Chapter 1- Introduction

1.1 Background

The growing concerns of global warming and climatic change have been one of the most urgent issues due to growing concentration of Carbon dioxide (CO₂) and other greenhouse gases (Malhi & Grace, 2000; Bhat 2003; IPCC, 2007, Devagiri et al. 2013). The Intergovernmental Panel on Climate Change (IPCC) estimates that the level of CO₂ in the atmosphere is increasing by 1.4 parts per million (ppm) per year and this will further to increase in temperature from 1.8 celsius to 4 celsius by the end of this century (IPCC, 2007). The anthropogenic factors such as heavy use of fossil fuels, deforestation, degradation of land and change in land use pattern have caused increase concentration of CO₂ in the atmosphere. Forest degradation and deforestation have contributed for about 20% of GHGs emissions, a major issue for climate change (World Bank, 2010; Ahrends et al., 2010).

The terrestrial and marine ecosystems sequesters and stores about two-thirds of the globe’s terrestrial carbon. (Gibbs et al., 2007; IPCC, 2007). Forest biomass accounts for the largest terrestrial carbon pool (Zhao and Zhou, 2005; Tan et al., 2007; Madugundu 2008; Borah et al. 2013). Tropical forests have the maximum capacity to store carbon in their tissues while growing hence considered as the best potential for mitigation of greenhouse gases (Zianis et al., 2005; Maynard et al., 2007). In the next 50-100 years, tropical forests could sequester 3.7-5.5 billion metric tons of carbon dioxide. (Zheng et al., 2004; IPCC, 2007). Healthy forests play a vital role in stabilizing global climate by sequestering and storing higher carbon as compared to any other terrestrial ecosystem (Gibbs et al., 2007; Chaturvedi 2011; Bellard et al., 2012; Zhu et al., 2012). Forests releases large amount of carbon in the atmosphere on clearing or degrading from anthropogenic actions and natural disturbances (Gibbs et al., 2007; IPCC, 2007; REDD, 2009; Thakur and Swamy, 2010; Das and Singh, 2014). It is estimated that clearing and burning of tropical forests releases more than a billion metric tons of carbon (3.7 billion tons of carbon dioxide) into the atmosphere each year (Gibbs et al., 2007). The CO₂ concentration over the past 100 years has increased by 15% to 25% (Haripriya 2000). Forest covers nearly one-third of the total global land area and store a vast amount (289 Gt) of atmospheric carbon in their biomass alone (FAO, 2010). Forest can act as both sink and source of carbon. When forests sequester CO₂ from the atmosphere through photosynthesis process it act as a carbon sink but when forests are destroyed, overharvested or burned, and converted to non-forest use forest at the same time can act as source of carbon emission.
As a response to these effects, various international agreements on climate change such as UNFCCC of 1992 and Kyoto Protocol of 1997 (Patenaude et al., 2005), have addressed this problem to reduce carbon and GHGs emissions through mitigation and adaptation mechanisms (USAID, 2009). The UNFCCC have created financial opportunity for developing countries from the carbon stored in forests in the interest of reducing carbon emissions and sustainable forest management by introducing "reducing emissions from deforestation and forest degradation" (REDD, 2009) mechanism (Corbera et al., 2009; Tacconi et al., 2010; Cerbu et al., 2011; Van de Sand, 2012). All the greenhouse gas emissions reduction programs necessitate reliable, accurate, cost-effective and scientifically robust methods for measurement and monitoring of forest carbon storage (ANSAB, 2010). The two principal data sources used to estimate AGB (Krankina et al., 2004) and hence ultimately carbon stocks are forest inventories and remote sensing (RS).

1.2 Factors affecting the biomass of forest ecosystem

Topography plays a very crucial role in influencing the biomass, stem size, stand density and spatial heterogeneity of stems in the forest region (Katagiri & Tsutsumi, 1975; Tanner, 1980a, 1980b; Clark et al., 2000). The interaction of solar radiation with soil creates change in soil properties like soil moisture and soil nutrients, thus influencing carbon in the vegetation biomass through photosynthetic process (Todd, 1998). The biomass in forest areas has significant relationship with slope and aspect in that region (Tajchman et al., 1983; Hicks et al., 1984; Sexton, 2009; kwak, 2010; Bijalwan, 2010). Typically the south facing slopes have hot and dry soil surface as compared to north-facing slopes due to greater amount of solar radiation received at the south facing slopes. Biomass stock is also influenced by the forest management activities (Bravo et al., 2008). The role of forest management techniques and biophysical parameters like temperature, rainfall and humidity influences on forest growth and biomass has been emphasized in the studies of (Janssens et al., 1999; Huete, 2002; Edirisinghe, 2012).

1.3 Forestry and Climate Change

Forests are the world's most significant terrestrial storehouses of carbon, and they play a crucial role in operating its climate. The world persisting forest ecosystems store an estimated 638 gigatonnes (Gt) of carbon, 283 Gt of which are in the forest biomass alone. This is a significant amount of carbon—approximately 50 percent more than entirely the carbon in the
atmosphere (Cairns et al., 2003). Forest ecosystems are sensitive to climatic change (Krishnamurthy, 2010, Metsaranta et al., 2011). Over long periods of time plants have accommodated to local climatic, atmospheric, and soil circumstances, and this, aggregated with temperature and rainfall patterns, is what characterizes an ecosystem. A change in these variables can dramatically impact species viability (Sanchex, 2012, Con, 2013). Stress caused by a change in the conditions of an ecosystem may also increase its vulnerability to pests and fires. Hence, massive areas of forests could be lost from these climates caused threats, which in turn could further accelerate climate change in a vicious positive feedback iteration.

On the other hand, land-based activities interpret one of the most significant undeveloped opportunities for mitigating climate change. Simply allowing mature forests intact will lock up important amounts of carbon that might otherwise be released into the atmosphere. Land-use changes, pre dominately deforestation, presently impart about one-fifth of global carbon emissions (Bijalwan, 2010). Deforestation forms the biggest source of GHG emissions in several developing countries, including India, Brazil and Indonesia, the worlds greatest GHG emitters after the United States and China (Houghton, 2009). Reducing emissions from afforestation may be among the important cost-ecficient tools for minimizing GHG emissions globally and could give people the time needed to mobilize the resources and produce the technology for "decarbonizing" the world's energy and industrial production. Sustainably managed forests can develop wood and other biomass that is a renewable, carbon-neutral alternative to fossil fuels and other construction materials. In this way sustainable forest management can assist to reduce energy-related emissions. Forest ecosystems store majority (around 60 %) of the carbon in terrestrial ecosystems (Houghton, 2009; Santoro, 2013).

1.4 Climate influences on forest disturbances

Climate has a major influence on the growth and productivity of forests, insect outbreaks, invasive species, wildfires, and storms (Metsaranta et al., 2011). Warming temperatures could shift the habitats geographic ranges of some tree species to northward or to higher altitudes (Con, 2013). The effects of each disturbance are acted upon by climate and impact the forest. Species in a particular forest can represent the past disturbances. For example, species that grow in droughty sites can thrive well under dry condition with uncertain rainfall. Gymnosperm species with serotinous cones are found in places having frequent fires. Hence the climate alternation would results in loss of species regeneration. The species at marginal range could face severe effects.
1.5 Significance of Study

Forests play an important role in ecological functioning, global warming and climate change through its unique potential to capture and hold carbon (C) (Cairns et al., 2003; de Gier, 2003; Hall et al., 2006; Srinath, 2008; Kale et al., 2009; Pandey, 2010; Das and Singh, 2014). Forest ecosystem comprises approximately 90% of all living terrestrial biomass in terrestrial ecosystem (Zhao and Zhou, 2005; Tan et al., 2007; Mohanraj et al., 2011) hence United Nations Framework Convention on Climate Change (UNFCCC) together with Kyoto Protocol has recognized that forest play crucial role in carbon sequestration. Biomass is one of the indicators of the status of forests hence accurate assessment and biomass mapping is important for understanding and sustainable forest management. Biomass assessment is necessary as it helps in understanding the changes taking place in the forest ecosystem due to fire, deforestation, silviculture, pests, harvesting and climatic change (Schroeder et al., 1997; IPCC, 2006). Carbon constitute 47.5 to 50% of forest dry biomass, hence the measure of the carbon sequestered by any forest could be deduced from the accumulated biomass (Cairns et al., 2003; Zianis and Mencuccini, 2004). Biomass plays a critical role in global carbon cycle through its association with carbon sequestration (Somogyi et al., 2006).

The estimation of above-ground biomass (AGB) is necessary to evaluate forest ecosystem productivity (Somogyi et al., 2006; Hu and Wang, 2008), determine carbon (C) budgets, monitoring biomass changes with time (Zianis and Mencuccini., 2004; Devi and Yadava 2009), evaluating forest biomass as use for energy (Chirici et al., 2007) and studies on the role of forests in global carbon cycle (Hall et al., 2006; Viana et al., 2010). The UNFCC along with Kyoto protocol recognize forests playing an important role in carbon sequestration. The Kyoto protocol necessitates clear accounting of forest removal and biomass change. Knowing the spatial distribution of forest biomass can also help in estimating the sources and sink of carbon that result from change in land use.

1.6 Problem statement

Recently the estimation of forest biomass has received considerable interest for both scientific studies and practical forestry purposes (Tan et al., 2007; Madugundu, 2008; Swamy, 2010; Akhavan, 2010; Pandey, 2010; Tsui, 2012; White, 2013). The lack of accurate vegetation indices with biomass in the Western Ghat region of Maharashtra has affected biomass assessment for scientific studies of ecosystem productivity, carbon budgets. The local forest management authorities do not have information on the available carbon
sequestration potential of the forest area which is essential for sustainable management planning. The light detection and ranging (LIDAR) is one of the effective methods but data are unavailable in India, expensive and cannot be operated in large scale in a cost-effective manner (Drake et al., 2003; Hese et al., 2005; Wulder et al., 2007). The remote sensing technologies have emerged as a promising method to estimate biomass with high accuracy (Rai, 1984; Rai, 1986; Roy, 1996; Ravindranath, 1997; Parresol, 1999; Zianis and Mencuccini, 2004; Zheng et al., 2004; Murali, 2005; Maier et al., 2008; Srinath, 2008; Kale et al., 2009; Swamy, 2010; Dadhwal, 2010; Saatchi, 2011; Cerbu, 2011).

In recent years (Sales et al., 2007; Hernández and Emery, 2009; Hengl, 2009; Pierce et al., 2009; Akhavan and Kia- Daliri, 2010; Tsui, 2013; Devagiri, 2013; Das and Singh, 2014), many studies have been carried out applying geostatistical approaches to predict continuous forest variables such as density, basal area, tree height, LAI, above-ground biomass, standing volume, productivity, etc. using remote sensing data (Nanos et al., 2004; Berterretche et al., 2005, Madugundu, 2008; Akhavan and Kia- Daliri, 2010). Geostatistical techniques have become popular tools and are widely used in several studies for modeling spatial structure of ecological data (Burrough, 1986; Berterretche et al., 2005; Maselli and Chiesi, 2006; Sales et al., 2007; Akhavan and Kia- Daliri, 2010; Das and Singh, 2014). This research focused on estimation of above ground biomass from field inventory data and to map AGB combining field inventory data, remote sensing and geo-statistical model. Co-kriging (CoK) is used to improve spatial predictions of vegetation biomass by integrating ground inventory data, remote sensing, GIS and GPS. Hence this research would reduce the gap that remains in the scientific domain of estimating of forest AGB and carbon with improvement in the assessment.

1.7 Research Objectives

The main objective of this study is to estimate above ground biomass from field inventory data and to map AGB combining field inventory data, remote sensing and geo-statistical model in the western ghat region of Maharashtra. The specific objectives of the research are

1. Assessment of algorithm to estimate terrestrial vegetation Biomass in the area Western Ghats of Maharashtra
2. Preparation of Land use & Land cover map & to generate geodatabase of the terrestrial biomass and carbon of western ghats of Maharashtra
3. To identify appropriate Geospatial indices to establish relationship between ground biomass and satellite image
4. To establish algorithm for prediction of biomass estimation in western ghats of Maharashtra

1.8 Outline of the thesis

The thesis consists of chapters namely introduction, materials and methods, results and discussion, conclusions and recommendation, references and appendices which have been structured as follows:

Chapter 1 – Introduction: introduces the background, briefly reviews the carbon sequestration potential of Indian forests, explains the significance of biomass assessment, highlights the factors affecting the biomass of forest ecosystem, focusing on the problems and research objectives, briefly reviews and the studies carried out using different approaches to estimate ABG biomass and a overview of estimates of biomass in India.

Chapter 2 - Literature review: This chapter describes the different methods for assessment of above-ground biomass and carbon. It also covers an overview of biomass estimates and carbon sequestration potential in Indian forests.

Chapter 3 - Study area: describes in details about the Western Ghats, discuss the districts under study in the Western Ghats region of Maharashtra, brief their relevant topographic, Physiographic, Geology, climate and vegetation characteristics of the study area.

Chapter 4 - Materials and methods: Materials deals with the satellite data, maps, instruments and softwares used in the research. Method describes conceptual framework of research approach, sampling design, outline of field work, digital classification of satellite data, relating above ground biomass to satellite image, geostatistical approach for mapping of forest biomass and phytosociological analysis.

Chapter 5 - Results and discussion: presents results obtained after subsequent implementation of the methods. Statistics of study sites are presented for biomass estimation from field analysis. It highlights the outcomes of satellite image classification. It presents the comparative correlation analysis made between vegetation indices and AGB. The chapter also shows the predicted biomass and carbon map. It also incorporates the findings of the phytosociological analysis. The results obtained discuss image classification and accuracy assessment of the method. It also discusses the model developed for biomass and carbon stock estimations. The chapter closes with possible sources of error or uncertainties for biomass and carbon mapping.
Chapter 6 - Conclusions and recommendation: brings together all the research findings from the previous chapters and links to the research objectives. The application of the research findings to society and for forest management is explained. It concludes the study with the direction for future research.