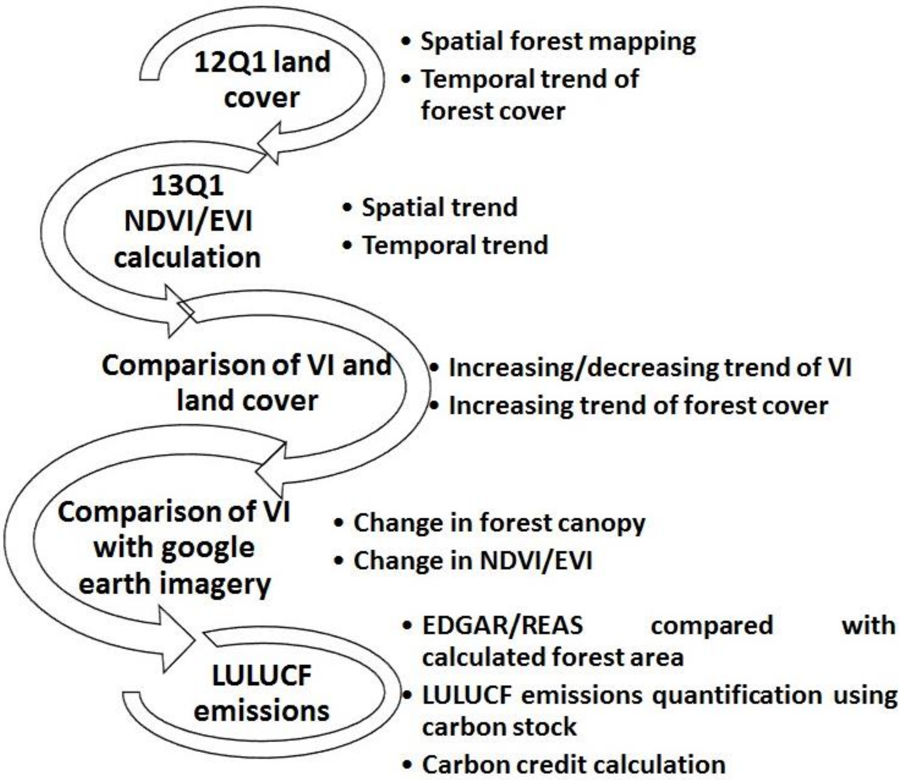

Figure 6: Steps for data processing

3.4. Quantifying CO_2 Emissions from LULUCF

CO_2 emissions data from land use change (LULUCF) was calculated using a standard formula provided by IPCC (2003) Eq. (2).

$$CO_2 \text{ emissions/year} = \text{Change in Forest Area (hectare)} \times \text{Carbon Stock per hector} \quad \text{Eq. (2).}$$

Chapter 4

Results and Discussion

4.1 Spatial and temporal variation of forest cover

Figure 7 shows spatial distribution needle/broadleaf forests derived using MODIS 12Q1 product. Land cover classification used here is in accordance with International Geosphere Biosphere Programme (IGBP) global vegetation classification scheme. To calculate forest area formula given in Eq. 1 was used. For MODIS land cover product area of one pixel is 25 hectare. This is a clear overall increase in the area of needle/broadleaf forests (fig. 7a), however this increase is mainly observed after 2005. This can be attributed to the widespread plantation scheme and the ban imposed on green felling by Government of Pakistan. Fig. 7b is depicting the spatial dynamics for forest cover over Murree. It also shows that though deforestation has occurred on some locations between 2000 and 2012, however the overall area of forests has progressed.

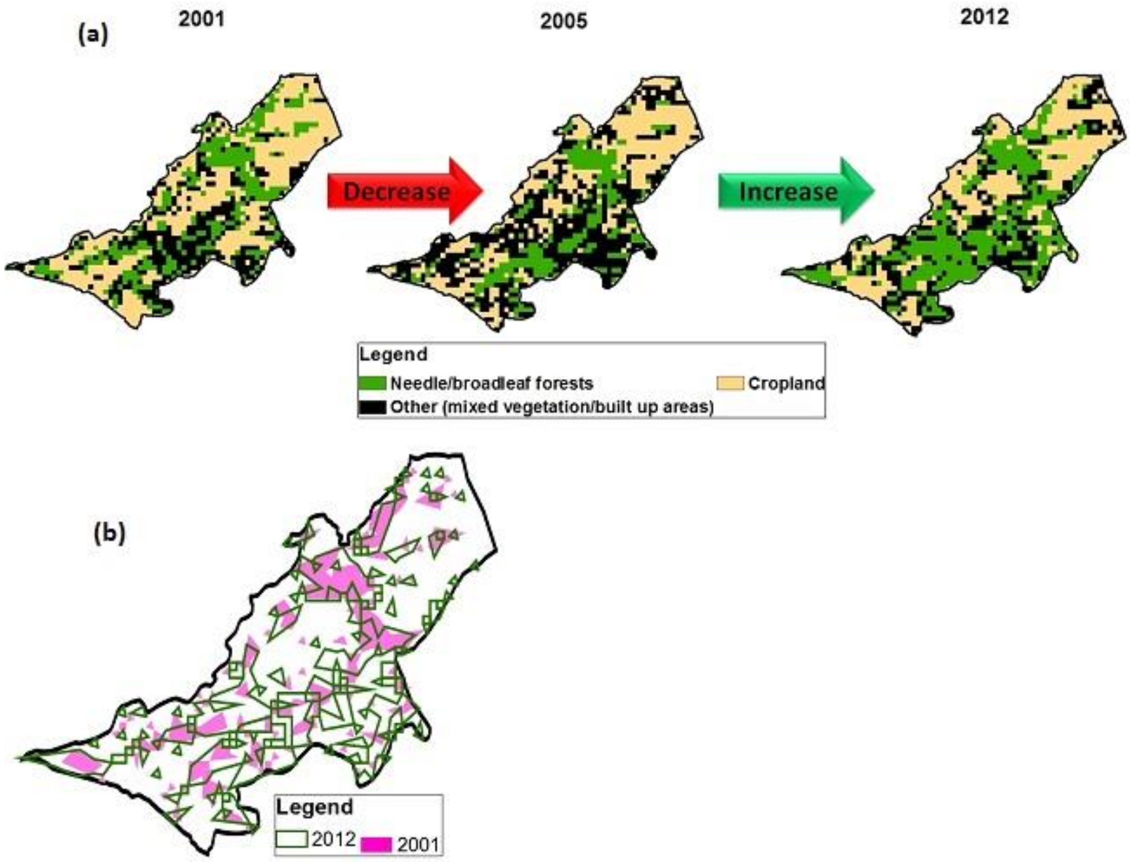

Figure 7: Spatial and temporal variation of needle leaf/broadleaf forests over Murree Hills between 2001 and 2012

4.2 Spatial and temporal trend of MODIS Vegetation Index

Spatial and temporal trend of vegetation indices over Murree hills were monitored to further assess the increasing pattern of vegetation and mixed forests. According to the spatial trend shown in fig. 8 NDVI is exhibiting more increase than EVI. This could be due to NDVI giving saturated signals over high biomass conditions.

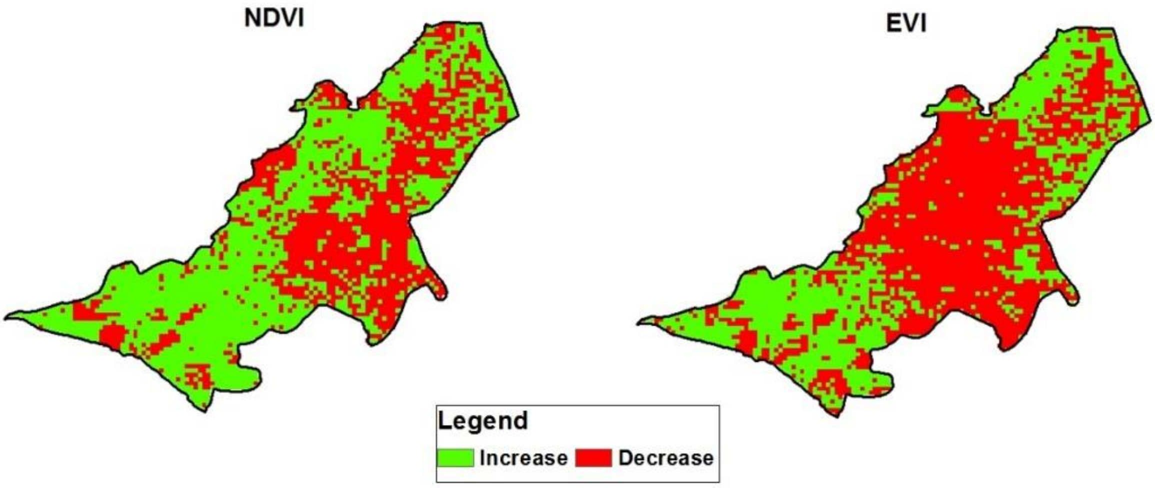

Figure 8: Spatial variation of MODIS NDVI and EVI over Murree between 2001 and 2012

Similarly in fig. 9 NDVI and EVI are qualitatively similar, however their overall temporal trend is quantitatively opposite, where NDVI is showing 9 percent increase and EVI is showing 2 percent decrease.

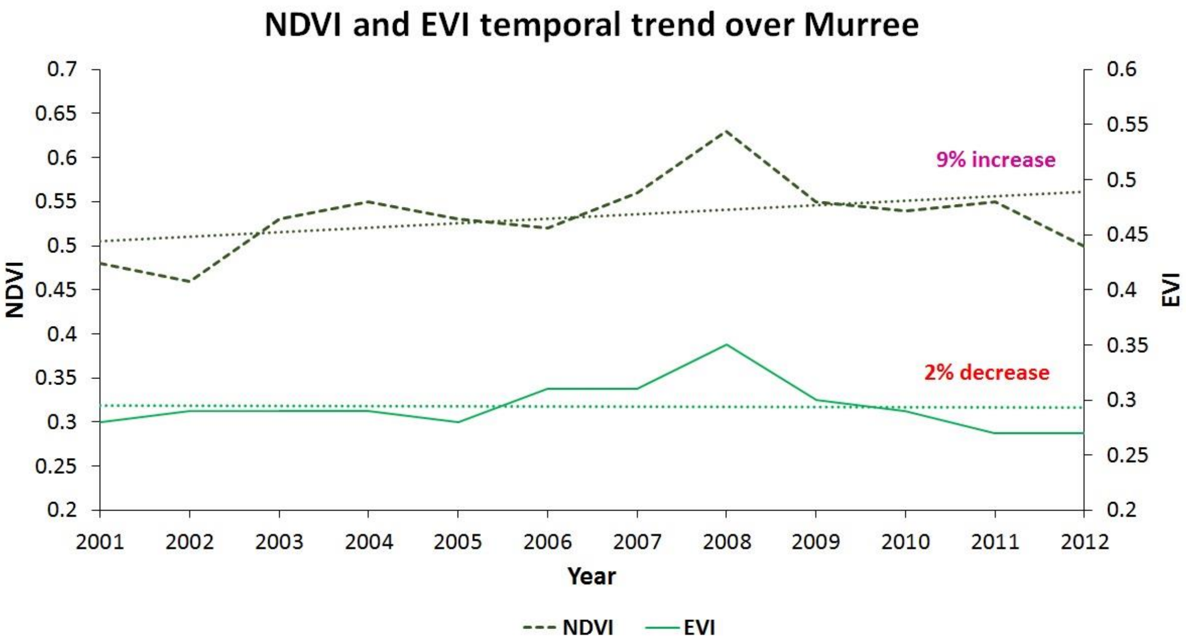

Figure 9: Temporal variation of MODIS NDVI and EVI

4.3 Comparing trends of vegetation indices with forest area

Spatial and temporal trends of vegetation indices were compared with increasing forest area. Maps in fig. 10 reveal information of NDVI and EVI only on areas spatially assigned as forests. EVI is showing an overall decrease, contrary to increasing trend of NDVI. A possible explanation could be EVI being sensitive to areas experiencing degradation of forest canopy

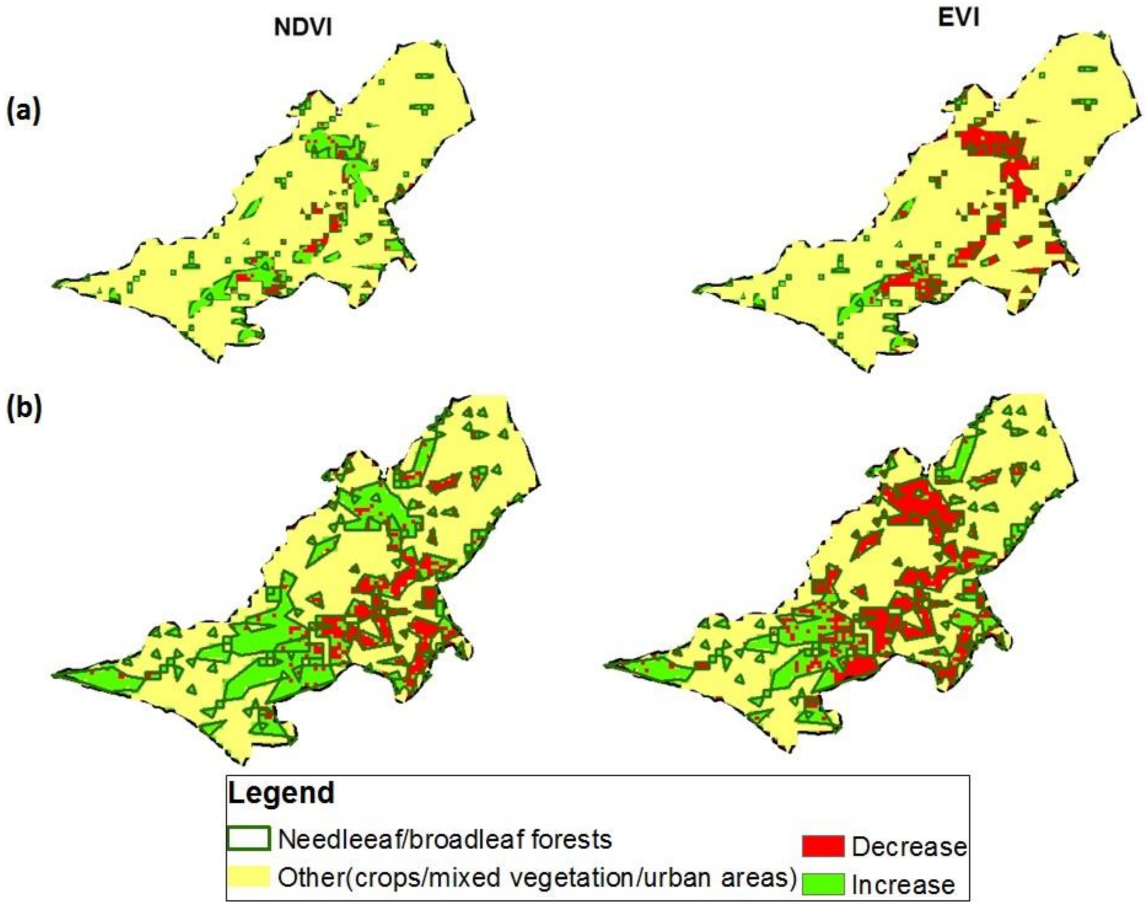

Figure 10: NDVI and EVI trend between 2001 and 2005 (a) and 2001 and 2012 (b) on forested area only

4.4 Comparing trend of vegetation indices with google earth imagery to identify canopy damage

To investigate decreasing trend of EVI, both vegetation indices were compared with google earth imagery of 2001 and 2012. Google earth imagery shown in figure 11 was randomly selected pixels where NDVI was showing increasing trend and EVI was showing decreasing trend. Comparison of image 2001 with 2012 clearly highlights areas where forest degradation has taken place. Therefore this makes decreasing trend of EVI more accurate.

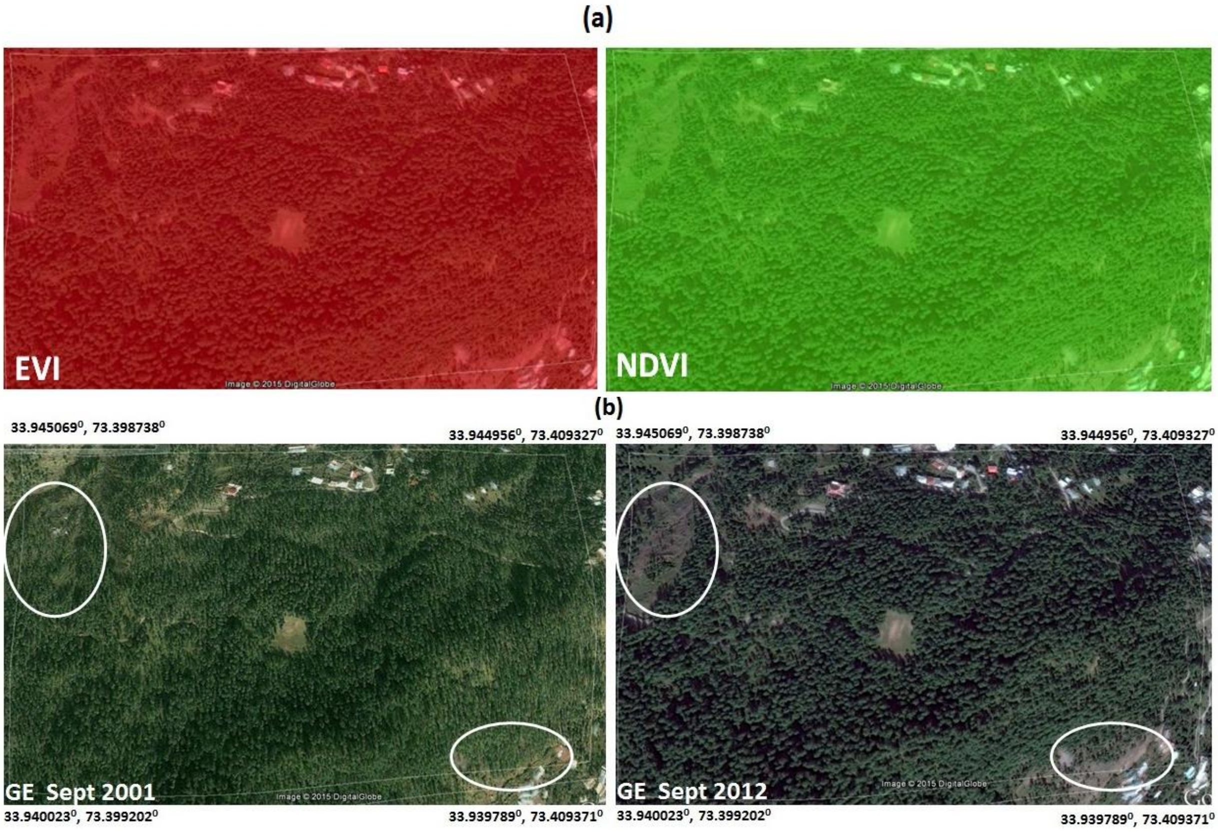

Figure 11: Comparison of google earth imagery and trend of vegetation indices between 2001 and 2012. Red colour shows decrease in EVI and green colour shows increase in NDVI

4.5 Comparing Time Series of CO2 Emissions with Calculated Forest Area

EDGAR and REAS emission inventory data were extracted over study area and compared with forest area calculated using MODIS 12Q1 product (figure 12). Temporally forest area of needleleaf and broadleaf forests have increased by 42%. In principle the CO2 emissions should decrease, however they show an opposite trend.

EDGAR and REAS anthropogenic are broadly used emission inventories, which are based on CO_2 emissions from transport, industrial, land use change and agricultural sector. Based on the trend depicted in fig. 12 CO_2 emissions are increasing, which is mainly contributed by industrial sources as shown by REAS estimates. On the other hand, EDGAR LUC emissions displayed constant trend, therefore there is a poor comparison between global/ regional emission inventory and calculated forest area. Pakistan does not have any national emission inventory, especially for land use change, that's why EDGAR LUC CO_2 emission can be questionable. To more accurately quantify LULUCF CO_2 emissions, it is essential to account for the emissions from other sources as well (transport and industrial).

Murree hills are hot spots for ecotourism to attract the tourist throughout the world due aesthetic beauty, diversity of vegetation, snowfall in the winter and a variety of food. The transport sector and land use change sector can be two major contributors in CO_2 emissions at Murree Hills.

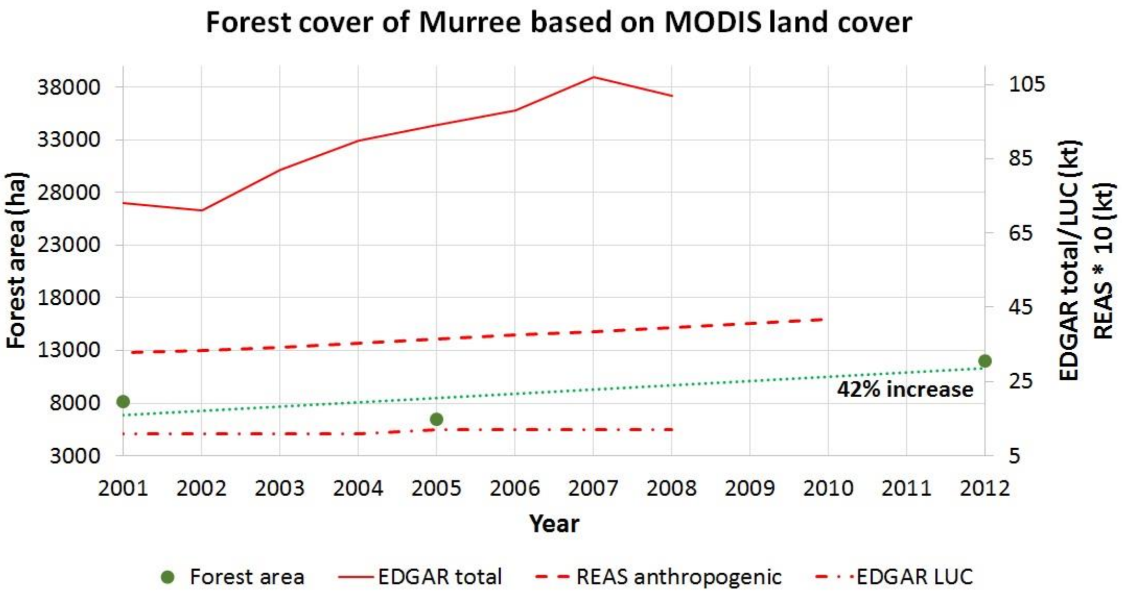

Figure 12: Comparison of calculated forest cover with CO2 emission inventory

4.6 CO_2 Flux, Total Emissions and Sequestration over Murree Hills

Table 2 shows a change in forest area between 2001 and 2005 and 2005 and 2012. Negative sign is showing decrease in forest cover and emissions while positive sign is depicting an increase in forest cover and sequestration. Land use Change (LUC) emissions were calculated in Kilo tons, employing standard IPCC formula in Eq. 2. Carbon stock 126 +2.94 t/ha calculated by (9) is used to compute the CO_2 emission.

Table 2: Calculated change in forest area using IPCC Equation

Year	Change in forest area (ha)	LULUCF emissions (kt)
2005	-1750	-221
2012	5575	482
Net sequestration (kt)		261

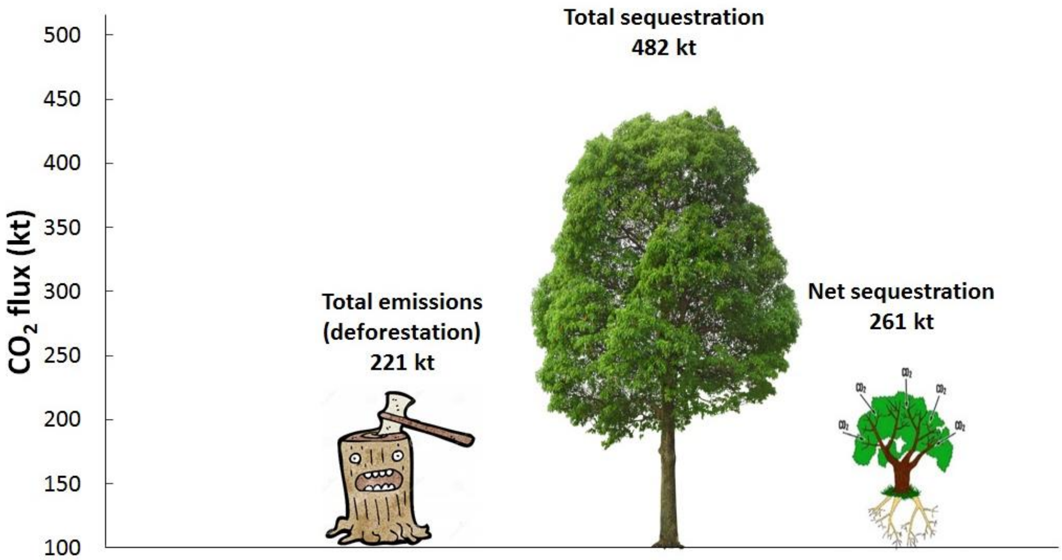

Figure 13: Change in CO2 Flux over Murree based on MODIS land cover product. Red colour represents total emissions, green represents total sequestration blue net sequestration

3.7 Carbon Credit Potential

Figure 13 revealed that the total sequestration of CO_2 (i.e., 482000 tons) has exceeded than the total emissions, thus leading net sequestration of carbon (261000 tons) and generating carbon credits. Selling these credits in the international carbon market at rate of $ 6.7/carbon credit will produce financial revenue worth $ 1.7 million.

Conclusions

Spatial and temporal monitoring of forest cover over Murree Hills was performed using MODIS vegetation indices and land cover product. Analysis of MODIS vegetation indices and land cover product indicated a net CO_2 sequestration of 261000 tons and generation of carbon credits. To accurately quantify CO_2 emissions from selected region, it is inevitable to carry out ground-based carbon stock and forest cover assessment (ground trothing) and to constrain emissions from all sources within the study area. Overall, results highlighted that the selected site of Murree Hills has huge potential for REDD+ implementation and reasonable amount of revenue can be generated by selling the carbon credits in international market. This revenue can be utilized to provide a sustainable livelihood to forest dependent communities and for the conservation of forests of Murree Hills Pakistan. Furthermore, it is recommended that in future a detailed study should be carried out to examine carbon stock by various forests types in Pakistan.

Recommendations

- ❖ To conduct supervise classification/ OBI analysis of high resolution imagery (30 m or less) and perform land use change analysis
- ❖ To conduct ground trothing in order to validate satellite observations
- ❖ Carbon stock assessment of forest types of Pakistan
- ❖ Forest inventory should be updated on regular bases
- ❖ To Quantify CO_2 emissions from all sectors including industrial and vehicular emissions
- ❖ To prepare GHG inventory of Pakistan

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