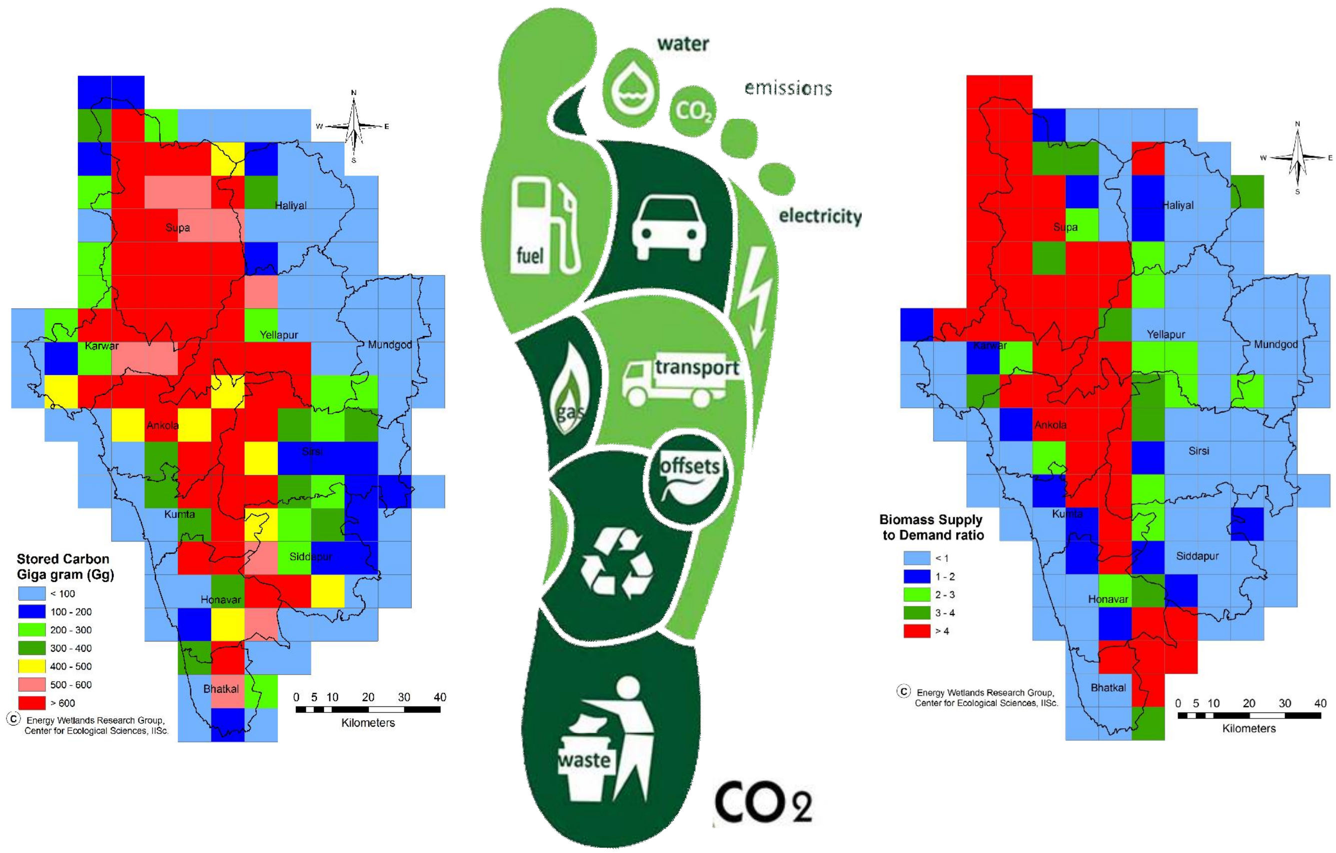
Sahyadri Conservation Series 33

CARBON SEQUESTRATION IN UTTARA KANNADA

Ramachandra T.V. **Subash Chandran M.D** **Joshi N.V.**

Bharath Setturu



Western Ghats Task Force, Government of Karnataka
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1.0 SUMMARY

Carbon dioxide, nitrous oxide, methane, chlorofluorocarbon and water vapors are major greenhouse gases (GHG). Carbon dioxide (CO_2) is one of the more abundant greenhouse gases and a primary agent of global warming. It constitutes 72% of the total anthropogenic greenhouse gases. IPCC (2007) reported that the amount of carbon dioxide in the atmosphere has increased from 280 ppm (1750) to 394 ppm in 2012. Similarly, methane (CH_4) and nitrous oxide (NOx) concentrations have risen substantially from pre-industrial levels (from 715 ppb to 1730 ppb, and 270 ppb to 319 ppb respectively). For these gases, most of the concentration increases have occurred during the last 100 years. Higher concentrations of GHG in the atmosphere have contributed to global warming and changes in the climate. Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer).

Carbon footprint refers to the total set of greenhouse gas (GHG) emissions in a region due to anthropogenic activities. Major sources of GHG are forests (deforestation), power generation (burning of fossil fuels), agriculture (livestock, farming, rice cultivation and burning of crop residues), water bodies (wetlands), industry and urban activities (building, construction, transport, solid and liquid waste). Forests mitigate global warming through sequestration of carbon in the environment due to anthropogenic activities. Atmospheric carbon dioxide is taken up by trees, grasses, and other plants through photosynthesis and stored as carbon in biomass (trunks, branches, foliage, and roots) and soils. The sink of carbon sequestration in forests and wood products helps to offset anthropogenic sources of carbon dioxide to the atmosphere. Emission and sequestration of carbon needs to be in balance in the Earth system to maintain the environmental conditions. This necessitates quantification of emissions and carbon sequestration potential to ensure the sustainability of resources. Budgeting carbon involves region wise quantification of the sources and sinks of carbon. Sustainable management practices will enhances the ability of forests to sequester atmospheric carbon apart from other ecosystem services, such as improved soil and water quality.

Forests are vital ecosystems, playing a key role in the food chain, hydrology, and other ecosystem functions. Need to manage these fragile ecosystems has been realized in recent times considering their significant role in sustaining the ecosystem services such as bio-geo chemical cycling, nutrient and hydrologic cycling. Sustainable management of forest ecosystems helps in the conservation as well as the sustenance of ecological services.

Carbon sequestration is a phenomenon for the storage of CO_2 or other forms of carbon to mitigate global warming through biological, chemical or physical processes. Kyoto protocol emphasizes the need to reduce carbon emissions and role of (http://unfccc.int/kyoto_protocol/items/2830.php). In this regard, many clean development mechanism (CDM) projects were initiated to enhance the assimilation and sequestration of carbon.

The current study assesses the carbon sequestration potential of forest ecosystems in Uttara Kannada district, central Western Ghats. Uttara Kannada district in Karnataka, has a unique distinction of having highest forest cover (~80%). Forests in the southern part (Bhatkal, Honavar, Siddapur and Kumta) have more evergreen-ness than central (Sirsi, Ankola and Yellapur) and northern (Karwar, Supa taluks) regions. Mundgod and Haliyal in the north-east are dominated by deciduous forests and teak plantations. Eastern parts of Sirsi and Yellapur tend to be of deciduous nature. Endemic species of trees occur in evergreen forests of the Ghat areas of Honavar, Siddapur, Bhatkal, and Kumta.

Carbon gets sequestered in the system through vegetation (forest, plantation, horticulture, etc.), aquatic ecosystems (phytoplankton) and soil. Stored carbon and annual sequestration were quantified based on the data from field investigations and compiled from government agencies and literatures. Total carbon stored in forest vegetation and soils are 56911.79 Gg and 59693.44 Gg and annual carbon increment is about 975.81 Gg (1951.61 Gg biomass). Carbon uptake from natural forest is 2416.69 Gg/yr and from forest plantations is 963.28 Gg/yr amounting to the total of 3379.97 Gg/yr.

The study quantifies taluk wise sources and sinks of carbon. Aggregation of carbon emissions from different sources (livestock, paddy cultivation, fuel wood consumption and vehicular transport) are 87.70 Gg/yr, 101.57Gg/yr, 77.20 Gg/yr, 437.87 Gg/yr respectively. The ratio of carbon sink to the source indicates the carbon status of a region. The analysis highlights that forest ecosystems in Uttara Kannada are playing significant role in the regional as well as global carbon budget. Hence the district is a true candidate to enjoy the benefits under Clean Development Mechanism (CDM), as per Article 12 of the Kyoto Protocol. This would help in the improved livelihood of ecosystem people while practicing the conservation and sustainable management of forests

Keywords: Carbon storage, carbon emissions, forest ecosystems, sustainable management

2.0 INTRODUCTION

Forests are the integral part of human life because of their ecological roles of interaction with living non-living part of the environment - including the soil, water, air. Forests sequester carbon (Gallaun et al., 2010; Pan et al., 2011) and hence play a vital role in mitigating climate change (Jackson and Baker, 2010) by lowering carbon levels in the atmosphere. The aggregate carbon content of forests consists of active above and below ground biomass, dead organic matter and soil organic matter. Carbon management is a prime concern due to the enhanced rates of forest degradation during post industrial revolution period coupled with the increasing carbon dioxide concentration in the atmosphere at an alarming rate. It has increased from 270 ppm (prior to the industrial revolution) to 394 ppm now (Manua Loa observatory, 2013). The recent estimates of emissions in 30 developing countries (including Brazil, Bolivia, Indonesia, Myanmar and Zambia) highlight that deforestation and forest degradation are the largest source of CO_2 (JRC, 2009). The effective forest management greatly influences the amount of carbon stored in the above ground biomass, soils, and in associated forest products.

Carbon dioxide, nitrous oxide, methane, chlorofluorocarbon and water vapors are major greenhouse gases (GHG). These GHG induce greenhouse effect by absorbing and re-emitting infrared radiation in Earth's atmosphere. This results in the increase of the earth's ambient temperature, leading to global warming, climate changes and other impacts on living organisms. Among these gases, amount of carbon dioxide is increasing very rapidly, due to enhanced industrial activities, power generation, biomass burning and transport consequent to burgeoning population coupled with the increased consumption levels. Concentration of greenhouse gases in the atmosphere has been increasing rapidly due to anthropogenic activities resulting in significant increase in the temperature of the earth causing global warming. This is quantified using an indicator like global warming potential (GWP) and expressed in units of carbon dioxide equivalent (CO_2 Eq), which indicate the carbon footprint of a region. Carbon footprint is thus a measure of the impact of human activities on the environment in terms of the amount of greenhouse gases produced. The amount of carbon storage expressed as amounts in metric tons or Gg (Giga gram) per hectare, which indicates the amount of carbon uptake by forests.

Deforestation and forest degradation accounts to 20–25% of the total anthropogenic carbon emissions (IPCC 2007). Deforestation is the long-term reduction of tree canopy cover and forest degradation is typically considered partial deforestation, with more than 10–30% of forest cover remaining (ex: selective logging) (van der Werf et al., 2009). Increasing demand of forest resources has led to deforestation, imperiling high productive ecosystem. Forest clearance leads to the release of stored carbons and the global phenomenon of deforestation have contributed to an increase in atmospheric CO_2. Land use land cover (LULC) changes involving deforestation, harvesting of industrial wood, forest fire, plantation of exotic species, etc. are responsible for carbon emissions. The oxidation and combustion of deforested and drained tropical peat lands may also involve substantial carbon emissions. The forest management practice of reduced timber logging can also substantially impact in reduction of carbon emissions from forest-timber harvesting management operations (Putz et al., 2008). Moreover, reductions in the emissions by arresting deforestation and degradation of peat are cost effective measures that can help to stabilize atmospheric CO_2 levels.

Carbon dioxide and other gases released into the environment create an imbalance in the system leading to global warming. This necessitates the quantification of sources and sinks of carbon in order to evolve appropriate mitigation and adaptation strategies. Terrestrial, aquatic plants and soil are major carbon sinks, which accumulate the carbon. Vegetation store the carbon in the form of carbohydrate and soil accumulate the carbon in the form of soil organic carbon and soil inorganic carbon.

Carbon sequestration is the process of removing carbon from the atmosphere and depositing it in a reservoir. It is a controlled disposal or storage of carbon compounds to prevent their release into the environment. Carbon dioxide is sequestered by plants during photosynthesis. The process of photosynthesis is done by the leaves which help in extracting the carbon from the atmosphere.

$$6CO_2 + 12H_2O + \text{photons} \longrightarrow 6C_6H_{12}O_6 + 6O_2$$

The movement of atmospheric air takes place in plants through diffusion by general body surface (stems, roots, fruits, seeds), lenticels (bark of the tree), stomata (opening in leaves). Carbon dioxide in the presence of light and water is used by plants during photosynthesis and gets converted into sugars and this process is known as carbon fixation. During night, the plants respire and CO_2 is released into the air (Taiz and Zeiger, 1991). At night plants release carbon dioxide but as the stomata are closed at night it captures carbon in less quantity.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 38ATP$$

This is an external respiration where mere exchange of gases takes place. During respiration a plant releases energy through chemical reactions. This results in the breakdown of sugar into oxygen, to carbon dioxide. Respiration is basically the opposite of photosynthesis because it uses energy and photosynthesis stores energy. It uses food instead of producing food. It gives carbon dioxide instead of oxygen and it does not require light (Forster et al., 2007).

Carbon cycle begins with plants and microorganisms (Fig.1) that sequester the atmospheric carbon dioxide through photosynthesis.

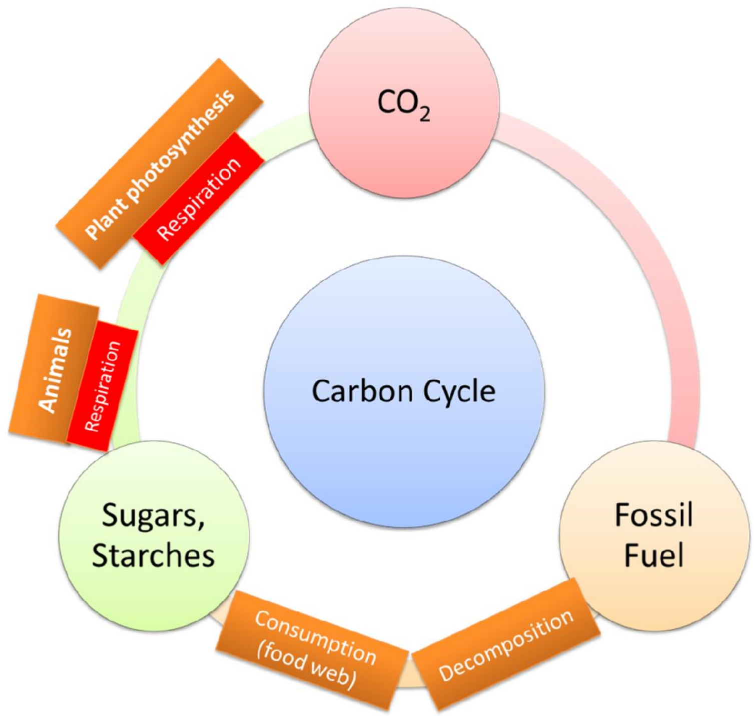


Figure 1: The carbon cycle (Source: Google)

Carbon fixed during photosynthesis is returned to the atmosphere by the decomposition of dead organic matter. Not all carbon is respired in the process, as some is fermented or stored in solid form. The volatile carbon compounds that enter the atmosphere after anaerobic metabolism, such as methane and more complex molecules are readily oxidized to carbon dioxide in the atmosphere (Clapham, 1983). Other major carbon stores are soil organic matter, ocean, marine sediments (e.g. coal) and sedimentary rocks (e.g. limestone).

Carbon is released to the atmosphere either by natural process or anthropogenic activities. The contribution of natural sources is very less, and is neutralized by the environmental processes. Gases in the atmosphere contribute to the greenhouse effect both directly and indirectly. Direct radiative effects occur when the gas itself is a GHG and absorbs radiation, such as CO_2. Indirect radiative forcing occurs when chemical transformations of a substance produce other GHGs, when a gas influences the atmospheric lifetimes of other gases, and/or when a gas affects atmospheric processes that alter the radiative balance of the earth.

Burgeoning population coupled with the increased consumption levels have led the release of a large amount of carbon from anthropogenic sources, which are accumulating in the atmosphere as greenhouse gases (GHG). The Intergovernmental Panel on Climate Change (IPCC) developed the global warming potential (GWP) concept to compare the ability of each GHG to trap heat in the atmosphere relative to other gases (IPCC, 2006). The GWP of a greenhouse gas is defined as the ratio of the time integrated radiative forcing from the instantaneous release of 1 kg of the trace substance relative to that of 1 kg of a reference gas (IPCC, 2006). The reference gas used is CO_2 and therefore GWP-weighted emissions are measured in giga grams of CO_2 equivalent ($GgCO_2Eq$). GWP values allow comparisons of the impacts of emissions and reductions of different gases. According to the IPCC, GWPs typically have an uncertainty of roughly ±35% (Forster et al., 2007). The effectiveness of different gases at trapping heat in the atmosphere as estimated by EPA (2002) is 1, 21, and 310 for CO_2, CH_4, and N_2O, respectively, calculated over a 100 year time horizon.

The carbon budget of a region (United Nations Framework Convention on Climate Change, UNFCCC) include emissions from burning fossil fuels for electricity generation and industrial production, direct emissions from heating in households and businesses, emissions from burning petrol and diesel in cars and other vehicles, and emissions arising from other activities, including agriculture, waste management, and land use, land use change and forestry (LULUCF). Carbon budgeting of a region provides the current spatial and temporal distribution of major pools of carbon sources and sinks that help in assessing the pattern and variability of carbon in the atmosphere. Sources of GHG for a region are from livestock, agriculture, fuel wood consumption, industries, transportation, land use changes, etc.

2.1 **Livestock:** Livestock is an important component of an agro ecosystem. Livestock provides the critical energy input to the croplands required for ploughing, threshing and other farm operations. Livestock are a crucial source of financial capital for the rural poor. Animal dung provides essential nutrients required for soil fertility and crop yields in the form of organic manure. But livestock produces Greenhouse gases like methane, carbon dioxide, nitrous oxides. There are two types of methane emissions from livestock productions: one from enteric fermentation and one from manure. The amount of methane that is released depends on the type of digestive tract, age, weight of the animal, the quality and quantity of the feed consumed in enteric fermentation. Methane from enteric fermentation in livestock is account for nearly 70% of the emissions from this category (IPCC, 2006; EPA, 2006). Ruminant livestock (e.g., cattle, sheep) are major sources of methane with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses). The ruminant gut structure fosters extensive enteric fermentation of their diet. Then decomposition of manure under anaerobic conditions (i.e., in the absence of oxygen), during storage and treatment, produces CH_4. These conditions occur most readily when large numbers of animals are managed in a confined area (e.g., dairy farms, beef feedlots, and swine and poultry farms), and where manure is disposed of in liquid-based systems. GHG emissions from agriculture sector include livestock, rice cultivation, crop residue burning and agricultural soil, where livestock-derived GHG emissions in India has maximum share (NATCOM, 2004; Singhal et al., 2005).

Livestock production can result in methane (CH_4) emissions from enteric fermentation and both CH_4 and nitrous oxide (N_2O) emissions from livestock manure management systems. Cattle are an important source of CH_4 in many countries because of their large population and high CH_4 emission rate due to their ruminant digestive system. Methane emissions from manure management tend to be smaller than enteric emissions, with the most substantial emissions associated with confined animal management operations where manure is handled in liquid-based systems. CO_2 emissions from livestock are not estimated because annual net CO_2 emissions are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2. A portion of the C is returned as CH_4 and for this reason CH_4 requires separate consideration. Although greenhouse gases (GHGs) like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) occur naturally in the atmosphere, human activities have changed their atmospheric concentrations (IPCC, 2006).

Many researchers have estimated Indian emission inventories of different gases and years (Mitra, 1991; ALGAS, 1998; Garg et al., 2001a, b; Reddy and Venkataraman, 2002; Garg and Shukla, 2002; Mitra and Bhattacharya, 2002; Garg et al., 2002; Mondal et al., 2004; PCRM, 2002). Approximately 20 and 35% of the global GHG emissions originate from agriculture. These figures are 40 and >50% of the anthropogenic emissions of CH_4 and N_2O, respectively (IPCC, 2006). Most important agriculture related CH_4 sources are animals and their excreta (manure), whereas, most of the N_2O is produced in the field (manure excreted during grazing, chemical fertilizers), and from animal houses where straw or litter is used

(Freibauer and Kaltschmitt, 2001). Production and emission of CH_4 and N_2O from manure depends on digestibility and composition of feed, species of animals and their physiology, manure management practices and meteorological conditions like sunlight, temperature, precipitation, wind, etc. (Brown et al., 2002; Yamulki et al.,1999). As the information about CH_4 and N_2O emissions from bovine manure management systems in India/Asia is lacking, their previous emission inventories were prepared using IPCC (Intergovernmental Panel on Climate Change) default emission factors (IPCC, 1996) (Garg et al., 2001a; Mitra, 1992, 1996; Yamaji et al., 2003, 2004). IPCC guidelines suggest nations to develop country specific emission factors (EFs) as its default values may result in large uncertainties in the absence of region-specific information. Singhal, et al., (2005) computed emission factors for methane emission from enteric fermentation of Indian livestock. They used dry matter intake (DMI) approach for their calculation, in which they collected data for daily DMI for different classes of animals and methane conversion factors were reviewed from numerous feeding experiments conducted in different Indian laboratories.

Gupta, et al., 2007 developed country specific emission factors for methane and nitrous oxide emission from bovine manure management in Delhi using dry matter intake approach for calculating the gross energy of livestock. Methane emissions varied from 0.8 to 3.3 kg $CH_{4\ Head}$−1 yr−1 and nitrous oxide emission factors were varied from 3 to 11.7mg Head−1 yr−1, which was lower than the IPCC default values.

2.2 **Agriculture (Paddy cultivation)**: Agricultural sources are the largest global source of non-CO_2 emissions. Globally, 70% of methane emission was contributed by 6 anthropogenic sources and 20% of methane emission was contributed by paddy cultivation. Rice is the seed of the monocot plants *Oryza sativa* or *Oryza glaberrima* is the most important staple food for a large part of the world's human population, especially in East and South Asia, the Middle East, Latin America, and the West Indies. There are around 120,000 varieties exist in all over the world. About 65% of Indian population fully depends on rice. It is the grain with the second-highest worldwide production, after maize (corn) (FAO STAT, 2006-12-26; DRD, 2006). Rice (*Oryza sativa*) belongs to grass family and grows fast when submerged in water. Moist and warmth conditions are required for their growth. It requires different temperature ranges (18 to 32 ºC) at the different phases of growth. Rice cultivation is well-suited to tropical regions. In India, rice has three growing seasons: early Kharif, mid Kharif and Rabi. The early Kharif growing season will be from March-May to June-October, the mid Kharif season from June-October to November-February, and the Rabi season from November-February to March-June.

The traditional method for cultivating rice involves transplantation stage with flooding the fields while, or after, setting the young seedlings. This simple method requires sound planning and servicing of the water damming and channeling, but reduces the growth of less robust weed and pest plants that have no submerged growth state, and deters vermin. While flooding is not mandatory for the cultivation of rice, all other methods of irrigation require higher effort in weed and pest control during growth periods and a different approach for fertilizing the soil. Usually plant will be 2 to 6 feet tall and growing period will vary from 60 to more than 20 days. Rice plants are capable of doing C3 photosynthesis, where CO_2 is incorporated into a three carbon compound (3-phosphoglycerate). Root and shoots have morphological adaptation such as shallow and laterally spread roots, pore space that can hold or retain air, to grow well in saturated soil. Plant's respiratory system is also adapted to survive in lower oxygen availability (Tivy, 1990).

Methane is emitted from flooded paddy fields due to anaerobic fermentation of organic soil conditions and is transported through rice plants (Ferry, 1992; Bandyopadhyay et al., 1996). Carbon dioxide methane and nitrous oxide are the key greenhouse gases (GHG) that contribute towards the global warming at 60, 15 and 5%, respectively (Watson et al., 1996). Global and regional estimates of GHG emission from rice paddy fields vary greatly with the assumptions made on the importance of different factors affecting the emissions. Only a few studies (Bachelet and Neue, 1993; Mathews et al., 2000 a, b; Li et al., 2004) have attempted to calculate detailed regional GHG emissions. The methane emission from rice fields depends on several factors such as soil, paddy type, climate, water management, agricultural practices and application of fertilizers. Flooding of rice fields is the main reason for the emission of methane. This condition develops the environment for the development of methanogenic bacteria. Methanogen bacteria convert organic matter to methane by the process of methanogenesis. A large fraction of methane will come out in the atmosphere, but a small fraction will remain the shallow overlaying water, which will be oxidized by methanotrophes. Thus flooded rice fields provide ideal conditions for methane formation and rice plants act as a channel to transport the methane into the atmosphere. Rice paddy cultivation alone has contributed around 20% of the global methane budget from various sources (Hogan, et al., 1991). Earlier studies indicated that the CH_4 release per m^2 and per year from different rice ecosystems follows the order: deep-water rice > irrigated rice > rain fed rice (Neue, et al., 1997). Upland paddy areas were not studied because they are assumed to emit negligible CH_4 (Hogan and Braatz, 1990; Mitra, 1991; Bolin, 1995).

CH_4 emissions are estimated by multiplying daily emission factors (1.11 by IPCC 2006) by cultivation period of rice and annual harvested areas. Bandyopadhyay, et al., (1996) quantified the emission of methane from paddy cultivation and from livestock of India, based on inventory and census data. The mean seasonal integrated methane flux and the methane budget from Indian paddy fields is based on consideration of emission from total area under rain fed water logged, total area under deep water, total area under irrigation, total area under upland.

Methane emissions from Indian paddy fields were 4 Mt/year and livestock were 8.0 Mt/year (about 6.47 Mt/year from digestive process of rumen and about 1.6×10^6 t/year from animal wastes). Parashar, et al., (1996) determined methane budget for paddy fields of India, based on static box technique for measurement of methane emissions. The total CH_4 budget for continuously flooded (irrigated), intermittently flooded (rain fed), and deep water regimes was between 2.7 to 5.4 Mt/year with a mean of 4.0 Mt/year. Frolking, et al., (2006) developed new geospatial data set for India, which provides input data for regional analysis of rice cultivation area of 1999-2000. District and state level data from datasets were used.

2.3 **Fuel wood consumption**: Energy is a fundamental and strategic tool even to attain the minimum quality of life. Sustainable development of a region depends critically on the health of renewable resources like soil, water, vegetation, livestock and genetic diversity. The procurement of energy is also responsible in varying degrees for the ongoing deforestation, and loss of vegetation and topsoil. Energy use patterns are closely linked to agro-climatic and socio-economic conditions. Energy problems in rural areas are closely linked to Soil fertility, landholding, livestock holding, etc. Energy planning of any region should be based on the existing levels of energy consumption. Regional developmental activities have to be based on detailed information from each sector (Ramachandra et al, 2000a). The burning of wood is currently the largest use of energy derived from a solid fuel biomass. Wood fuel has been used for cooking, water and space heating, and occasionally for fueling steam engines and steam turbines that generate electricity. Wood fuel may be available as firewood (e.g. logs, bolts, and blocks), charcoal, chips, sheets, pellets and sawdust. The particular form used depends upon factors such as source, quantity, quality and application.

Wood burning does not release any more carbon dioxide than the eventual biodegradation of the wood if it was not burned. However, the carbon dioxide released through incineration occurs at a much faster rate than decomposition because burning wood takes a few seconds and decomposition takes years. Therefore, by burning wood carbon dioxide gets released into the atmosphere at a more concentrated rate than if one was to allow the wood fuel to decompose in soil. Wood harvesting and transport operations do produce varying degrees of greenhouse gas pollution. Inefficient and incomplete combustion of wood can result in elevated levels of greenhouse gases other than CO_2, which may result in positive emissions where the byproducts have greater carbon dioxide equivalent values (http://www.epa.gov/woodstoves/index.html). Energy content of wood ranges from 14.89 to 16.2 mega joules per kilogram (4.5 to 5.2 kWh/kg). The energy content of wood is much more dependent on the moisture content than the species.

Wood used for non-energy purposes produces emissions in the form of CO_2 and also sequesters carbon in the soil standing biomass and the different options have been assessed using the PRO-COMAP model (Ravindranath et al., 2004, 2009). Ghosh et al. (2004) highlight the use of biomass gasification plant using dual-fuel engines for Gosaba Islands of Sundarbans with a population of 10,000 in five villages. Five 100 kW diesel engines, each coupled to gasifier systems, are used to generate electricity. Electricity is provided to majority of the population, both for domestic and industrial applications. The average fuel consumption works out to be about 0.82 kg/kWh of wood and 135 mL/kWh of diesel, which accounts for about 60% diesel replacement or saves about 60% of the diesel.

Jae Edmonds and John (1983) had formulated a long-term global energy–economy model of CO_2 release from the utilization of fossil fuels. They had projected that if the same trend continues; there will be tremendous amount of emission in the future. David Reister (1984) had presented a simple model could be implemented in conjunction with an elaborate model to develop CO_2 emission scenarios. Subsequently, they (Jae Edmonds and John, 1985) had presented three emission scenarios—which cover the future range. The impact of alternative energy evaluations other than commercial energy systems over the next 100 years had been analyzed by them. Bhattacharya et al., (1986) analysed the energy consumption patterns and highlights the dependence of rural communities on non-commercial energy sources. Newborough and Probert (1987) had discussed the energy-consumption and health-care concerts relating to diet choices.

2.4 **Transportation:** The demand for infrastructure augmentation increases with the region's pursuit of development goals. The basic infrastructures required for the region's economic growth are roads, railways, and water and air connectivity. With the increase in economic activities, the dependence of fossil fuel based energy sources and consequent greenhouse gas (GHG) emissions have increased rapidly in recent times. The transport sector in India consumes about 16.9% (36.5 mtoe: million tons of oil equivalent) of total energy (217 Mt in 2005–2006). Vehicular emissions account for about 60% of the GHG's from various activities in India (Patankar, 1991). Total transport emission of CO_2 was 258.10 Tg. CO_2 contribution of road sector, aviation, railways and shipping was 243.82 Tg (94.5%), 7.60 Tg (2.9%), 5.22 Tg (2%) and 1.45 Tg (0.6%), respectively (Ramachandra and Shwetmala, 2009).

Globalization and liberalization policies of the government has spurted the economic activities. Consequent to this policy change are increase in urbanization and concentrated economic activities in certain load centers resulting in higher mobility. Energy consumption also varies with the modes of transport and public transport system has least average energy consumption per passenger kilometer (Singh, 2006). Around 80% of passenger and 60% of freight movement depend on road transport (MoF, 2000). Transport has a key role in the development of a nation. As a nation develops, it also increases the demand of transport. Urbanization and centralization of activities in and around the urban centers are main reasons to increase the need of transportation (Singh, et al. 2008). Transport includes road, rail, water and air. Percentage of two wheelers is growing very rapidly with doubling in every five years and it around 70% of total motor vehicles of India (MoSRTH, 2004).Transportation consumes energy in the form of coal, diesel, petroleum (gasoline) and electricity. In India, transport energy demand is increasing with an average annual rate of 2.9%. Energy consumption of transport varies from mode of transport like among different type of road based transport (bus, car, jeeps, two wheelers etc.) bus has least average energy consumption per passenger kilometer (Singh, 2006). Transportation has been an increasing source of greenhouse base. In India vehicular emissions are accounting for about 60% of the total population from all the sources (Patankar, 1991). The transport emission depends on type of transport, fuel consumption, operating system, emission control, maintenance procedures and vehicle age.

Singh, (2006) estimated the demand for road based passenger mobility in India and projected the energy demand and CO_2 emissions for the year 2030-2031, based on business as usual scenario and efficiency gain scenario. Traffic mobility of India increased at the rate of 7.55% per year between 1990-91 and 2000-01. It is expected that this rate will increase to 6.72% per year between 2000-01 and 2010-11, 4.69% per year between 2010-11 and 2020-21, and 3.01% per year between 2020-21 and 2030-31. It is estimated that during the year 2030-31, 26.8% of the road based traffic mobility will be provided by the two wheelers, 21.0% by the cars, and 7.5% by the auto-rickshaws and rest by the buses. Increase in traffic mobility will have implication for energy demand and CO_2 emission. Gurjar, et al., (2004) estimated greenhouse gas emissions of Delhi (1990-2000), based on emission factor approach for the different source categories. During the study period, power and transport sector was the largest source of NO (About 82%), CO (86%) and MNVOC (80%). CO_2 was mainly emitted by power plants (about 60% in 1990, and 48% in2000) followed by transport (27% in 1990), and 39% in 2000). Agriculture was the largest emission source of NH3 (70%) and N_2O (50%), and CH_4 was mainly (80%) emitted from solid waste disposal.

Das and Parikh (2004) estimated energy demand and gaseous emissions from the transport sector of Delhi and Mumbai. Based on projection they also calculated for the years 2005, 2010, 2015 and 2020. Econometric model, spread sheet model and long range energy alternative planning model are used for calculation. Singh et al., (2008) computed the energy consumption and greenhouse gas emission in the road transport sector of India during 1980 to 2000. The category-wise vehicles and fuel consumption statistical data were used with IPCC approach for calculating the emission. The emission of CO_2, CO and CH_4 were 27 Mt, 0.9 Mt and 2.9 kt during 1980 and 105 Mt, 3.5 Mt and 11.6 kt during 2000. Jalihal et al., (2005) has analysed the changes in traffic composition of six mega cities of India (Delhi, Mumbai, Bangalore, Hyderabad, Chennai and Kolkata) and described the traffic characteristics (traffic, volume, composition, travel patterns and speed measurements in major roads) of Delhi, Mumbai and Bangalore. Data for the year 1965, 1988, 1998 and 2002 are used for traffic characteristics of Bangalore and found that the share of bicycles has reduced from 70% in 1965 to 5% in 1998.

2.5 **Land Use, Land Cover [LULC] dynamics**: Land use land cover analysis of a region provides the status of a landscape and its health. Land cover [LC] relates to the discernible Earth surface expressions, such as vegetation or non-vegetation (soil, water or anthropogenic features) indicating the extent of Earth's physical state in terms of the natural environment (Lambin et al., 2001, Ramachandra et al., 2012). Land cover changes induced by human and natural processes play a major role at global as well as at regional scale patterns of the climate and biogeochemistry of the Earth system. Land cover information is vital for regional planning and management activities and has been considered as an essential element for modeling and understanding the earth as a system (Ramachandra and Shruthi, 2007). Monitoring LULC plays an important role at the local/regional as well as global level to understand the dynamics associated with the Earth. Monitoring and management of natural resources requires timely, synoptic and repetitive coverage over large area across various spatial scales that help in assessing the temporal and spatial changes. LULC changes include the conversion of an area (land transformation) from one land use type to another, as well as decline in the biological or economic productivity and complexity of the land. LULC changes due to the human management of ecosystems modify the biogeochemical cycles, climate, and hydrology of a primeval ecosystem (Ramachandra and Savitha, 2008), driving biodiversity loss through habitat fragmentation and destruction. These changes directly impact biodiversity of a region (Sala et al., 2000), leads to soil degradation, induces local climate change (Chase et al., 1999) as well as global warming (Houghton et al., 1990; Tolba et al., 1992). Land use and related land cover modifications have a strong impact on ecological integrity. Alterations of ecological integrity lead to increasing or decreasing supplies of selected ecosystem services, on which human societies depend. The LULC changes alter the ecosystem services by affecting the ability of biological systems to support human needs and posing challenges to the decision makers.

2.6 **Forest and Soil**: Forests plays a vital role in the global environment, moderating whether pattern and climate stability. Forest vegetation and soil are major sinks of carbon. The soil carbon pool is approximately 3.1 times larger than the atmospheric pool of 800 GT (Oelkers & Cole 2008). Vegetation stores the carbon as biomass by the process of photosynthesis, where carbon dioxide is converted into carbohydrate. The atmospheric CO_2 is utilized by the plants for the manufacture of food in the form of glucose, later on its gets converted to other forms of food materials i.e. starch, lignin, hemicelluloses, amino acids, proteins etc. and is diverted to other tree components for storage. Usage of plant biomass as fuel, leads to the release of carbon to the atmosphere. Biomass burning and industries are the major reasons to increase the percentage of atmospheric carbon dioxide during post industrialisation (Brown & Lugo, 1992). In undisturbed condition, after death of plant it becomes part of food chain and ultimately enters the soil as soil carbon. In soil, carbon is present as both soil organic carbon and soil inorganic carbon. The primary way that carbon is stored in the soil is as soil organic matter (SOM). SOM is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria), and carbon associated with soil minerals. Soil organic carbon input rates are primarily determined by the root biomass of a plant, but also include litter deposited from plant shoots. SOM improves soil structure and reduces erosion, leading to improved water quality in groundwater and surface waters, and ultimately to increased food security and decreased negative impacts to ecosystems. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere by climatic condition. Climatic conditions, natural vegetation, soil texture, and drainage all affect the amount and length of time carbon is stored. The destruction of rainforests that hold a significant amount of the carbon stored in terrestrial ecosystems contributes significantly to rising atmospheric carbon dioxide (CO_2) levels linked to climate change, while reductions in SOM levels from soil disturbance from mining can impact infiltration of rainfall and the storage of soil moisture important for flood mitigation. Soil disturbance also leads to increased erosion and nutrient leaching from soils, which have led to eutrophication and resultant algal blooms within inland aquatic and coastal ecosystems, ultimately resulting in dead zones in the ocean (Ontl and Schulte, 2012). Deforestation of forest contributes a significant amount of carbon to the environment (Clark, 1982; Houghton, 1990; 1991) and it also decreases the quantity of carbon sink. Carbon sequestration by growing forests has been shown to be a cost effective option for mitigating global climate change (Andrasko, 1990). Forest biomass is an important non-renewable source of energy. It is the important supplier of fodder, feed and fuel (Rawat and Nautiyal, 1988). Importance of forested areas in carbon sequestration is already accepted, and well documented (Brown, 1997; Cummings et al., 2002; FSI, 1988; Tiwari and Singh, 1987; Ramachandra et al., 2000b).

2.7 **Afforestation, forest plantations**: Afforestation activities are aimed at removal of emissions due to land-use changes. Forest biomass represents the potential amount of C that can be added to the atmosphere or conserved or sequestered on the land when forests are managed for meeting emission targets (Brown et al., 1999). Mitigating the carbon content from atmosphere through the establishment of forest plantation on wastelands, community lands and in agricultural land has become effective solution (Mohit et al., 2003). This solution would not only fulfill the target of covering the forest areas but also mitigate the climate change (Buma et al., 2013). But, intensified plantations will impact on biodiversity of tropical forests and the effect will vary with size, disturbance type (Gibson et al., 2011). Rapid conversion of forests for timber production, agriculture, and other uses has caused serious consequences on the ecology and biodiversity (Laurance et al., 2012; Setturu et al., 2012). Monoculture plantations are associated with relatively low ecological values, and may be vulnerable to disturbances caused by anthropogenic climate change. The expansion of dominated monocultures will result in widespread population declines of native cover, increased extinction risk for many forest dependent taxa (Chapin et al., 2000; 2007) and also led to an increase in the acidity of soils, with long-term associated consequences for biodiversity and subsequent land cover (Jonsson et al., 2003; Adam et al., 2010). The replacement of elegant monocultures with mixed native species in the managed forest landscapes are expected to result in an increase of biological diversity, improve conditions for endemic forest species. This management solution will also help in climate change adaptation strategies, such as risk-spreading etc. (Adam et al., 2010). The mixed-species stands provide multiple services such as improved habitats for biodiversity, reduced damage to focal tree species by grazers, pest insects, fire, wind and also increased recreational value to a wide end users, while concurrently reducing the risk of abiotic or biotic impacts on production (Knoke and Seifert, 2008).

Traditionally, forest inventories are based on ground data, with the upgrading of technologies modern inventory concepts are combined *in situ* and remote sensing data for the estimation of surface characteristics such as total biomass (Gallaun et al., 2010; Avitabile et al., 2011). The *in situ* surveys assess detailed information carbon stocks and carbon stock changes on sampling units, whereas satellite data provide whole coverage of area to be assessed (Brown, 1997; Hasenauer et al., 2012). The multi-temporal images allow estimating forest area changes with combining 'ground-based' *in situ* data. This approach provides us the advantages of data utilisation at cost-efficient and reliable information on carbon stocks and carbon stock changes over large scale forest areas (Ahamed et al., 2011; Donato et al., 2011; Mohren et al., 2012). The main carbon pool of tropical forest ecosystems is typically the above ground biomass - AGB (Gibbs et al., 2007). AGB at a landscape scale can be estimated by extrapolating results measured in the field (Brown, 1997; Chave et al., 2005). Above-ground biomass (AGB) is a valuable measure for assessing changes in forest structure (Brown et al., 1999; Cummings et al., 2002) and an essential aspect of studies of carbon cycle. AGB data can also be used to understand changes in forest structure resulting from succession or to differentiate between forest types (Cairns et al., 2003). There are numerous models exists which accounts emissions based on an empirically carbon tracking models with land-cover and land use change rates (Hooijer et al., 2010). These models are developed at global scale and greatly vary when applicable to regional level. Many of these studies use forest inventory data and national-scale biomass estimators for forest-level biomass and carbon stock assessments. The models and estimation of carbon by considering *in situ* data sets as a base are least explored.

Chhabra et al., (2002) estimated total standing biomass of Indian forests as 8683.7 Mt (1992-93) and the contribution of above ground biomass and below ground biomass was 79% and 21% respectively. Haripriya, (2000) measured biomass in Indian forests for the year 1993, using species-wise volume inventories data of various States and biomass carbon stock was calculated as 50% of estimated above grown biomass. The above ground biomass densities were ranging from 14-210 t/ha, with a mean of 67.4 t/ha and the total carbon stock in Indian forests were 2156 Mt with a carbon density of 34 tC/ha (tree DBH was 10 cm to 70+ cm) and 44 tC/ha (when trees with DBH<10 cm were also considered). Haripriya, (2003) estimated the average carbon content in Indian forests of 126 tC/ha of which 36% (45.8 tC/ha) was in biomass and 64% (79.8 tC/ha) in forest soils, based on simulation model. The net change of carbon pools is about 0.2 tC/ha/year in all forest ecosystems. The highest amount of carbon was released by temperate forest (0.58 tC/ha/year) and subtropical and alpine forests were acted as sinks of carbon (0.09 and 0.19 tC/ha/year).

Ravindranath, et al., (1996) estimated biomass accumulation, carbon storage and net carbon emission for Indian forests and also calculated annual mean net change in forest area of all states of India. They used inventory data and satellite imagery assessments for their calculation. For the reference year 1986, total above ground biomass in Indian forests (10% crown cover) was 8372 x 10^6 t and mean standing biomass was 130.8 t/ha. Carbon storage was calculated as 50% of the biomass. Total stored carbon was 9585 x 10^6 tC (44% in vegetation and 56% in soil) and the net carbon emission was 5 x 10^6 tC. Ramachandran et al., (2007) estimated forest carbon stock of Kolli hills of the Eastern Ghats of Tamil Nadu, India, based on geospatial technology (IRS ID, LISS III digital data). The total biomass carbon stock was 2.74 Mt of which the semi evergreen forest contributed 22% (0.6 Mt), the deciduous forest contributed 57% (1.57 Mt) and the other forest types contributed 21% (secondary deciduous was 0.35 Mt, southern thorn forest was 0.22 Mt and Euphorbia forest was 0.01 Mt) and the soil organic carbon stock was 3.48 Mt which was distributed as the semi-evergreen forest 1.01 Mt, the deciduous forest 1.63 Mt and the other forest types 0.84 x 10^6t (secondary deciduous was 0.35 Mt, southern thorn forest was 0.47 Mt and Euphorbia forest was 0.03 Mt).

Tropical deforestation makes a major contribution to emissions of greenhouse gases, especially if the additional emissions from subsequent land use are counted. The United Nations Framework Convention on Climate Change (UNFCCC) has mooted a financial mechanism to reduce emissions from deforestation and forest degradation (REDD) in developing countries by demarcating and protecting significant forest types. However, biodiversity and carbon value are distributed differently among tropical ecosystems. The funding from REDD needs to protect biodiversity while easing pressures on other ecosystems. Funds for other purposes such as sustainable forest management (SFM) and conservation would help to fill the gap (Miles and Valerie, 2008). The active sustainable forests management for optimal carbon storage requires identification and mapping of ecosystem attributes, including spatially implicit and explicit analyses of carbon dynamics including its drivers. The well accepted factors such as disturbance regimes, age, net primary productivity, species diversity, and decomposition dynamics have been described as drivers influencing carbon storage and sequestration of forests. Furthermore, net carbon storage and cycling in forest ecosystems depends on land use and forest management practices (Pregitzer and Euskirchen, 2004; Houghton, 2012). The monitoring of forested landscapes provides detailed scientific descriptions of key biota, habitat composition, structure dynamics and also regional disturbance systems. This consistent data helps in evaluating existing management approaches and their impacts on forest ecosystems. Continuing carbon storage in a forest ecosystem is highly dependent on factors such as disturbances, ambient climate. Most disturbances leads to the release of considerable amount of carbon into the atmosphere with the significant changes in the structure and composition of forest landscape (Page et al., 2002; Heath et al., 2011; Lindroth et al., 2009).

Forest inventory techniques were developed and formalised in the 19th century for more detailed information on forest structure in addition to areal estimates of forest stands. With the realization of forests role in global carbon cycle, increasing interest in inventory for accounting forest carbon pools are being developed by innovative methods. The progression of statistical sampling design theory systematic sampling was implemented in inventory methods. In the 20th century, the assessment of change was done via permanent sampling units in which the same trees are repeatedly recorded over time and by utilizing the co-variances between measurements on successive occasions, changes in forest attributes are detected with smaller sampling error. The sample population for forest inventories is defined by forest area definitions which are based on quantitative criteria such as a certain minimum size of a forest patch, minimum crown cover, or (potential) height (Mohren et al., 2012). Initially, forest inventory data and specific allometric formulas from destructive sampling scarcely exist. Non-destructive forest inventory methods have been developed based on the statistical relation of field measurements to destructive harvest measurements, and the conversion to biomass estimates using allometric equations (Brown, 1997; Chave et al., 2005; Basuki et al., 2009). Carbon dynamics in the forest ecosystem provide insights to their importance in mitigating the impacts of changes in the climate. This entails region wise quantification of sources and sinks of carbon and the current study focuses on forests of Uttara Kannada district, Central Western Ghats.

3.0 OBJECTIVES: The objective of the current research is to carry out taluk wise carbon budget for Uttara Kannada district, Central Western Ghats. This involves:

I. Source wise carbon sequestration assessment with the combination of field and remote sensing data;
II. Sector wise Carbon emission assessment; and
III. Computation of carbon metric (ratio of carbon sink to source).

The analysis is based on the literature, compilation of data from each sector in all taluks of Uttara Kannada district and review of the emission and sink experiments.

3.1 Study area: The Western Ghats also known as the Sahyadri Mountains is a mountain range along the western side of India. The area is one of the world's ten "Hottest biodiversity hotspots" and Karnataka state covers the central part of Western Ghats. Karnataka state comprises of 30 districts, of which only three are the costal belt and Uttara Kannada (Figure 2) is one among the three. The region is bounded between 13.769º to 15.732º north and 74.124º to 75.169º east. It encompasses an area of 10,291 sq. km, which is 5.37% of the total area of the State. The district extends to about 328 km north to south and 160 km east west. Most of the district is hilly, undulating and thickly wooded and comprises of 11 taluks. Supa taluk is the largest with an area of 1910.47 sq. km and Bhatkal taluk the smallest in district with 355.5 sq km. The district is surrounded by state of Goa and Belgaum district in the north, Dharward and Haveri in the east; southern neighbours are Udipi and Shimoga districts, the Arabian Sea on the other side. This district takes away maximum portion of the shoreline, i.e., 120 km of 300 km of the total costal belt of Karnataka. The west flowing rivers break the shoreline of Uttara Kannada by deep and wide mouthed estuaries. Kalinadi, Bedthi, Aganashini, Sharavathi, Venkatapur, Bhatkal, Belambar, Navgadde halla, Hattikeri halla and Belambar are west flowing rivers. Of these major rivers are Kalinadi, Bedthi, Aganashini, and Sharavathi River. The two east flowing rivers are Dharma and Varada. The rivers give raise to magnificent waterfalls in the district.

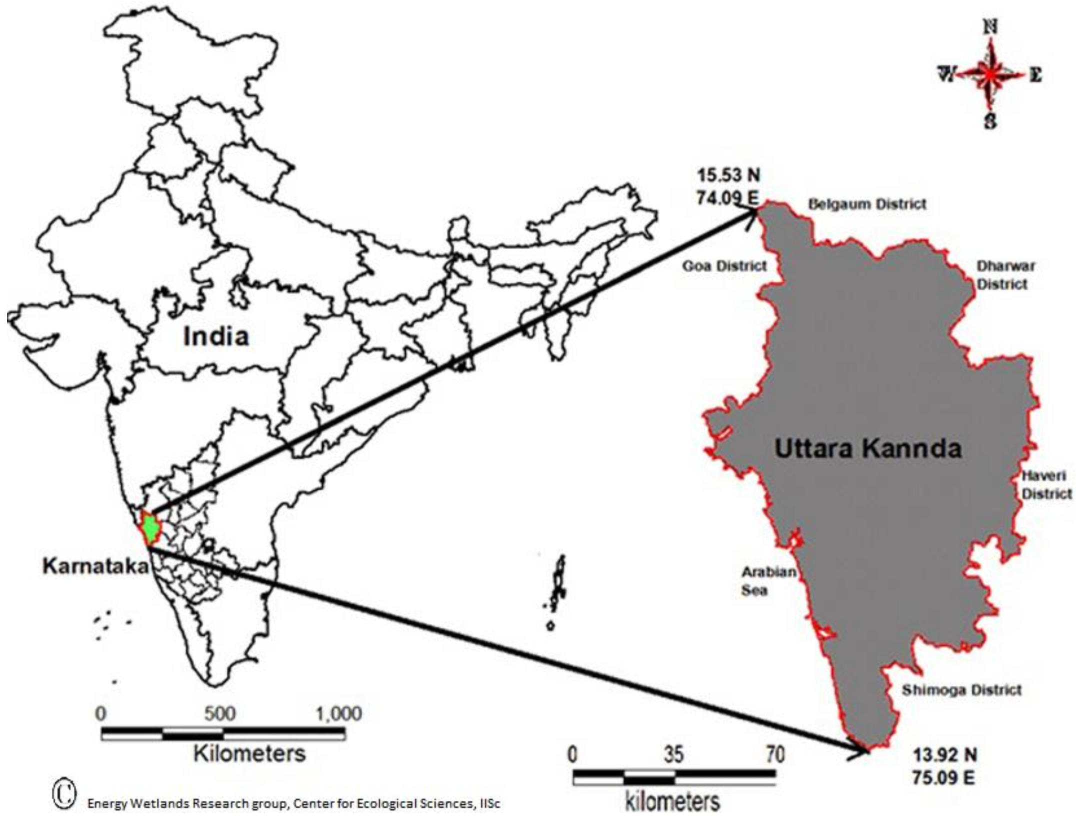


Figure 2: Study region - Uttara Kannada district

Topographically, the district can be divided into 3 distinct zones namely narrow and flat coastal zone, abruptly rising ridge zone and elevated flatter eastern zone. The coastal zone is thickly populated with coconut clad villages. Ridge zone is a part of the main range of Western Ghats, which runs north to south, parallel to the coast. The flat eastern zone joins the Deccan plateau (Ramachandra et al., 2013).

The population of Uttara Kannada district was 1,353,644 (according to 2001 census data) which account to a population density of 132.42 persons per sq. km implying a growth of 10.9 % in population data of 1991. As per 2011 census population density is 140 persons per sq. km. Bhatkal taluk has maximum, while Supa taluk has minimum population density. Nearly 75 % of the population of the district lives in rural area and remaining 25 % in small towns. The male and female population and population residing urban and rural areas are shown in table 1.

Table 1: Population of Uttara Kannada (as per 2011 population census)

SNo.	TALUK	Area in Sq.Kms	Total	Male	Female	Rural	Urban
1	Ankola	904.79	107428	54171	53257	75,427	32,001
2	Bhatkal	355.5	161577	80893	80684	111847	49,730
3	Haliyal	847.62	170976	86916	84060	91,039	79,937
4	Honnavar	756.15	166390	83316	83074	147284	19,106
5	Karwar	724.12	155143	78269	76874	73,716	81,427
6	Kumta	590.45	154515	77962	76553	117759	36,756
7	Mundgod	667.44	106,265	57597	48668	83,694	22,571
8	Siddapur	847.27	97435	48392	49043	83,222	14,213
9	Sirsi	1322.32	187014	94182	92832	123999	63,015
10	Supa	1910.44	52,013	26194	25819	52,013	0
11	Yellapura	1298.75	78,091	39532	38559	58,216	19,875
Uttara Kannada		10291	1436847	727424	709423	1,018,216	418631

Source: http://censusindia.gov.in

Table 2: Population density of Uttara Kannada for the year 2001 and 2011

Taluk	Population 2001	Density persons/sq.km	Population 2011	Density persons/sq.km
Ankola	101549	108.84	107428	119
Bhatkal	149338	425.46	161577	455
Haliyal	159141	185.91	170976	202
Honavar	160331	212.36	166390	220
Karwar	147890	198.24	155143	214
Kumta	145826	246.74	154515	262
Mundgod	90738	134.03	106,265	159
Siddapur	100870	116.08	97435	115
Sirsi	175550	132.59	187014	141
Supa	48914	25.88	52,013	27
Yellapura	73497	56.49	78,091	60
Total	1353644	131.51	107428	140

Population of Uttara Kannada and density at taluk wise for the 2011 and 2001 is given in Table 2. The coastal taluks of the district i.e. Karwar, Bhatkal, Honnavar, Kumta experiencing major change as an increase of population density. There are 2162 Primary Schools, 234 High Schools, 28 Junior Colleges, 20 Colleges, 2 TCH Schools, 3 C. P. Ed. Schools, 13 Polytechnics, 6, one Law College and One Engineering College in the District. Besides these there are 107 Libraries. Number of Households for the year 2011 is been shown in table 3. According to the census of 2011 the maximum households is found to be in Sirsi 36,103 followed by Karwar 35273 and minimum of 10186 in Supa. The district households density is 26 houses per sq. km. The highest is Bhatkal (71 houses/sqkm) and least is Supa (6 houses/sqkm).

Table 3: Taluk wise number of households

Taluk	House Holds			
	Urban	Rural	Total	Density (Houses/sqkm)
Ankola	5453	15626	21079	23
Bhatkal	5952	19236	25188	71
Haliyal	16409	15072	31481	37
Honnavara	3750	29058	32808	43
Karwar	17391	17882	35273	49
Kumta	6839	21412	28251	48
Mundgod	3311	13852	17163	26
Siddapura	3007	17591	20598	24
Sirsi	14052	22051	36103	27
Supa	0	10186	10186	6
Yellapura	3852	11440	15292	12
Uttara Kannada	**80016**	**193406**	**273422**	**27**

The soil can be described as derivatives of the most ancient metamorphic rocks in India, which are rich in iron and manganese (Pascal, 1988). The soils of the district are basically divide into two distinct zones based on topography; the coastal alluvial soil and the upghat lateritic and granitic soils. Mixed lateritic soils are found in taluks of Supa, Haliyal and Mundgod, which contains certain patches of black soil as well. The lateritic soils are highly leached, reddish brown in colour, shallow to medium in depth and loamy in texture. These soils are found in the taluks of Karwar, Kumta, Honnavar, Bhatkal, Sirsi and Siddapur. Red loamy soils are also to some extent found in taluks of Supa, Mundgod and Haliyal. Red sandy loams are poor in water holding capacity, and are therefore well drained, and acidic. Such soils are found in taluks of Sirsi, Yellapura, Karwar and Ankola. In the coastal taluks there are numerous patches of land which contain saline soil of light yellow or brownish colour. These lands are not quite suitable for cultivation. (Ramachandra et al., 1997). Figure 3 shows the soil types of Uttara Kannada district which includes clay loamy, clay skeletal, sandy and loamy soils (French institute map 1:50,000).

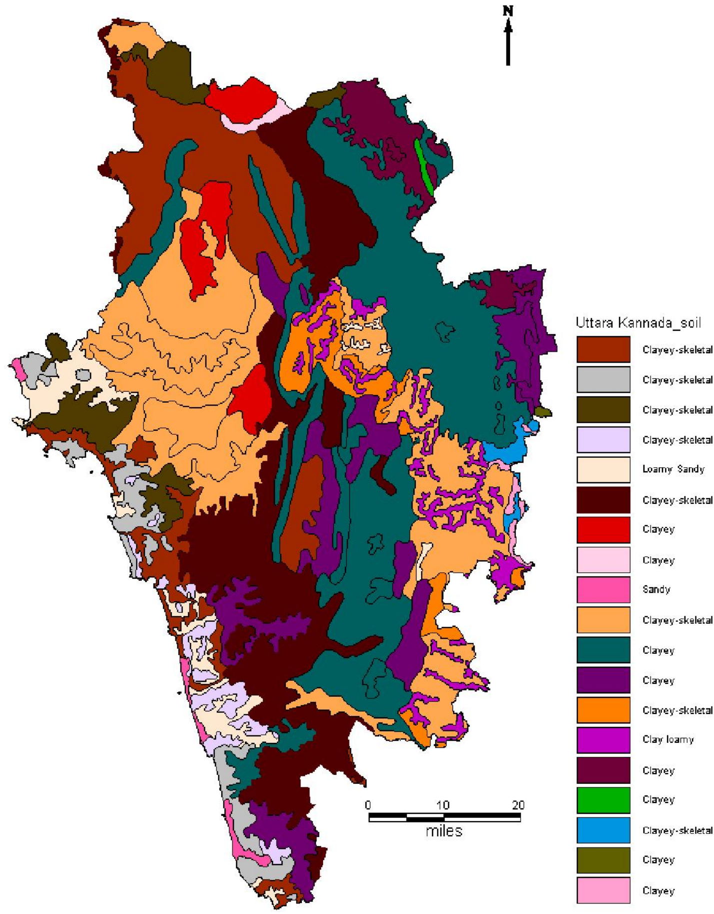


Figure 3: Soil type in Uttara Kannada

The total forest of Uttara Kannada is about 8, 29,151 ha and the per capita forest is about 0.77 ha (Ramachandra et al., 1997). The forests of Uttara Kannada can be classified into 3 categories based on density (Akbar Sha, 1988) as *partially open forest* (20-40% density), *Medium density forest* (40-80% density) and closed forest (above 80% density). Depending on ecological factors, the forests of Uttara Kannada are broadly divided into two types namely Moist and Dry types. The moist type may be sub divided into evergreen, semi evergreen and moist deciduous. The dry type can be divided into dry deciduous and thorny forest. The central part of Uttara Kannada is of the evergreen type. The rainfall in this forest is as high as 4000-5000 mm. The semi evergreen forests are seen in pockets and often merge with the evergreen and the moist deciduous type. Plantations in the district are catering the wood demand of society. Some important plantations are *Tectona grandis, Areca catechu, Cocos nucifera, Casuarina equisetifolia, Acacia auriculiformis, and Acacia nilotica, Eucalyptus spp.* Normally *Areca catechu is* seen in valleys and *Acacia spp*.; *Tectona grandis* in plain area.

Agricultural sector continues to play a prominent role in the development of the economy of Uttara Kannada District. Nearly 80% of the total area is under forest. Paddy is the major crop in the district. Haliyal, Mundgod and Sirsi are predominantly cultivating paddy. The other important crops grown in the district are sugar cane and ground nut. The other minor crops cultivated are Ragi, Jower and Pulses. Approximate annual production of paddy is 182000 Tons; Sugarcane is 45000 Tons and Groundnut 4695 Tons.

In the Coastal belt Coconut, Areca nut, Cashew nut, Pepper, Betel, Banana, Mango, Pineapple, Sapota, Guava and Vegetables are the main cash crops. The main crops cultivated in malnad are Coconut, Areca nut, Cashew nut, Pepper, Cardamom and Fruit crops like Mango, Pineapple and all kinds of vegetables. Areca nut is the main cash crops. Comparison of area under Horticulture in Uttara Kannada District between 2004-05 and 2007-2008 is given in table 4 (NRDMS, 2008-2009). In semi-malnad the fruit crops like mango, sapota, guava, banana and pineapple, all varieties of vegetables and subsidiary food crops like potato, tapioca, etc. are the common horticulture crops grown. In up-ghat taluks cocoa is grown, in addition to the spice crops like cloves, nutmeg, cinnamon, and turmeric. The average annual production of Areca nut is about 23400 Tons, Coconut about 3800 Tons, Banana 39000 Tons, Mango 10000 Tons , Pineapple 6500 Tons and Papaya 12000 Tons. In this back ground for an alternate source of income, cultivation of fruit, intercrops, flower crops, medicinal and aromatic crops are to be encouraged. Cultivation of wide range of tropical and subtropical fruit crops like Sapota, Banana, Pineapple etc., could be taken up. Commercial flower crops like Orchids, Anthuriums, BOP, Heliconias, Jasmine and medicinal and aromatic crops like Patchouli, Gloriosa, Sandal, Amla, Lavancha and Lemon Grass have vast potential in the near future.

Table 4: Comparison of Area under Horticulture in Uttara Kannada District between 2005 and 2008

Comparison of Area under Horticulture in Uttara Kannada District between 2004-05 and 2007-2008											
Sl. No.	Taluk	Horticulture in 2004-05					Horticulture in 2007-08				
		Area (in Ha.)	% on District Total	Production (in MT)	% on District Total	Product (in ons/Ha)	Area (in Ha.)	% on District Total	Production (in MT)	% on District Total	Productivity (in tons/Ha.)
1	Ankola	1720	6.49	10898	7.11	6.34	1779	5.40	10782	6.00	6.06
2	Bhatkal	1345	5.08	2952	1.93	2.19	1753	5.32	4437	2.47	2.53
3	Haliyal	706	2.66	14100	9.20	19.97	838	2.54	14214	7.91	16.96
4	Honnavar	3770	14.23	13846	9.03	3.67	5232	15.88	13023	7.25	2.49
5	Joida	600	2.26	4805	3.14	8.01	668	2.03	5739	3.19	8.59
6	Karwar	1253	4.73	9935	6.48	7.93	1459	4.43	15665	8.72	10.74
7	Kumta	2737	10.33	12306	8.03	4.50	3952	11.99	16630	9.26	4.21
8	Mundgod	768	2.90	8503	5.55	11.07	981	2.98	10948	6.09	11.16
9	Siddapur	4338	16.37	19427	12.68	4.48	4672	14.18	18864	10.50	4.04
10	Sirsi	5946	22.44	42753	27.90	7.19	8209	24.91	57650	32.09	7.02
11	Yellapura	3311	12.50	13732	8.96	4.15	3410	10.35	11719	6.52	3.44
	Total	26494	100.0	153257	100.0	5.78	32953	100.0	179671	100.00	5.45

Table 5: Taluk wise transport and communication of Uttara Kannada district

Taluks	Motor cycles	Car	Cabs	Auto rickshaws	Omni buses	Tractors and trailers	Ambulance	Good vehicle	others
Ankola	8141	775	55	341	124	31	10	592	406
Bhatkal	16776	1056	117	1078	76	41	6	353	467
Haliyal	14705	968	28	289	184	751	11	566	309
Honnavar	11479	687	145	449	177	22	8	645	376
Karwar	21763	1601	139	1018	325	85	12	1129	748
Kumta	12835	989	159	557	36	22	11	741	534
Mundgod	4171	275	11	87	35	574	4	227	105
Siddapur	4970	226	12	81	38	90	2	204	94
Sirsi	26001	1792	118	678	316	423	16	1545	1295
Supa	2423	400	25	9	39	96	8	89	63
Yellapura	5339	304	15	110	35	154	4	293	105
Total	128603	9073	824	4697	1385	2289	92	6384	4502

Transport heralds the development of a region. The demand for infrastructure augmentation increases with the region's pursuit of development goals. The basic infrastructures required for the region's economic growth are roads, railways, and water and air connectivity. Taluk wise transport and communication of Uttara Kannada district is shown in table 5. The west coast Highway N.H.-17 runs through the district covering a total length of 162 KM. from Bhatkal to Majaii. The total length of roads including National Highway, State Highway, roads in charge of PWD, Village roads is 7975 KM. The communication roads in the rural areas and coastal areas are extensively damaged during rainy season. The length of National Highway is 238 KM and State Highway is 741 Km. Konkan Railway line passes through the coastal belt connecting important villages and taluk headquarters. Apart from this Railway Line about 46 Km connecting Dandeli to Ainavar on the Puna Bangalore section of South Central Railway and a line from Londa to Castlerock in Joida Taluka. Total Railway track is 179 Km with fifteen no. of railway Stations. 14 minor and small ports of which Karwar, Belekeri, Bhatkal,Honnavar are very important as they provide good potential for the development of trade and Industries particularly Marine Based Industries. The industries and their details are shown in table 6.

Table 6: Industries of Uttara Kannada

Sno.	Unit head	Particulars
1	Registered industrial unit	9,543
2	Total industrial unit	14,813
3	Registered medium and large unit	6
4	Estimated avg. no. of daily workers employed in small scale industries	75,613
5	Employment in large and Medium industries	3,134
6	No. Of industrial area	1
Turnover of Small scale industries (Lakhs)		80,000
Turnover of Medium & Large scale industries (Lakhs)		1,65,000

The major products of small scale industries in Uttara Kannada are roofing tiles, coir products, jewelry, food products, wood and steel furniture, glass and ceramics and seafood. Some of these small scale industries and tiny industries providing job works, components and spares required for large and medium scale industries, both within and outside the district. Eight large and medium scale industries in the district produce a variety of products like paper, duplex board, caustic soda, Ferro alloys, transmission gears, food concentrate, herbal medicines and pharmaceuticals.

4. METHOD

Figure 4 outlines the method adopted for budgeting carbon in the district. The forest cover types were identified using vegetation maps (Pascal et al., 1982; Pascal, 1986; Ramachandra and Savitha, 2008). Uttara Kannada vegetation can be grouped into 5 broad zones namely – Coastal, Northern evergreen, Southern evergreen, Moist deciduous and Dry deciduous zones (Daniels et al., 1993). Based on this, forest vegetation is sampled using transect-based quadrats, which is validated and found appropriate especially in surveying undulating forested landscapes of central Western Ghats (Chandran et al., 2010; Ramachandra et al., 2006). Topographic maps of 1:50000 scales were used to do ground surveys and selection of sample plots. The study area is divided in to 5'x5' equal area grids (168) covering approximately 9 km^2 to account the changes at micro scale (figure 5). Field investigations were carried out in chosen grids with 116 transects and compiled data pertaining to the basal area, height, species, etc. Along a transect of 180 m, 5 quadrats each of 20x20 m were laid alternatively on the right and left, for tree study (minimum girth of 30 cm at GBH or 130 cm height from the ground), keeping intervals of 20 m length between successive quadrats. Within each tree quadrat, at two diagonal corners, two sub-quadrats of 5 m × 5 m were laid for shrubs and tree saplings (< 30 cm girth). Within each of these 2 herb layer quadrats, 1 sq. m area each, were also laid down for herbs and tree seedlings (figure 6). Climbers and other associated species were noted. A rapid assessment was made to track vegetation changes from the densely populated coast through the rugged mountainous terrain to the undulating and drier eastern lands using point-centered quarter method along line transects Ankola (coastal) and Yellapura (hilly to undulating) taluks. Sampling efforts were higher in high endemism areas (eg. Kathalekan in Siddapur). The above ground biomass is estimated as a prime variable to analyse standing biomass and net carbon stored. The above ground standing biomass of trees is referred to the weight of the trees above ground, in a given area, if harvested at a given time. The change in standing biomass over a period of time is called productivity. Carbon storage in forests is estimated by taking 50% of the biomass as carbon. The mathematical equations for biomass estimations of trees have been developed and used by many researchers for different biogeography regions (Brown, 1997; Ramachandra et al., 2000; Chandran et al., 2010).

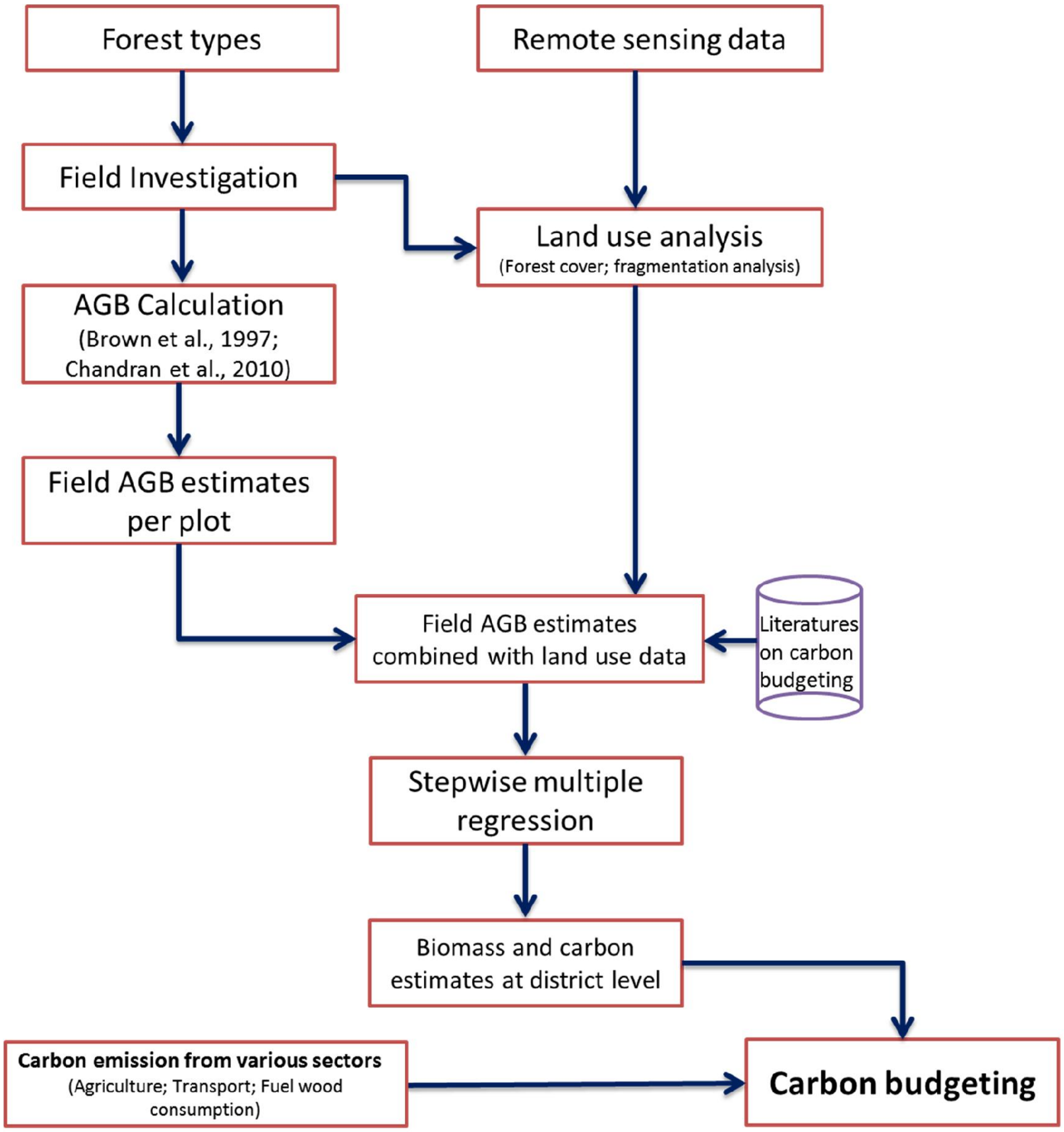


Figure 4: Method adopted for carbon budgeting

For the current study, the standing above-ground biomass (AGB) was calculated using the basal area equation and indirect estimation was done for calculating below ground biomass (Ramachandra et al., 2000; Murali et al., 2005; Ravindranath and Ostwald, 2008; Chandran et al., 2010). The carbon storage is computed by considering 50% of total biomass. Data compiled from field were analysed for diversity, biomass and carbon sequestration. Remote sensing data of high resolution (5 m) is used for quantifying biomass at taluk level. Land use analysis was performed to identify forest cover and percentage of interior forest at grid level. These variables were used to estimate the standing biomass in the regression analysis and to predict an outcome variable that is categorical from one or more categorical or continuous predictor variables (Brown, 1997). The multiple regression analysis is adopted, for estimating relationship between dependent (standing biomass) and independent variables (forest cover, percentage of interior forests). The probable relationship helped in predicting the standing biomass in all grids. This approach helped to estimate biomass and carbon stock at district level. Sector-wise carbon emissions were assessed and finally, carbon budgeting of the district was done through computation of carbon status in each taluk.

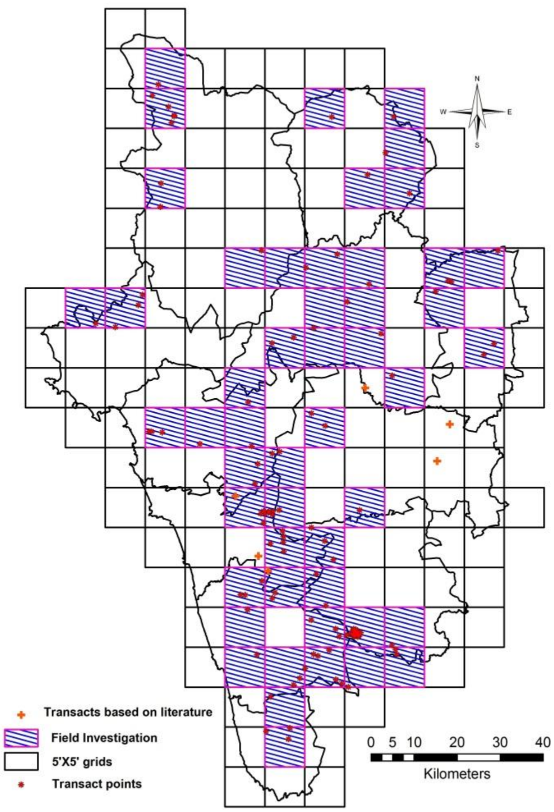


Figure 5: Study area and distribution of transacts

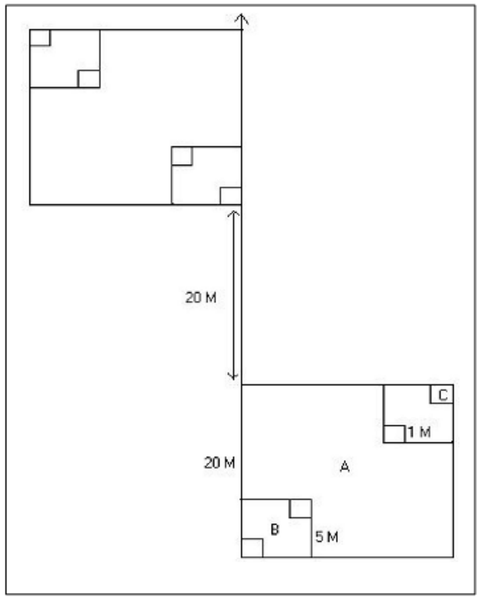


Figure 6: Transect cum quadrats for sampling vegetation

The study uses multiple data sets of various themes for assessing carbon sequestration potential at district level. Data used for accounting carbon sequestration and emission from each sectors are explained next.

I. Carbon sequestration analysis:

A. **Land use analysis:** Spatio temporal land use analysis is performed to identify landscape transition with time. This analysis will provide vegetation status and its potentiality in sequestration of carbon. The method followed for LULC analysis is represented in figure 7. The remote sensing data (table 7) has been used to state the land use and land cover of the region. Ancillary data include cadastral revenue maps (1:6000), the Survey of India (SOI) topographic maps (1:50000 and 1:250000 scales), vegetation map of South India developed by French Institute (1986) of scale 1:250000. Topographic maps provided ground control points (GCP's) to rectify remote sensing data and scanned paper maps. Vegetation map of South India (1986) of scale 1:250000 (Pascal, 1986) was digitized to identify various forest cover types and classify RS data of 1980's. Other ancillary data includes land cover maps, administration boundary data, transportation data (road network), etc. Pre-calibrated **GPS** (Global Positioning System - **Garmin GPS units)** were used for field data collection, which were used for RS data classification as well as for validation.

Table 7: Details of Remote sensing data

Year	Satellite	Sensor	Number of Bands	Resolution (M)
1973	Landsat	**Multi Spectral Scanner (MSS)**	4	57.5
1979	Landsat	**Multi Spectral Scanner (MSS)**	4	57.5
1989	Landsat	**Thematic Mapper (TM)**	7	28.5
1999	Landsat	**Thematic Mapper (TM)**	7	28.5
2010	IRS P6	**LISS IV Multi spectral (L4MX)**	3	5
2013	Landsat	**Enhanced Thematic Mapper Plus (ETM^{+})**	8	30

Remote sensing data obtained were geo-referenced, rectified and cropped corresponding to the study area. Geo-registration of remote sensing data (Landsat data) has been done using ground control points collected from the field using pre calibrated GPS (Global Positioning System) and also from known points (such as road intersections, etc.) collected from geo-referenced topographic maps published by the Survey of India. Land cover analysis essentially involves delineating the region under vegetation and non-vegetation, which is done through the computation of vegetation indices NDVI (Normalized Difference Vegetation Index), which is widely accepted and being applied (Weismiller et al., 1977; Nelson, 1983; Ramachandra et al., 2009). NDVI is calculated by using visible Red and NIR bands which are reflected by vegetation. Healthy vegetation absorbs most of the visible light that hits it, and reflects a large portion of the near-infrared light. Sparse vegetation reflects more visible light and less near-infrared light. NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1). NDVI was calculated using Eq. (1)

$$\mathbf{NDVI} = {(\mathbf{NIR} - \mathbf{R})}\big/{(\mathbf{NIR} + \mathbf{R})} \qquad \ldots (1)$$

Land use analysis involved (i) generation of False Color Composite (FCC) of remote sensing data (bands–green, red and NIR). This composite image helps in locating heterogeneous patches in the landscape, (ii) selection of training polygons by covering 15% of the study area (polygons are uniformly distributed over the entire study area) (iii) loading these training polygons co-ordinates into pre-calibrated GPS, (vi) collection of the corresponding attribute data (land use types) for these polygons from the field. GPS helped in locating respective training polygons in the field, (iv) supplementing this information with Google Earth and (v) 60% of the training data has been used for classification, while the balance is used for validation or accuracy assessment. The land use analysis was done using supervised classification technique based on Gaussian maximum likelihood algorithm with training data (collected from field using GPS). Maximum Likelihood algorithm has been widely applied as an appropriate and efficient classifier to extract information from remote sensing data. The analysis is done through **GRASS GIS *(Geographical Resources Analysis Support System)*** a free and open source software having the robust support for processing both vector and raster files accessible at http://wgbis.ces.iisc.ernet.in/grass/index.php. Temporal remote sensing data have been classified through supervised classification techniques by using available multi-temporal "ground truth" information. Earlier time data were classified using the training polygons along with attribute details compiled from the historical published topographic maps, French institute vegetation maps, revenue maps, land records available from local administrative authorities, etc. Accuracy assessments of the classified information have been done through error matrix (also referred as confusion matrix), and computation of kappa (κ) statistics and overall (producer's and user's) accuracies.

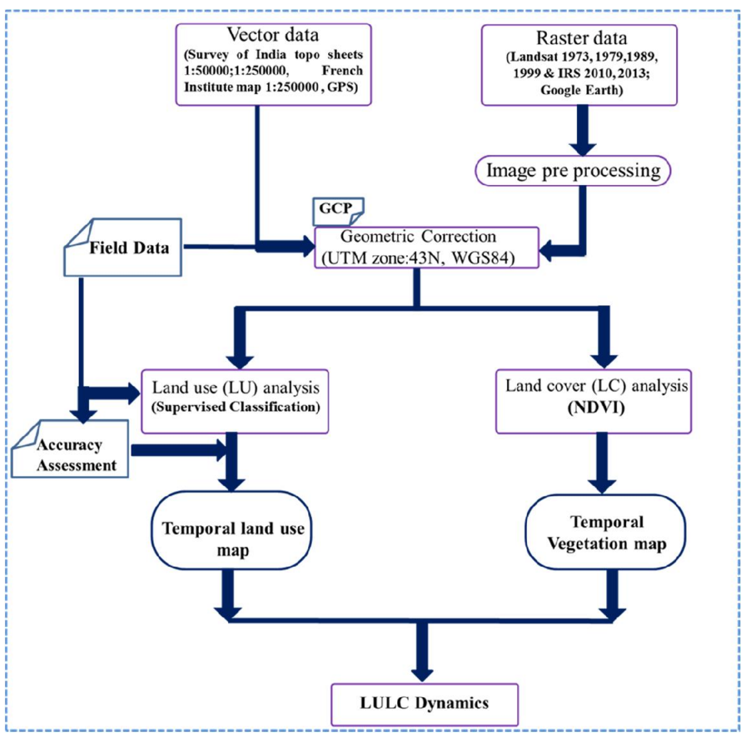


Figure 7: Method followed in the LULC analysis

B. **Biomass estimation:** Uttara Kannada district in Karnataka, located in the central Western Ghats has the distinction of having forested area of about 80%. Total standing biomass and carbon storage in the terrestrial vegetation and soil are calculated based on the standard approaches (Brown, 1997; Ravindranath et al., 1997; Ramachandra et al., 2000) using field data and remote sensing data. The standing biomass (Rai, 1981; Swamy, 1989; Singh, 1989; Yoda, 1968, Cannell, 1982 &1984; Singh, 1990; Toky and Ramakrishnan, 1983; Chaturvedi and Singh, 1984; Yadava, 1986; Rana, 1985; Ramakrishnan and Kushwaha, 2001) and average crown cover (Ravindranath et al., 1997) of different types of forests have been used earlier to calculate total standing biomass (Table 8.1).

Table 8.1: Maximum standing biomass of different forest types.

Forest type	**Standing biomass (t/ha)**	**Reference**
Tropical Wet Evergreen Forest	607.7	Rai, 1981
Tropical Semi Evergreen Forest	468	Swamy, 1989
Tropical Moist Deciduous Forest	409.3	Swamy, 1989
Littoral and Swamp Forest	213.8	Singh, 1989
Tropical Dry Deciduous Forest	93.8	Singh, 1990
Tropical Thorn Forest	40	Ravindranath et al., 1997
Tropical Dry Evergreen Forest	40	Ravindranath et al., 1997
Sub-Tropical Broad Leaved Hill Forest	108.7	Toky and Ramakrishnan, 1983
Sub-Tropical Pine Forest	210.8	Chaturvedi and Singh, 1984
Sub-Tropical Dry Evergreen Forest	159.7	Ravindranath et al., 1997
Montane West Temperate Forest	237.67	Yadava, 1986
Himalayan Moist Temperate Forest	562.2	Rana, 1985
Himalayan Dry Temperate Forest	169.1	Ravindranath et al., 1997
Sub Alpine and Alpine Forest	127.4	Yoda, 1968; Cannel, 1982

Table 8.2: Net Primary Productivity for different types of forests.

Forest type number	**Forest type**	**% NPP (% of the standing biomass)**	**References**
1	Tropical Wet Evergreen Forest	1.28	Rai, 1981
2	Tropical Semi Evergreen Forest	1.28	Ravindranath et al., 1997
3	Tropical Moist Deciduous	1.46	Rana, 1985
4	Littoral and Swamp Forest	1.46	Ravindranath et al., 1997
5	Tropical Dry Deciduous Forest	2.86	Sharma, et al., 1990
6	Tropical Thorn Forest	2.86	Ravindranath et al., 1997
7	Tropical Dry Evergreen Forest	2.86	Ravindranath et al., 1997
8	Sub-Tropical Broad Leaved Hill	2.86	Ravindranath et al., 1997
9	Sub-Tropical Pine Forest	2.07	Rana, 1985
10	Sub-Tropical Dry Evergreen	2.07	Ravindranath et al., 1997
11	Montane Wet Temperate Forest	2.07	Ravindranath et al., 1997
12	Himalayan Moist Temperate	2.07	Rana, 1985
13	Himalayan Dry Temperate	2.07	Ravindranath et al., 1997
14	Sub Alpine and Alpine Forest	2.07	Ravindranath et al., 1997

Annual net biomass accumulation and carbon uptake is calculated for 2013, based on the percentage of net primary productivity (Rai, 1981; Rana, 1985; Sharma, et al., 1990; Ravindranath et al., 1997; Ramachandra et al., 2000) for different forests (Table 8.2). Stored soil carbon is calculated based on the mean soil carbon reported earlier (Ravindranath, et al., 1997) in top 30 cm soil of different forests (Table 8.3). The average carbon content of the biomass is calculated as 50% of total standing biomass.

Table 8.3: Soil carbon storage in different forest types.

Forest Types	Mean soil carbon in top 30 cm (Mg/ha)
Tropical Wet Evergreen Forest	132.8
Tropical Semi Evergreen Forest	171.7
Tropical Moist Deciduous Forest	57.1
Littoral and Swamp Forest	34.9
Tropical Dry Deciduous Forest	58
Tropical Thorn Forest	44
Tropical Dry Evergreen Forest	33
Sub-Tropical Broad Leaved Hill Forest	108.7
Sub-Tropical Pine Forest	90.4
Sub-Tropical Dry Evergreen Forest	33
Montane Wet Temperate Forest	188.3
Himalayan Moist Temperate Forest	140.4
Himalayan Dry Temperate Forest	74.7
Sub Alpine and Alpine Forest	258.1
Source: From various literatures as quoted in Ravindranath et al., 1996	

The region specific allometric equations (Table 8.4) have been used to compute biomass (Brown, 1997; Chandran et al., 2010). The current distribution of forest biomass is assumed to be a combination of the potential biomass density (basal area/hectare), which is based on prevailing forest cover, climatic and geomorphological conditions; natural disturbances; and the cumulative impact of human activities (land use). The study area falls in three diverse agro climatic variations i.e. Coastal; Sahyadri Interior; Plains. Probable relationship between basal area (BA), and forest cover and extent of interior forest (Eq.2) based on the field data coupled with land use data.

$$Basal\ area = F\{Interior\ forest,\ forest\ cover\} \quad ...2$$

The probable relationships were determined separately for three agro climatic regions considering the field data (sampled grids) with land use and levels of forest fragmentation information. The coastal region, which has hot and humid climate (rainfall varies between 3000-4500 mm) and comprises Karwar, Ankola, Kumta, Honnavar and Bhatkal taluks. The

Sahyadri interior region of the Western Ghats (500-1000 m high), which is very humid to the south (rainfall varies from 4000-5500 mm) and comprises Sirsi, Siddapur, Supa and Yellapura. The plains are regions of transition, which are drier (rainfall varies between 1500-2000 mm), and comprises Mundgod and Haliyal. Statistically significant equations based on basal area with land use and interior forest were obtained and given in equations 3, 4 and 5 respectively for coastal, Sahyadri and plains. Validation of basal area based on equation 3-5 was done with the known basal area in the respective grids (Figure 8.4). Later, basal area for all grids in the coast, Sahyadrian interior and plains of Uttara Kannada was computed considering forest land use and interior forests equations (in the respective grids) using equations 3, 4 and 5.

For Coastal regions,

$$\text{BA} = \{30.1 + \left(0.0414 \times (forest\ land\ use) + 0.053 \times (interior\ forest)\right)\};$$
$$n = 50, SE = 6.2 \qquad ...3$$

For Sahyadri Interior region,

$$\text{BA} = \{39.1 + \left(-0.099 \times (forest\ land\ use) + 0.091 \times (interior\ forest)\right)\};$$
$$n = 55, SE = 6.3 \qquad ...4$$

For plain region,

$$\text{BA} = \{34.8 + \left(-0.186 \times (forest\ land\ use) + 0.12 \times (interior\ forest)\right)\};$$
$$n = 11, SE = 5.5\ . \qquad ..5$$

Where n is number of transects and SE refers to standard error.

Biomass is computed for all grids considering the allometric equations (Table 8.4) of respective agro-climatic zones. Aggregation of grids for respective taluks, provided the taluk level biomass and sequestered carbon. Net annual increment is the rate of storage of organic matter in above-ground tree tissues. Taluk wise biomass productivity from forests in Uttara Kannada district is estimated based on Table 8.4 and 8.5. Gross annual increment in biomass is computed considering the average increments per ha in the respective forest type multiplied by its spatial extent. Biomass productivity (Table 8.5, fuel wood, litter, dead and fallen branches, etc.) is computed based on earlier estimates (Rai and Proctor, 1986; Ramachandra et al., 2000) taking into consideration wood litter fall and dead wood trees, etc. The values which are shown in bold (Table 8.5) are used for the computation of grid-wise annual biomass productivities in the three agro climatic zones: Sahyadri interior 6.50 t/ha/y; coastal 1.50 t/ha/y; plains 0.50 t/ha/y. Per capita fuel wood consumption (PCFC) is considered as 0.7 t/capita/year (average estimate) based on the field data from villages in Kumta, Sirsi, Siddapur, Honnavar and Ankola. Taluk level fuel wood requirement is computed considering PCFC and the respective taluk population for 2001 and 2011. The ratio of biomass availability (biomass productivity) to the demand indicates the status of the bio resources in the region. Values >1 indicates the surplus resources while values <1 indicates the scarcity of resources in the region.

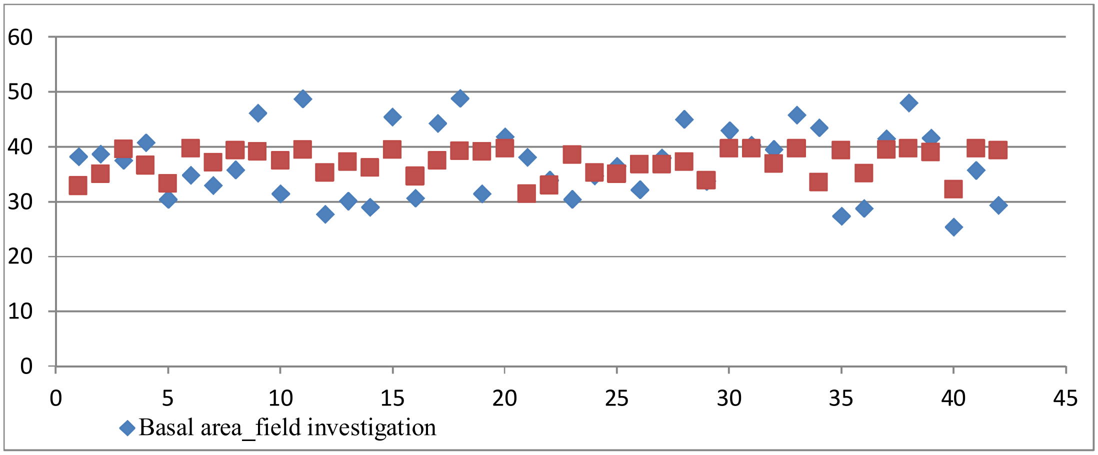


Figure 4: Comparison of predicted and estimated basal areas

Table 8.4: Biomass computation for different agro zones

Index	Equation	Significance	Region applied
Basal area (BA) (m^2)	$(DBH)^2/4\pi$	To estimate basal area from DBH values	All
Biomass (T/Ha)	$(2.81 + 6.78 \times BA)$	Biomass computation from basal area (effective for semi evergreen, moist deciduous forest cover types and having moderate rain fall)	Coastal
Biomass (T/Ha)	$(21.297 - 6.953(DBH)) + 0.740(DBH^2)$	Biomass computation from DBH values (effective for wet evergreen, semi evergreen forest cover types and having higher rainfall)	Sahyadri Interior
Biomass (T/Ha)	$exp\{-1.996 + 2.32 \times \ln(DBH)\}$	Biomass computation from DBH values (effective for deciduous forest cover types and having lower rainfall)	Plains
Carbon stored (T/Ha)	$(Estimated\ biomass) \times 0.5$	Sequestered carbon content in the region by	All

		forests	
Annual Increment in Biomass (T/Ha)	$(Forest\ cover) \times 6.5$	Incremental growth in biomass (Ramachandra et al., 2000)	Coastal
	$(Forest\ cover) \times 13.41$		Sahyadri
	$(Forest\ cover) \times 7.5$		Plains
Annual increment in Carbon (T/Ha)	(Annual Increment in Biomass) $\times 0.5$	Incremental growth in carbon storage	All
Net annual Biomass productivity (T/Ha)	$(Forest\ cover) \times 3.95$	Used to compute the annual availability of woody biomass in the region. (Ramachandra et al., 2000)	Coastal
	$(Forest\ cover) \times 5.3$		Sahyadri
	$(Forest\ cover) \times 3.5$		Plains
Carbon sequestration of forest soil (T/Ha)	$(Forest\ cover) \times 152.9$	Carbon stored in soil (Ravindranath et al., 1996)	Coastal
	$(Forest\ cover) \times 171.75$		Sahyadri
	$(Forest\ cover) \times 57.99$		Plains
Annual Increment of soil carbon	$(Forest\ cover) \times 2.5$	Annual increment in carbon stored in soil	All

Table 8.5: Biomass productivities in various types of vegetation

Sno.	**Vegetation types**	**Biomass (t/ha/year)**
1	Dense evergreen and semi evergreen	13.41 to 27.0
2	Low evergreen	3.60 to **6.50**
3	Secondary evergreen	3.60 to 6.50
4	Dense deciduous forest	3.90 to13.50
5	Savanna woodland	**0.50** to 3.50
6	Coastal (scrub to moist deciduous)	0.90 to **1.50**

II. **Carbon emission analysis:** Sector wise carbon emissions were estimated based on the data compiled from various sources.

i. **Livestock:** livestock population for 2011 were obtained from the State Veterinary Department, Government of Karnataka (2011 census) and are listed in Table 8.6. Siddapur, Sirsi, Joida and Yellapura are the potential regions for dairy development. Livestock density (equation 6) is computed village wise.

$$D = {}^{P_i}\!/_{A} \qquad \ldots.6$$

Where, D is Livestock density, Pi is Livestock population and A is Area of the region

Table 8.6: The livestock available at category wise of Uttara Kannada region for the year 2011

Taluk	Livestock Category								
	Cattle	Buffalo	Pig	Sheep	Goat	Rabbits	Dogs	Others	Taluk Total
Ankola	28570	5967	0	0	40	2	9575	0	44154
Bhatkal	24619	6094	84	0	110	44	6316	0	37267
Haliyal	41485	20820	32	354	3738	58	6421	0	72908
Honnavar	47828	8849	83	18	6	9	7396	0	64189
Karwar	11218	5460	294	55	4	85	8335	0	25451
Kumta	35891	5820	6	0	18	3	11847	0	53585
Mundgod	32122	8686	62	1433	3039	8	6460	19	51829
Siddapur	43881	18897	0	128	235	0	8080	6	71227
Sirsi	52230	18845	24	673	3101	44	13488	8	88413
Supa	19052	8224	0	0	843	6	5647	0	33772
Yellapur	30053	11007	315	41	860	18	9838	2	52134
Uttara Kannada (Dist. Total)	366949	118669	900	2702	11994	277	93403	35	594929

ii. **GHG gas emission: GHG emissions** from livestock through enteric emission were calculated following IPCC, 2006 (IPCC, 2006, ch. 10–11). As per the guidelines, Tier 1 uses emission factors based on empirical analysis and models provided by the IPCC (IPCC, 2006, ch. 10). The Tier 1 method was selected to estimate the emission values (Gg - giga grams) from livestock (IPCC, 2006; Velychko and Gordiyenko, 2007).

iii. **Methane emission from enteric fermentation:** The enteric fermentation methane emission factor EF_T for each animal category was taken from the IPCC guidelines (IPCC, 2006, table 10.10, prior to the 2009 revision). The differences in the emission factors are driven by differences in feed intake and feed characteristic assumptions; IPCC (2006) gives emission factors for typical regional (Indian) conditions. Methane emissions from enteric fermentation are given Equation 7 based on Tier 1 calculations (IPCC, 2006, eq. 10.19).

$$\boldsymbol{CH_4}\ \textbf{Enteric} = {\sum_T (EF_T \times N_T)}/{10^6} \quad \ldots\ldots 7$$

Where, CH_4 Enteric is CH_4 emissions from enteric fermentation,$GgCH_4/yr$; EF_T is emission factor for the defined livestock category, kg CH_4 $_{Head}{-1}$ yr−1; N_T is the number of head of livestock for category T; T is category of livestock.

iv. **Methane emission from manure:** Emission factors represent the range in manure volatile solids content and in manure management practices used in each region, as well as the difference in emissions due to temperature. The emission factors EF_T (for various average annual temperature) are given by IPCC for the respective livestock categories (IPCC, 2006, tables 10.14, 10.15, 10.16). Methane CH_4 emissions due to manure management (IPCC, 2006, eq. 10.22) is given by equation 8

$$\boldsymbol{CH_4}\ \textbf{Manure} = \sum_T (EF_T \times N_T) / 10^6 \quad \ldots..8$$

Where, CH_4 is methane emissions from manure (Gg CH_4/yr) by area; EF_T is emission factor for the defined livestock category, kg CH_4 Head−1 yr−1 by region; N_T is the number of head of livestock for category T in the region; Tis category of livestock.

Emission factors based on earlier field estimates were used to compute category wise emission, which are listed below.

- Emission factor 2.83 to 76.65 kg CH_4 $_{Head}$−1 yr−1 (Singhal et al., 2005) for enteric fermentation (table 8.7). Average values have been taken to compute the carbon emissions at village level. High and low case scenario has also being taken into consideration.
- Emission factor of 0.8±0.04 to 3.3±0.16 kg CH_4 $_{Head}$−1 yr−1 (Gupta et al., 2007 for manure management of bovines (table 8.8).
- Emission factor of 0.1 to 6 kg CH_4 $_{Head}$−1 yr−1 (IPCC, 1996) for manure management of non-bovines.

Table 8.7: Emission factors for enteric fermentation.

Source categories	Details	Emission factors (kg CH_4 Head−1 yr−1)
Cattle	Cattle-crossbred (male),4-12 months	9.02
	Cattle –crossbred (male),1-3 years	19.67
	Cattle–crossbred(male),,3years Breeding	36.14
	Cattle-crossbred male, Working	36.31
	Cattle–crossbred (male),Breeding and Working	34.05
	Cattle-crossbred(male),others	26.07
	Cattle-crossbred(female),4-12months	9.71
	Cattle-crossbred(female,1-3 years	21.31
	Cattle-crossbred(female),Milking	38.83
	Cattle-crossbred(female),Dry	38.51
	Cattle-crossbred(female)Heifer	21.49
	Cattle-crossbred(female),others	23.6
	Cattle-indigenous(male),0-12 months	7.6
	Cattle–indigenous(male),1-3years	16.36
	Cattle-indigenous(male,<3years Breeding	34.86
	Cattle-indigenous(male),Working	32.94
	Cattle-indigenous(male),Breeding and Working	29.42
	Cattle-indigenous(male),others	24.37
	Cattle-indigenous(female),4-12months	7.39
	Cattle-indigenous female,1-3years	15.39
	Cattle-indigenous(female),Milking	35.97
	Cattle-indigenous(female),Dry	29.38
	Cattle-indigenous(female),Heifer	22.42
	Cattle-indigenous(female),others	24.1
Buffalo	Buffalo(male),0-12months	5.09
	Buffalo(male),1-3years	14.78
	Buffalo(male),<3years Breeding	58.69
	Buffalo(male),Working	66.15
	Buffalo (male),Breeding and Working	54.28
	Buffalo (male),others	60.61
	Buffalo(female),(0-1)months	6.06
	Buffalo(female),1-3years	17.35
	Buffalo(female),Milking	76.65
	Buffalo(female),Dry	56.28
	Buffalo(female),Heifer	36.81
	Buffalo(female),others	38.99
Goat	Goat (male),<1 year	2.83
	Goat (male,>1 year	4.23
	Goat (female,<1 year	2.92
	Goat (female,<1 year milking	4.99
	Goat (female),<1 year dry	4.93
Sheep	Sheep	3.67
Others	Others	8.64
Livestock enteric fermentation (Singhal et al., 2005)		

Table 8.8: Emission factors for manure.

Source categories	Details	Emission factors (kg CH_4 Head−1 yr−1)
Cattle	Dairy cattle(crossbred),Adult	3.3±0.16
	Dairy cattle(Indigenous),Adult	2.7±0.13
	Non-Dairy cattle (Crossbred),0-1 year	0.8±0.04
	Non-Dairy cattle (Crossbred),1-2.5year	1.7±0.08
	Non -Dairy cattle(Crossbred),Adult	2.3±0.11
	Non-Dairy cattle (Indigenous),0-1 year	0.8±0.04
	Non Dairy cattle(Indigenous),1-3year	2±0.1
	Non Dairy cattle(Crossbred),Adult	2.8±0.14
Buffalo	Dairy buffalo	3.3±0.06
	Non-Dairybuffalo,0-1 year	1.2±0.02
	Non- Dairybuffalo,1-3year	2.3±0.04
	Non-Dairy buffalo, Adult	2.7±0.05
Livestock manure management (Gupta, et al., 2007)		

v. **Global Warming potential:** Global warming potential (GWP) compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. GWP is calculated over a specific time interval, commonly 20, 100 or 500 years. GWP values allow comparisons of the impacts of emissions and reductions of different gases. According to the IPCC, GWPs typically have an uncertainty of roughly ±35% (Forster et al., 2007). CO has a small direct GWP but leads to indirect radiative effects that are similar to those of CH_4. As in the case of CH_4, the production of CO_2 from oxidised CO can lead to double counting of this CO_2. The emission of CO perturbs OH, which in turn can then lead to an increase in the CH_4 lifetime (Daniel and Solomon, 1998). The greenhouse gas (GHG) emissions are converted into CO_2 equivalents so they can be compared.

Table 8.9: The effectiveness of different gases at trapping heat in the atmosphere (EPA, 2002).

Greenhouse gases	Global Warming potential (GWP)
CO_2	1
CH_4	21
N_2O	310
CO	1 to 3 = ~1.5

vi. **Paddy cultivation:** Rice is grown in almost all the parts of Uttara Kannada district. It occupies 30% of total cropped area of the area. Rain fed water logged category of paddy fields constitutes 41% of the total harvested area and methane emission is computed using equation 9.

$$CH_4 \textbf{ Rice} = (EF \times t \times A) \quad .....9$$

Where, CH_4 Rice is the annual methane emissions from rice cultivation, Gg CH_4 yr-1; EF is a daily emission factor for kg CH_4 ha-1 day; t is cultivation period of rice for day; A is annual harvested area of rice ha yr-1. The emission Factors were based on the earlier field experiments (Parashar et al., 1996 and Gupta et al., 2009) and are listed in table 8.10.

Table 8.10: Emission Factors for Paddy cultivation.

Paddy cultivation (Million Ha)		States	Integrated Seasonal CH_4 Flux (g/m2)			Total Methane Emission (Tg/Y)		
			Max	Mean	Min	Max	Mean	Min
Eastern Region	1.593	West Bengal	30.6	23.1	16	0.49	0.37	0.26
	1.892	Bihar	24.9	18.9	13.1	0.47	0.36	0.25
	1.44	Orissa	15.3	11.8	8.3	0.22	0.17	0.12
	0.525	Assam	62	46	32	0.33	0.24	0.17
	0.244	Northeast States	62	46	32	0.15	0.11	0.08
Southern region	2.705	Andhra Pradesh	15	11	7	0.62	0.45	0.29
	1.417	Tamil Nadu	15	11	7	0.62	0.45	0.29
	0.238	Kerala	15	11	7	0.62	0.45	0.29
	0.718	Karnataka	15	11	7	0.14	0.1	-0.07
Northern region	1.458	Uttar Pradesh	24.9	18.9	13.1	1.03	0.75	0.52
	1.91	Punjab	24.9	18.9	13.1	1.03	0.75	0.52
	0.62	Haryana	24.9	18.9	13.1	1.03	0.75	0.52
	0.003	Delhi	24.9	18.9	13.1	1.03	0.75	0.52
Western region	0.912	Madhya Pradesh	15.3	11.6	8	0.27	0.2	0.14
	0.28	Maharashtra	15.3	11.6	8	0.27	0.2	0.14
	0.39	Gujarat	15.3	11.6	8	0.27	0.2	0.14
	0.16	Rajasthan	15.3	11.6	8	0.27	0.2	0.14
All deep water areas	2.434		26	19	13	0.63	0.46	0.32
All rain fed areas	17.328		5.9	4.3	2.6	1.02	0.75	0.45
Upland areas	5.973		Nil	Nil	Nil	Nil	Nil	Nil
Grand Total	42.232					5.37	4.04	2.67
Paddy cultivation (Parashar et al., 1996) (g/m2)								

vii. **Fuel wood consumption:** Per Capita Fuel Consumption (PCFC) values (Equation 10, Table 8.11) were used to analyse fuel consumption pattern in various agro-climatic zones of the Uttara Kannada district and determine the carbon emissions due to fuel wood consumption at domestic level.

$$\text{PCFC} = {FC}/{\sum Ai} \quad \ldots.. 10$$

Where PCCF is per capita fuel consumption; FC is fuel consumed in kgs/day and Ai is number of adult equivalents, depend on the number of individuals and the age group (i = 1 for adult male, 0.8 for adult female, 0.6 for children (age group 6-18), 0.4 for children), for whom food was cooked.

Table 8.11: Season wise and region wise cooking fuel wood requirement (PCFC).

Agro-climatic Region	Cooking fuel wood (kg/person/day)								Cooking fuel wood (tons/person/year)
	Summer		Monsoon		Winter		Average		
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	
Coastal	1.98	1.40	1.95	1.34	2.11	1.73	2.01	1.49	0.73365
Plains	2.02	1.34	2.22	1.38	2.32	1.59	2.19	1.44	0.79935
Sahyadri	2.22	1.56	2.23	1.94	2.51	2.77	2.32	2.09	0.8468
(Ramachandra et al., 2000)									

The emission is computed based on the field data of fuel wood consumption (Ramachandra et al., 2000; NPC, 1987; TIFAC, 1991; IPCC, 1996) by equation 11:

$$\text{Carbon dioxide emission} = (No\ of\ households \times \text{PCFC} \times \text{emission factor}) \quad \ldots 11$$

viii. **Transportation:** The major pollutant emitted from transport are Carbon dioxide (CO_2), Methane (CH_4), Carbon monoxide (CO), Nitrogen oxides (NO_x), Nitrous oxide (N_2O), Sulphur dioxide (SO_2), Non-methane volatile organic compounds (NMVOC), Particulate matter (PM) and Hydrocarbon (HC). Diesel is used in public passenger and cargo vehicles, while private two wheelers, light motor vehicles (passenger), car and jeeps use gasoline. Region specific emission factors of road transport, based on the type of vehicle compiled from various literatures including regulatory agencies (Mittal and Sharma, 2003, Ramachandra and Shwetmala, 2009; EEA, 2001; CPCB, 2007). It is assumed that, diesel is used as fuel in buses, Omni buses, taxi, trucks, lorries, light motor vehicles (goods), trailers and tractors, while two wheelers, light motor vehicles (passenger), car and jeeps use gasoline. During 2008, total number of vehicles in (two wheelers, light motor vehicles, cars, jeeps, taxis, buses, trucks, lorries, trailers, tractors, and other vehicles) in Uttara Kannada were about 16 million (NRDMS, 2008). Vehicular emissions are calculated using equation12 (Gurjar, et al., 2004; Ramachandra and Shwetmala, 2009)

$$E_i = \sum(Veh_j \times D_j) \times E_{ij}\ km \qquad ....12$$

Where, E_i is emission of compound; Veh_j is Number of vehicles per type (j); D_j is Distance travelled in a year per different vehicle type (j); E_{ij}^{km} is Emission of compound (i) from vehicle type (j) per driven kilometer.

Bottom–up approach (Gurjar et al., 2004; Ramachandra and Shwetmala, 2009) was adopted for estimation of gaseous and particulate emission based on annual average utilization for different vehicle category, number of registered vehicles and the corresponding emission factors. Annual utilization of buses, Omni buses, two wheelers, light motor vehicles (passenger), cars and jeeps, and taxi were assumed to be 100 000, 100 000, 6300, 33 500, 12 600 and 12 600 km, respectively (buses, two wheelers, car and auto rickshaw; MoSRTH, 2007; Singh, 2006). Similarly for trucks and lorries, light motor vehicles (goods), and trailers and tractors were assumed as 25 000–90 000, 63 000 and 21 000 km yr^{-1} respectively (MoSRTH, 2007). These values were assumed based on five year planning reports of India. For other section of vehicles, annual utilization was calculated based on average of all above values. (Ramachandra and Shwetmala, 2009).

Taluk wise transport details were taken from NRDMS 2008-2009 for each taluk in Uttara Kannada district and are given in table 8.12. Figure 5 shows the distribution of vehicles in each taluk, where Karwar has the highest number of goods vehicles and auto rickshaws. Sirsi has the highest number of vehicles (32184) followed by Karwar with 26820 vehicles (table 8.12). Emission factors for vehicular emission were as per published literatures (CPCB, 2007; EEA, 2001; Ramachandra and Shwetmala, 2009) given in table 8.13.

Table 8.12: Taluk wise transport and communication of Uttara Kannada district.

Taluks	Motor cycles	Car	Cabs	Auto rickshaws	Omni buses	Tractors and trailers	Ambulance	Goods vehicle	others
Ankola	8141	775	55	341	124	31	10	592	406
Bhatkal	16776	1056	117	1078	76	41	6	353	467
Haliyal	14705	968	28	289	184	751	11	566	309
Honnavar	11479	687	145	449	177	22	8	645	376
Karwar	21763	1601	139	1018	325	85	12	1129	748
Kumta	12835	989	159	557	36	22	11	741	534
Mundgod	4171	275	11	87	35	574	4	227	105
Siddapur	4970	226	12	81	38	90	2	204	94
Sirsi	26001	1792	118	678	316	423	16	1545	1295
Supa	2423	400	25	9	39	96	8	89	63
Yellapura	5339	304	15	110	35	154	4	293	105
Total	128603	9073	824	4697	1385	2289	92	6384	4502

(NRDMS, 2008-2009)

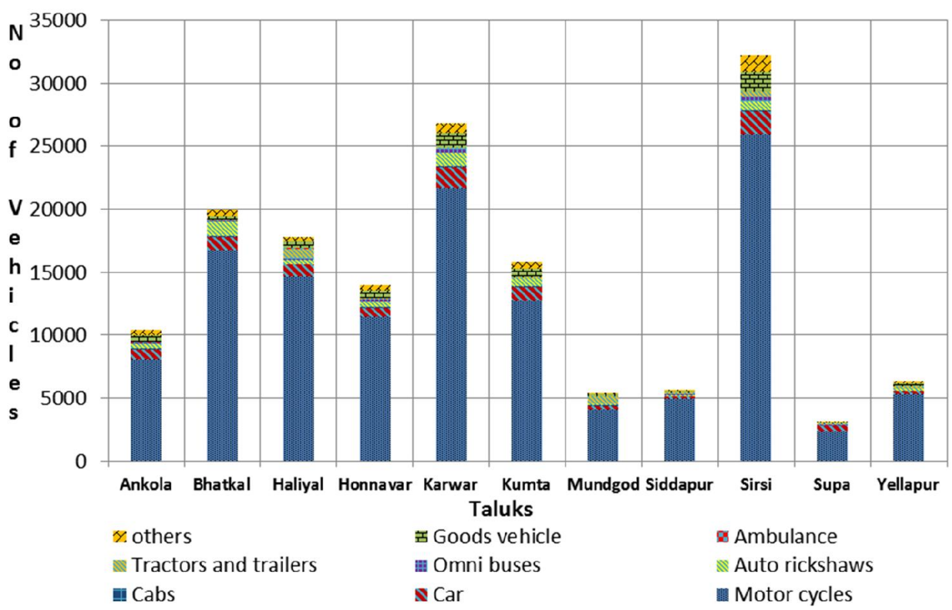


Fig 5: vehicles (category wise) in the district.

5. RESULTS AND DISCUSSION

The carbon sequestration and emission from various sectors is computed for budgeting carbon in the district. The land use is analysed and emission factors from various sources are collected for computation.

Table 8.13: Emission factors for vehicular emission.

Type of vehicle	Emission factors (g/km)			Reference
	CO_2	CH_4	CO	
Two wheelers for 2001-2005			2.2	CPCB, 2007
Motor cycles	26.6			Mittal and Sharma, 2003
Motor cycles		0.18		EEA, 2001
Auto rickshaw	60.3			Mittal and Sharma, 2003
Auto rickshaw		0.18		EEA, 2001
Passenger car gasoline(PCG)			2	CPCB, 2007
Cars	223.6			Mittal and Sharma, 2003
Cars		0.17		EEA, 2001
Taxi	208.3			Mittal and Sharma, 2003
Taxi		0.01		EEA, 2001
Taxi			1	Kandilikar and Ramachandran, 2000
Buses	515.2			Mittal and Sharma, 2003
Buses		0.09		EEA, 2001
Buses			3.6	CPCB, 2007
Goods vehicles	515.2			Mittal and Sharma, 2003
Goods vehicles		0.09		EEA, 2001
Trucks			3.6	CPCB, 2007
Light commercial vehicles(LCV)			5.1	CPCB, 2007

5.1 Carbon Sequestration: The necessity for environmental assessment at the landscape level has become vital to account the regional scale LULC changes. The land use land cover analysis is done to measure the spatio temporal changes of Uttara Kannada district. The spatial extent of temporal vegetation computed through NDVI reveals a decline of vegetation from 97.82% (1973) to 83.44% (2013). Areas under non-vegetation have increased to 16.66% (2013) from 2.18 % (1973), due to anthropogenic activities. Table 9.1 lists temporal land cover and figure 6.1 (a, b, c, d, e and f) depicts vegetation cover during 1973, 1979, 1989, 1999, 2010 and 2013.

Table 9.1: land cover analysis from 1973 to 2013

Year	% vegetation	% non-vegetation
1973	97.82	2.18
1979	97.24	2.76
1989	96.13	3.87
1999	94.33	6.67
2010	89.92	10.08
2013	83.44	16.66

Temporal remote sensing data have been classified through Gaussian Maximum Likelihood Classifier [GMLC]. Landsat data available in the public domain and IRS data (2010) corresponding to the study area were classified into eleven land use categories: Evergreen forest to semi evergreen forest, moist deciduous forest, Shrub lands/grass lands, Dry deciduous forest, Acacia/Eucalyptus/ other hardwood plantations, Teak/Bamboo/ other softwood plantations, Coconut/Areca nut plantations, Built-up, Water, Crop lands, Open fields. Table 3 lists land use details during 1973 to 2013. Figure 6.2 depicts land uses during 1973 to 2013 while land use category wise temporal changes is given in figure 6.3 (a, b, c, d, e and f). Comparative assessment of land use categories reveals the decline of vegetation cover in the district during 1973 to 2013 (table 9.2). The reduction of area under evergreen forests from **67.73**% (1973) to **32.09**% (2013) due to anthropogenic activities involving the conversion of forest land to agricultural and horticultural activities, monoculture plantations and land releases for developmental projects. Transition of evergreen-semi evergreen forests to moist deciduous forests, and some have been converted into plantations (such as Teak, Areca nut, Acacia spp., etc.). Enhanced agricultural activities is evident from the increase of agricultural land use from **7.00 (1973) to 14.13 % (2013)** and the area under human habitations have increased during the last four decades, evident from the increase of built-up area from **0.38%** (1973) to **3.07%** (2013). Unplanned developmental activities coupled with the enhanced agriculture and horticultural activities have aided as prime drivers of deforestation, leading to the irreversible loss of forest cover with the reduction of ecosystem goods and services. The increase in plantation of exotic species has led to the removal of forest cover and also extinctions of species. *Acacia auriculiformis, Casuarina equisetifolia, Eucalyptus spp., and Tectona grandis* have been planted widely in the district. Acacia and Teak plantations constitute 12.04% and 6.60% respectively in the district. The dry deciduous forest cover is very less (0.96%) and is found mainly in the north eastern part of the district in Mundgod taluk and partly Haliyal taluk.

The areas of each category were also compared with available administrative reports, statistical department data and forest division annual reports. Table 9.3 lists the accuracy of classifications, verified using field data and Google earth data. The collected field data is separated with respect to each category, 60% used as a training set and 40% used for verification. Accuracy of the classification ranges from 87 to 93% with more consistent results. Cautious steps were taken to make sure separate data sets used for training and validation. This is essential because there will be a chance of getting greater accuracy of classification but lesser ground consistent when same data is used both for classification and confirmation.

Table 9.2: land use variation from 1973 to 2013

Year / Category	1973		1979		1989		1999		2010		2013		Loss / Gain in area (1973-2013)
	Ha	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**Ha**	**%**	**(Ha)**
Built-up	3886	**0.38**	9738	0.95	12,982	1.26	21,635	2.10	28,491	2.77	31589	**3.07**	27703
Water	7,681	0.75	18527	1.80	16,604	1.61	32,983	3.21	26,119	2.54	28113	2.73	20432
Crop land	71,990	**7.00**	103163	10.02	121,167	11.77	138,458	13.45	148,187	14.40	145395	14.13	**73405**
Open fields	14071	1.37	15988	1.55	34,783	3.38	21,945	2.13	30,812	2.99	37660	3.66	23589
Moist deciduous forest	95,357	9.27	102967	10.01	143,849	13.98	179,075	17.40	166,266	16.15	161,996	15.74	66639
Evergreen to semi evergreen	696,978	67.73	589762	57.31	531,872	51.68	423,062	41.11	367,064	35.66	330,204	32.08	-366774
Scrub/grass	38,109	3.70	58936	5.73	44,123	4.29	47,366	4.60	35,158	3.42	40402	3.93	2293
Acacia/Eucalyptus/ hardwood plantations	40,905	**3.97**	50321	4.89	55,694	5.41	73,977	7.19	119,717	11.63	122927	**11.94**	82022
Teak/ Bamboo/ softwood plantations	13997	**1.36**	20896	2.03	21,937	2.13	38,588	3.75	44,794	4.35	67111	**6.52**	53114
Coconut/ Areca nut / Cashew nut plantations	20,702	**2.01**	29675	2.88	32,227	3.13	43,623	4.24	53,646	5.21	53,993	**5.25**	**33291**
Dry deciduous forest	25,410	2.47	29113	2.83	13,848	1.35	8374	0.81	9008	0.88	9873	0.96	-15537
Total	**1029086**												

Ecologically fragile swampy areas are being encroached and converted to plantations of *Areca catechu, Cocos nucifera*. Land use changes in this region is mainly due to extensive clearing of natural vegetation (deforestation) for agriculture expansions in the most productive lands, the abandonment of marginal lands and commercial plantations.

Construction of new roads and buildings, widening of highways increased dramatically during 1990's. The construction of roads and houses in valley slopes, have also enhanced the episodes of landslides in the district. More recently, the impetus to industrialization has encouraged the concentration of human populations at taluks such as Karwar, Bhatkal, Honnavara, Sirsi.

Table 9.3: Accuracy assessment of the study

Year	*Accuracy*	*Built-up*	*Water*	*Crop land*	*Open land*	*Moist deciduous*	*Evergreen to semi*	*Scrub*	*Acacia*	*Teak*	*Coconut*	*Dry deciduous*
1973	**PA**	67.61	90.73	83.14	86.54	82.36	90.24	58.92	72.39	74.85	50.16	92.27
	UA	66.69	89.94	79.26	86.42	81.45	89.82	57.52	71.58	78.18	66.02	91.84
1979	**PA**	68.66	92.00	95.45	81.73	68.16	93.00	64.41	65.58	47.18	38.57	46.47
	UA	90.00	85.40	74.30	78.56	85.05	89.15	90.78	93.43	94.84	94.67	74.10
1989	**PA**	98.28	99.62	95.83	91.58	88.76	94.59	92.28	97.44	84.41	38.83	80.89
	UA	77.6	95.53	87.09	93.84	97.00	97.84	98.16	74.33	59.18	73.75	70.07
1999	**PA**	79.88	98.14	98.62	76.22	88.72	98.02	85.61	89.93	81.63	88.22	88.86
	UA	88.4	97.67	98.35	83.32	95.9	96.68	84.79	85.81	82.4	89	31.5
2010	**PA**	60.34	99.77	97.49	89.81	87.92	93.91	93.24	92.53	78.68	89.92	86.78
	UA	94.14	99.56	90.11	89.13	85.54	96.3	85.7	90.98	91.1	80.02	86.85
2013	**PA**	92.53	95.32	80.00	86.25	92.84	96.53	67.71	69.08	78.68	91.03	97.49
	UA	23.87	96.80	98.10	68.05	88.50	98.90	13.59	94.10	91.10	97.70	90.11

*** PA – Producer's Accuracy; UA – User's Accuracy**

Year	*Overall Accuracy*	*Kappa*
1973	82.52	0.81
1979	84.29	0.81
1989	92.22	0.89
1999	90.71	0.87
2010	91.51	0.89
2013	91.98	0.90

Biomass and carbon sequestration by forests were estimated for each grids based on forest category. Biomass estimated per hectare for each grid is shown in figure 6.4. Sahyadri region shows higher standing biomass (>300 tons/Ha) due to the spatial extent of forests and in particular interior forests. In contrast to this, grids in the coastal and plains taluks have moderate and lower values of biomass per hectare. Sequestered carbon per hectare is computed with the help of biomass data (figure 6.5). Grids in the Sahyadri region have higher storage of carbon than other two regions. Standing biomass in each grid is estimated as explained in the methods section. The total standing biomass of the district is 118627.58 Gg. Figure 6.6 illustrates that Sahyadri region (Supa, Sirsi, Yellapura) have higher biomass of >1200 Gg. Coastal region (Karwar, Ankola, Kumta, Honnavar) is with moderate biomass.

The plains and part of coastal regions are with the lower biomass (< 200 Gg) due to higher deforestation. The plains taluks mainly consist of agriculture lands, built-up environments and sparse deciduous forest cover. Lowest biomass values were seen in savanna and disturbed moist deciduous forests (Eg. hill top savannas of Ankola, Siddapur and stretches of forests in Supa which were under extensive shifting cultivation until end of the 19^{th} century). Hill slopes and sacred groves had higher basal area and biomass with diverse species. Lowest biomass was also seen in deciduous to dry deciduous forests of Haliyal, Mundgod taluks.

Carbon sequestered by forests in each grid (of the district) is shown in figure 6.7, which accounts to 59313.8 Gg. Forests in Supa, Yellapura, Sirsi regions have stored higher carbon (600-800 & >800 Gg) compared to the plains and part of coastal regions. Sahyadri region with protected areas and 'sacred kan' forests have sequestered higher carbon, **emphasize the need for protecting forests to mitigate impending changes in the climate due to global warming**. These forests have been protected for long because of the cultural and religious significance attached to them and hence, were relatively less disturbed than others. This has allowed the trees to grow to their fullest and accumulate significantly more biomass than in most other areas, which are prone to ongoing human pressures or due to the disturbances in the past (as in a savannized land). The study of relic evergreen forests with swampy areas in Kathalekan of Siddapur taluk (Chandran et al., 2010) showed higher above ground biomass and carbon storage in the vegetation alongside streams and swamps and lesser above ground biomass in non-swampy regions. This compliment the current assessment of higher biomass and carbon >1200 Gg biomass and >500 Gg of carbon in the grids with relic kans, swampy regions (Sirsi, Siddapur taluks).

The annual increment in biomass is estimated and is given in figure 6.8 for all grids in the district. Grids in the Sahyadri region (Supa, Yellapura, Sirsi, Siddapur taluks) with the higher annual increment (>15-20 Gg) signify their role in carbon sequestration as well as mitigation of changes in the climate. This is followed by >10-15 Gg biomass increment by the central parts of coastal taluks with moderate growth in biomass (Kumta, Ankola, Karwar) and plains have least forest cover, with the lower increment in biomass. Carbon sequestration pattern in the district is illustrated in Figure 6.9. The Sahyadri taluks (Supa, Sirsi, Yellapura) have higher sequestration (>9 Gg) potential compare to other.

The net annual biomass productivity (dead wood, fallen branches, twigs, fuel wood) is computed to assess the biomass availability and is shown in figure 6.10. The grids in Supa, Karwar, Ankola, Yellapura, Kumta, Sirsi taluks have higher productivity (>15 Gg) compared to Mundgod with a very low biomass annual availability due to limited forest resources. Figure 6.11a shows biomass estimated for Uttara Kannada villages (figure 6.11(b) provides village names). The Sahyadri region villages have higher biomass compared to other regions and plains have very low biomass availability.

Bioenergy availability from forests is assessed as >80-85% population in this region (Ramachandra et al., 2000) depends on fuel wood as major source for cooking, heating, etc. Fuel wood demand is quantified for each grid considering the population and the annual PCFC (0.77 tons/person/year). Figure 6.12 (a) gives the population density for each grid as per 2011 population census. The population density values show Supa taluk (<50 person/sq.km) is having least density while Bhatkal (<250 person/sq.km) has higher population density. All coastal taluk grids towards west are highly populated; plains are showing moderate density and also taluk headquarters are also with the higher population density.

The supply (availability) to demand ratio is computed to assess the bioenergy status in each grid, considering the annual biomass productivity and fuel wood demand in each grid. Figure 6.12 (b) illustrates the bioenergy status in the district considering the ratio of availability to demand. The ratio less than one indicates of fuel wood scarcity while the ratio greater than one indicates of adequate availability of fuel wood.

The supply to demand ratio shows Supa taluk is having higher ratio revealing surplus biomass availability due to higher forest cover and lower demand. The central parts of grids (Karwar, Ankola, Sirsi) also show higher availability due to higher forest in those regions where as towards west in Karwar, Ankola and east part of Sirsi region shows lower ratio due to higher demand (presence of a larger population). Bhatkal, Haliyal, Mundgod and eastern part of Yellapura and Siddapur have the scarcity of resources evident from the supply to demand ratio less than one. Fuel wood scarcity is evident in thickly populated plains and coastal taluks, necessitating the policy interventions to augment bio-resources apart from viable energy alternatives.

Soil carbon constitutes the biggest terrestrial carbon pool. Carbon stored in soil pools is less vulnerable to release through disturbances like fire or harvest removals and emission to the atmosphere than the carbon that is stored in the above ground biomass. Table 9.4 lists the taluk wise carbon sequestration by forest soils. Supa (18585.35 Gg), Ankola (7460.48 Gg), Sirsi (7469 Gg) and Yellapura (6331.05 Gg) taluks have higher soil carbon due to good vegetation cover in the region. Bhatkal (1637 Gg) and Mundgod (595.49 Gg) taluks have very low soil carbon due to deforestation. The net storage of forest soil carbon in Uttara Kannada district is 59693.44Gg and figure 6.13 (a) gives grid-wise carbon sequestered in forest soil. The annual increment of 958.81 Gg is depicted grid wise in figure 6.13 (b). This indicates that forest soil in Supa, Yellapura, Karwar and Sirsi taluks have higher sequestration potential followed by Kumta and Ankola taluks with moderate potential. These regions have evergreen to semi evergreen and large patches of moist deciduous forest cover.

Table 9.4: Taluk wise natural forest soil carbon

Sno.	Agro-climatic region	Taluks	Total carbon stored in soil (Gg)	Annual Increment in Carbon (Gg)
1	Coast	Ankola	7460.48	119.90
2		Bhatkal	1637.00	26.75
3		Honnavar	3478.86	56.74
4		Karwar	5396.19	86.75
5		Kumta	3237.79	51.54
6	Sahyadri Interior	Siddapur	3739.44	54.64
7		Sirsi	7469.60	108.89
8		Supa	18585.35	271.08
9		Yellapura	6331.05	98.32
10	Plains	Haliyal	1762.19	59.47
11		Mundgod	595.49	24.73
Total			**59693.44**	**958.81**

Figure 6.1 (a, b, c, d, e, f) Land cover analysis from 1973 to 2013;

(a) 1973 (b) 1979 (c) 1989 (d) 1999 (e) 2010 (f) 2013

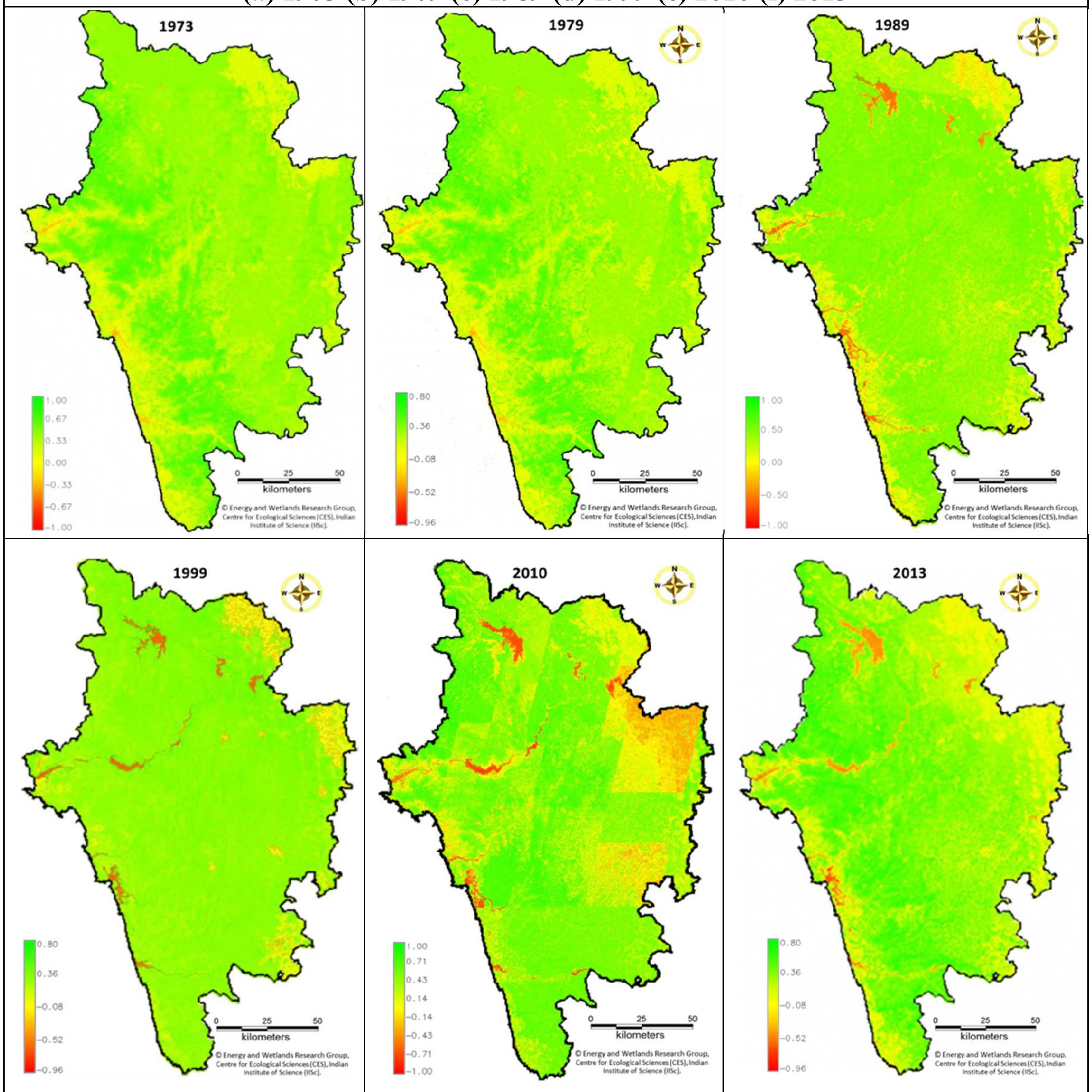


Figure 6.2: Spatio temporal land use dynamics from 1973 to 2013

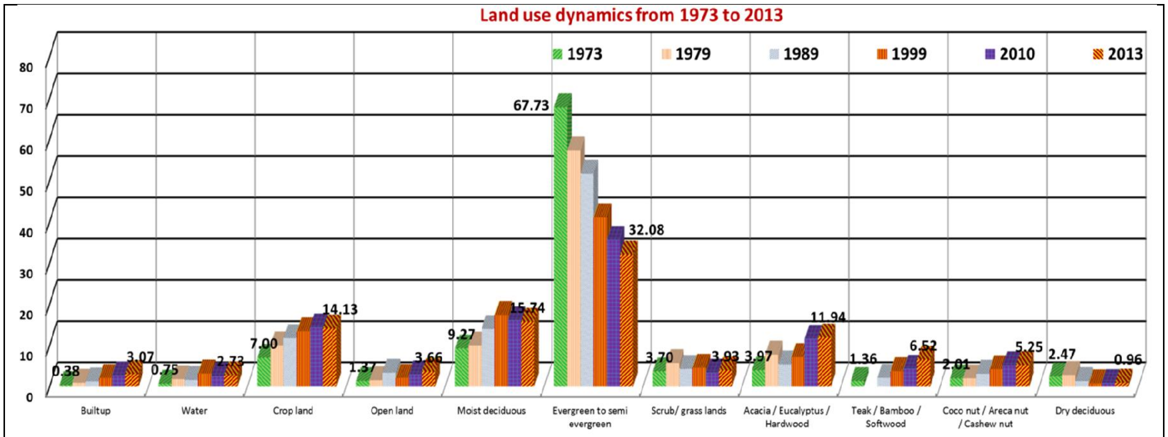
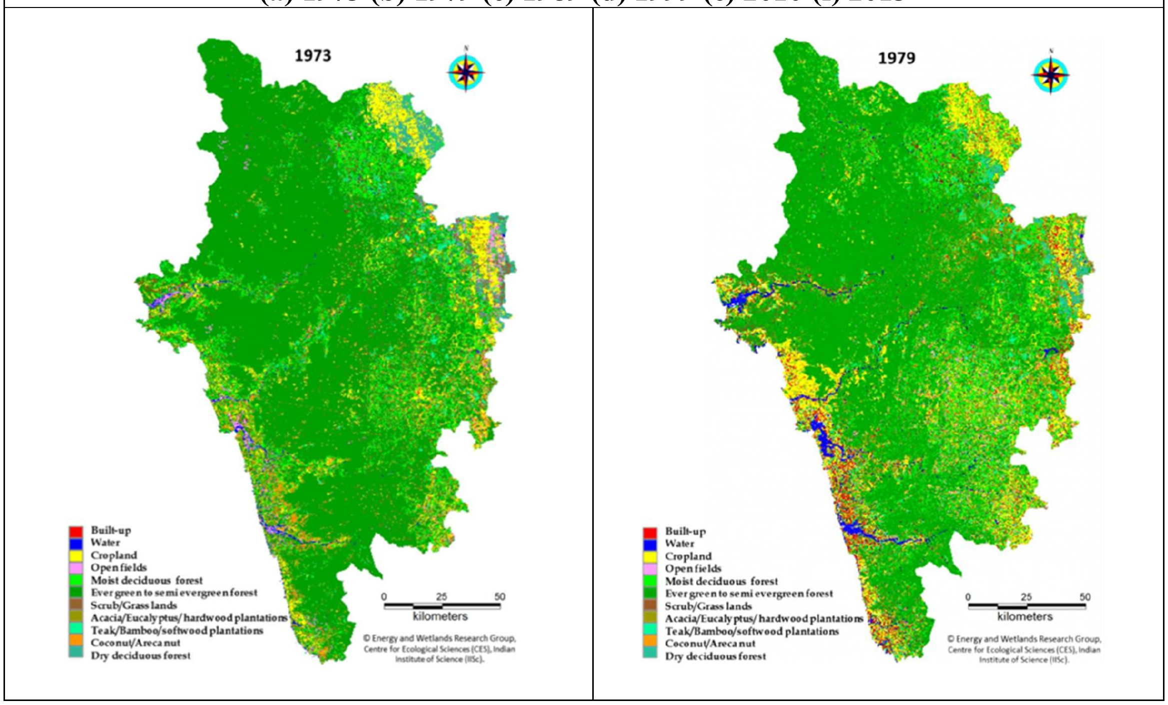
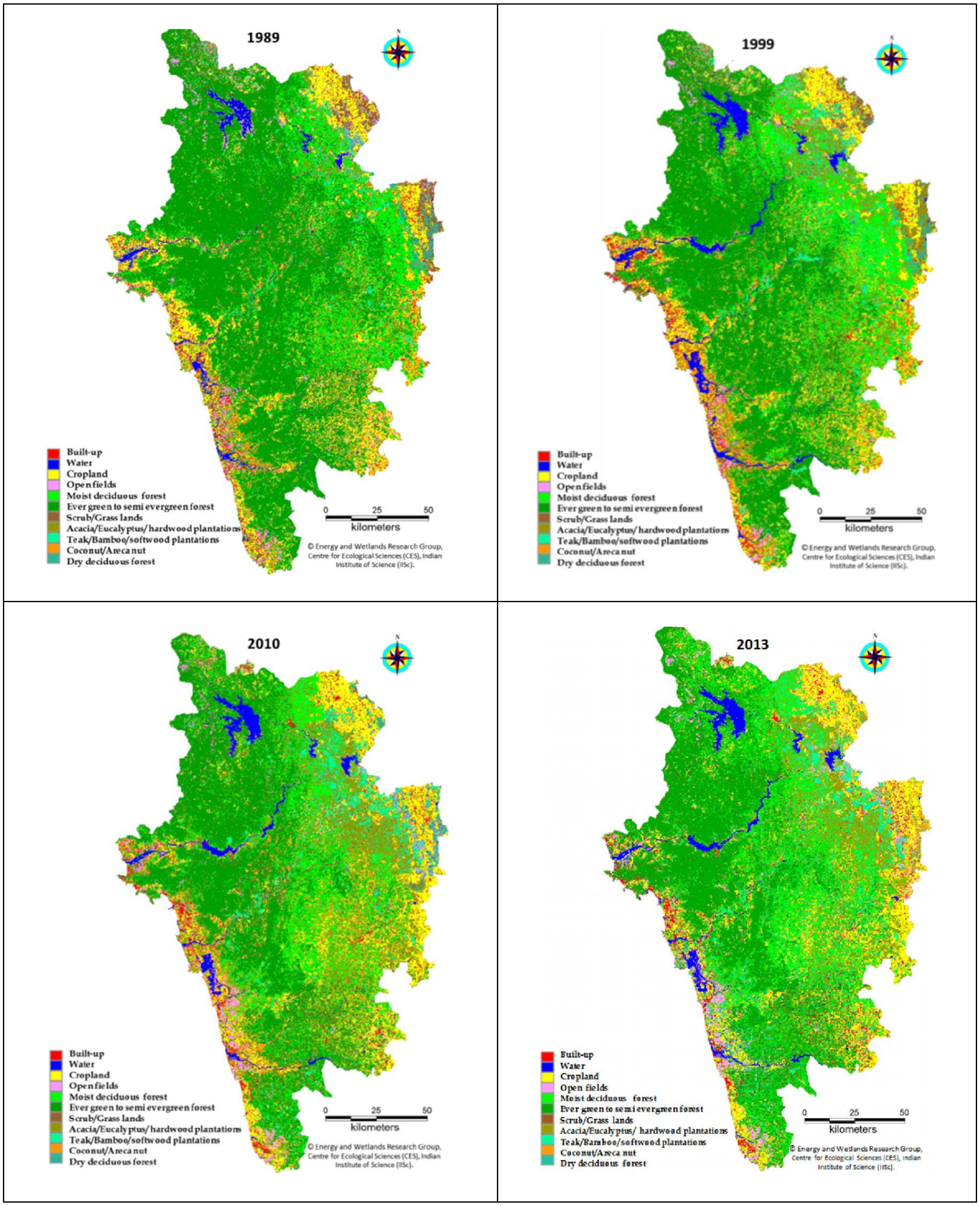


Figure 6.3: Uttara Kannada district land use change from 1973 to 2013;

(a) 1973 (b) 1979 (c) 1989 (d) 1999 (e) 2010 (f) 2013




1989
Built-up
Water
Cropland
Open fields
Moist deciduous forest
Ever green to semi evergreen forest
Scrub/Grass lands
Acacia/Eucalyptus/ hardwood plantations
Teak/Bamboo/softwood plantations
Coconut/Areca nut
Dry deciduous forest
0 25 50
kilometers
© Energy and Wetlands Research Group, Centre for Ecological Sciences (CES), Indian Institute of Science (IISc).
1999
Built-up
Water
Cropland
Open fields
Moist deciduous forest
Ever green to semi evergreen forest
Scrub/Grass lands
Acacia/Eucalyptus/ hardwood plantations
Teak/Bamboo/softwood plantations
Coconut/Areca nut
Dry deciduous forest
0 25 50
kilometers
© Energy and Wetlands Research Group, Centre for Ecological Sciences (CES), Indian Institute of Science (IISc).
2010
Built-up
Water
Cropland
Open fields
Moist deciduous forest
Ever green to semi evergreen forest
Scrub/Grass lands
Acacia/Eucalyptus/ hardwood plantations
Teak/Bamboo/softwood plantations
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Dry deciduous forest
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© Energy and Wetlands Research Group, Centre for Ecological Sciences (CES), Indian Institute of Science (IISc).
2013
Built-up
Water
Cropland
Open fields
Moist deciduous forest
Ever green to semi evergreen forest
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Teak/Bamboo/softwood plantations
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© Energy and Wetlands Research Group, Centre for Ecological Sciences (CES), Indian Institute of Science (IISc).

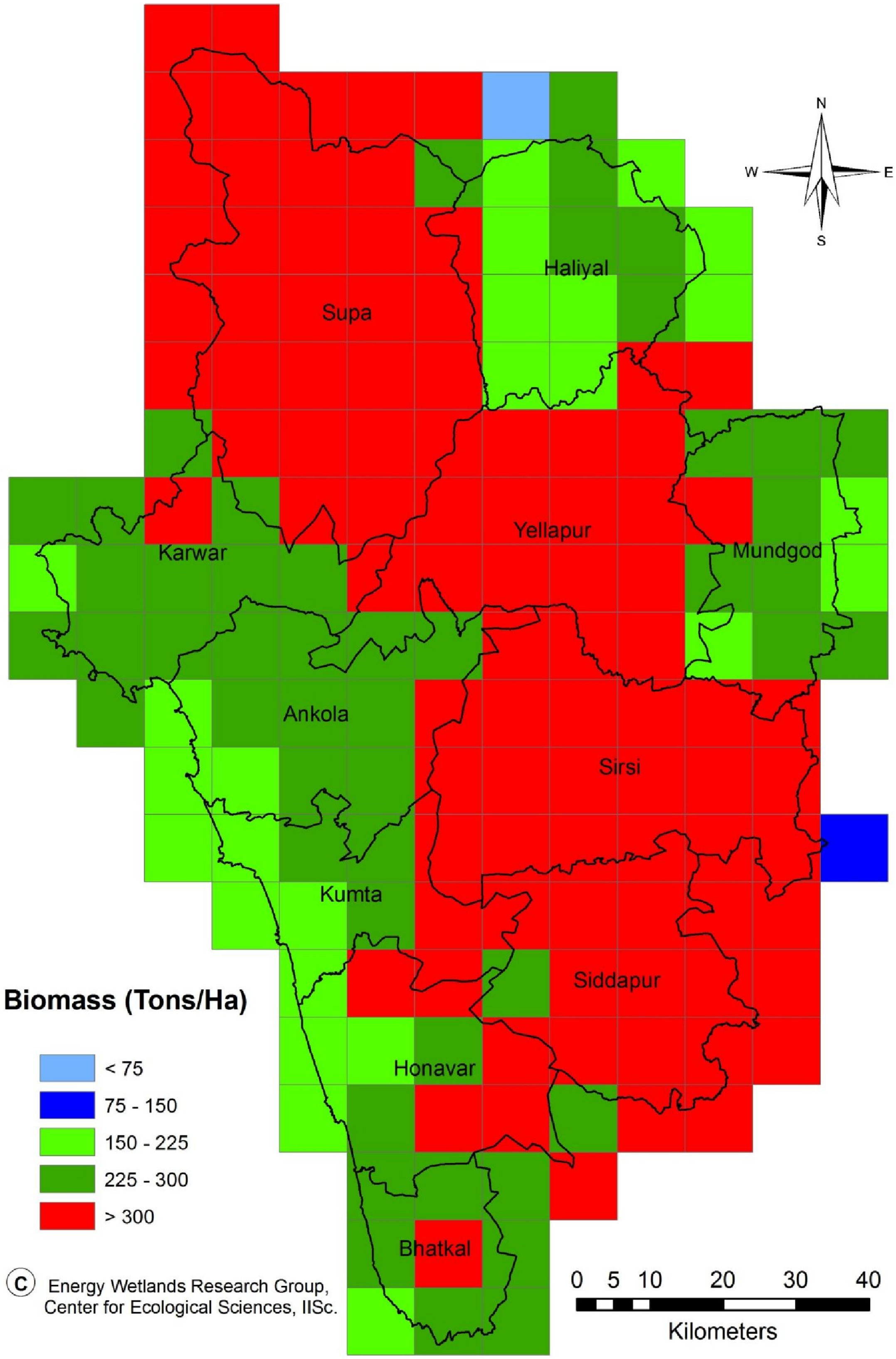


Figure 6.4: Biomass estimated per hectare

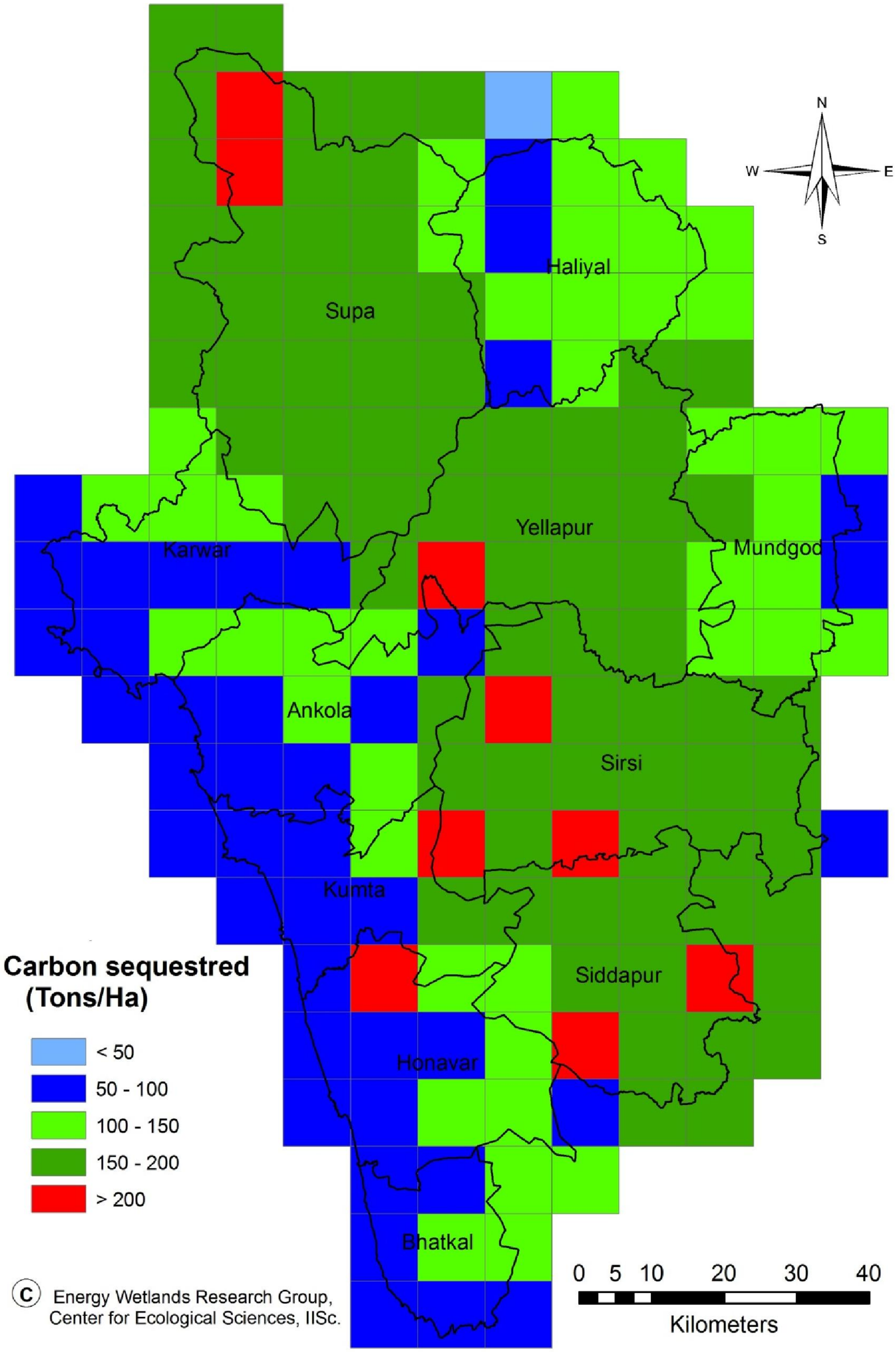


Figure 6.5: Carbon sequestered per hectare

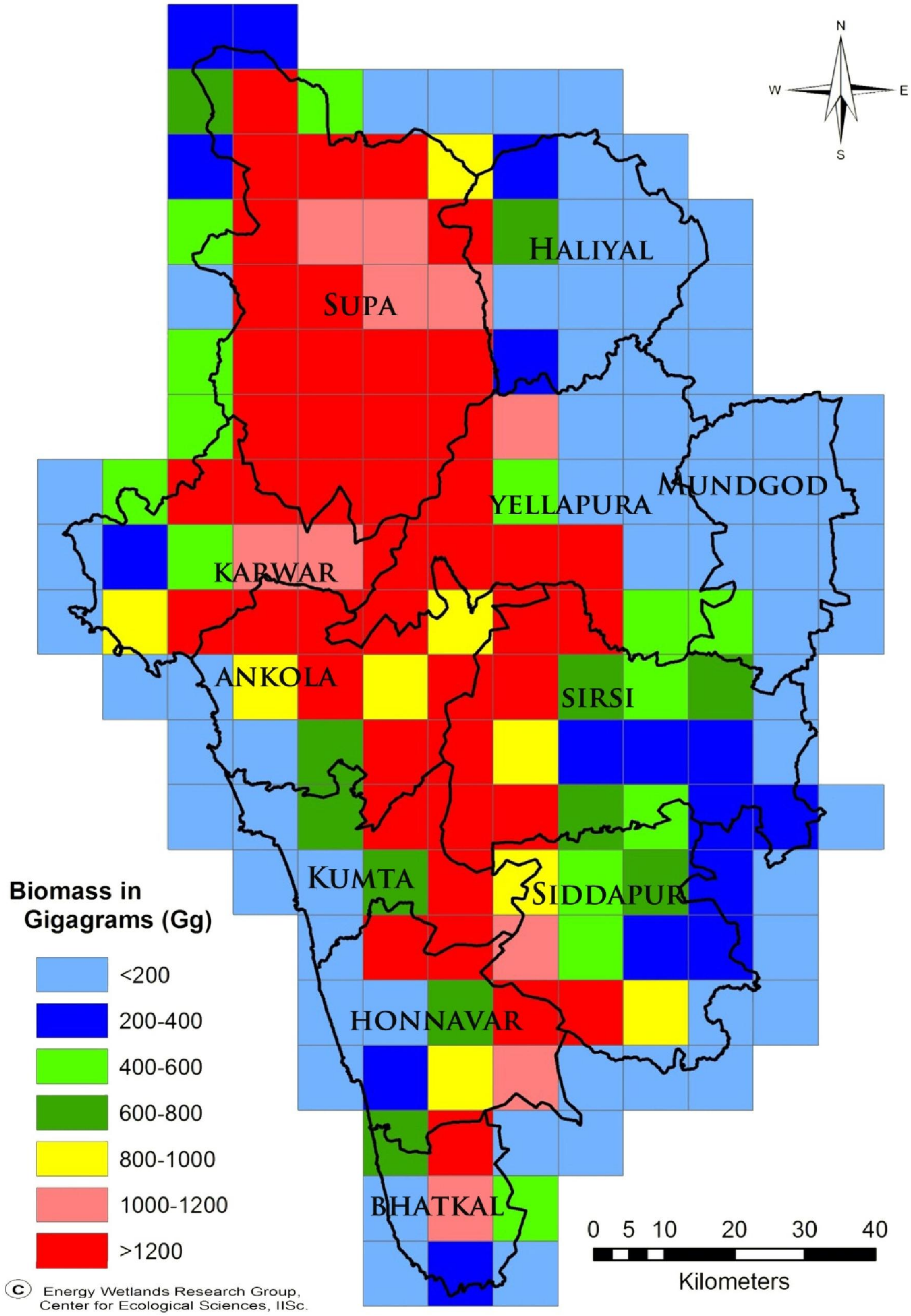


Figure 6.6: Biomass estimated in Gg.

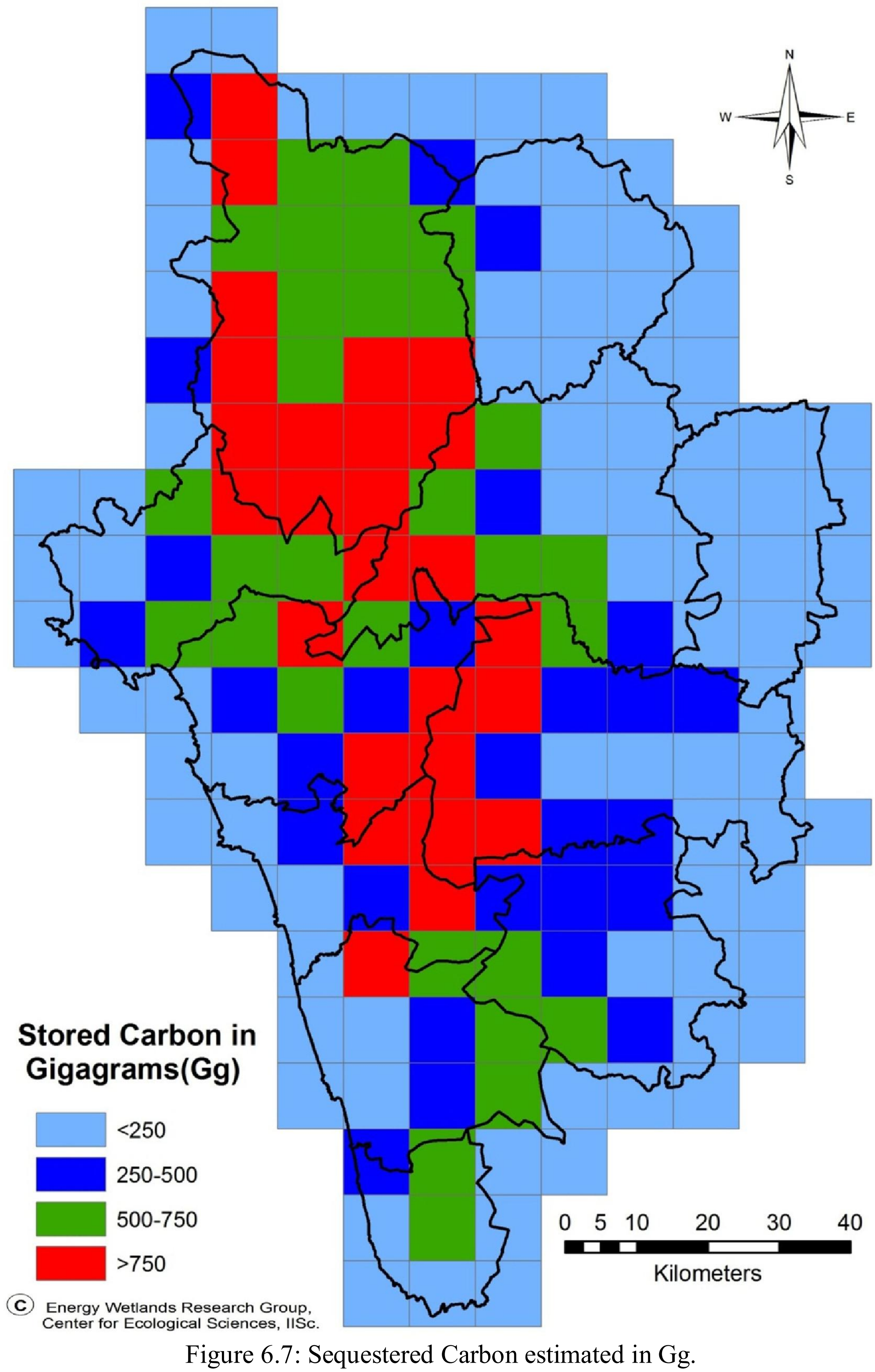


Figure 6.7: Sequestered Carbon estimated in Gg.

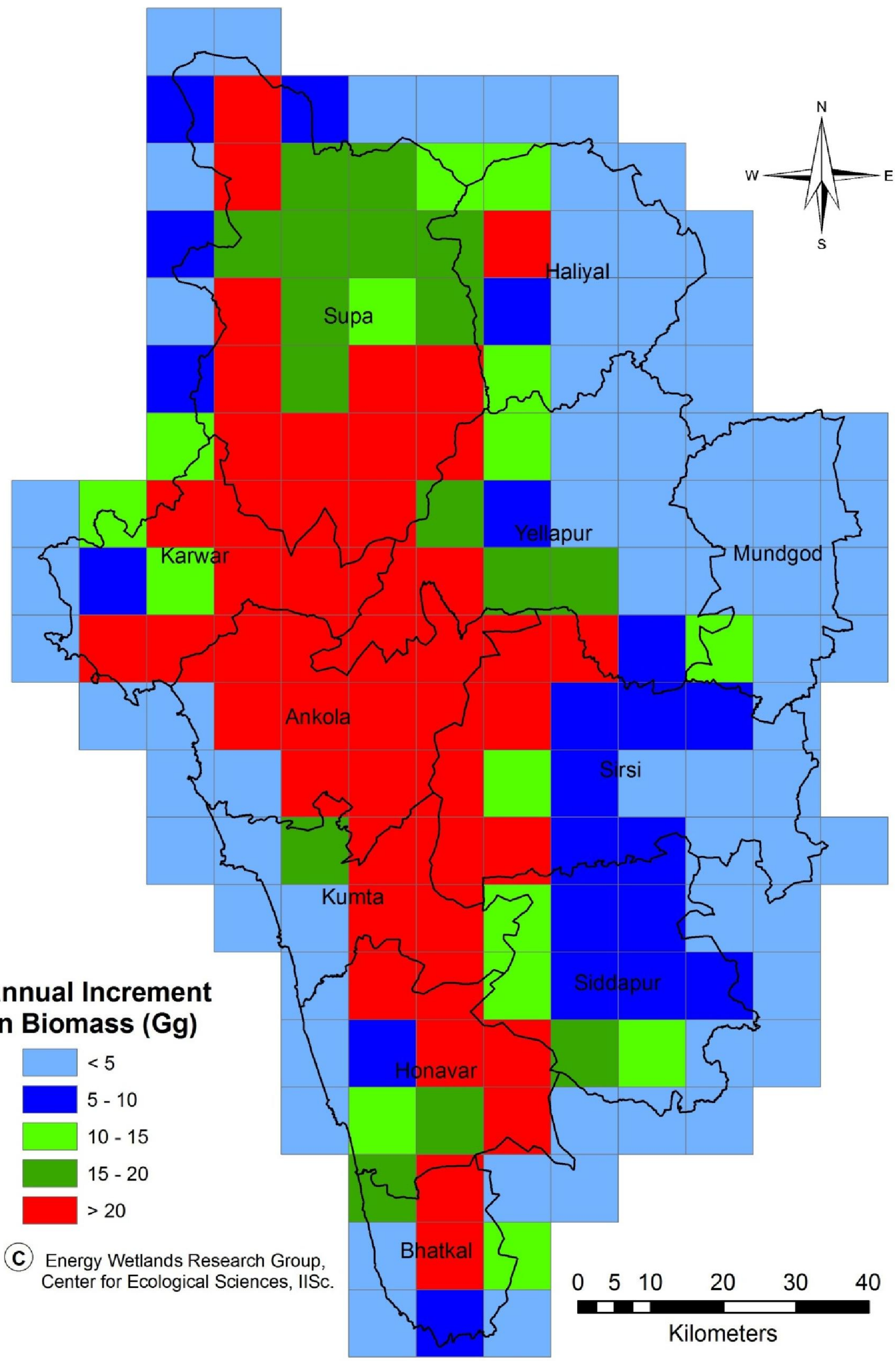


Figure 6.8: Annual increment in Biomass (Gg).

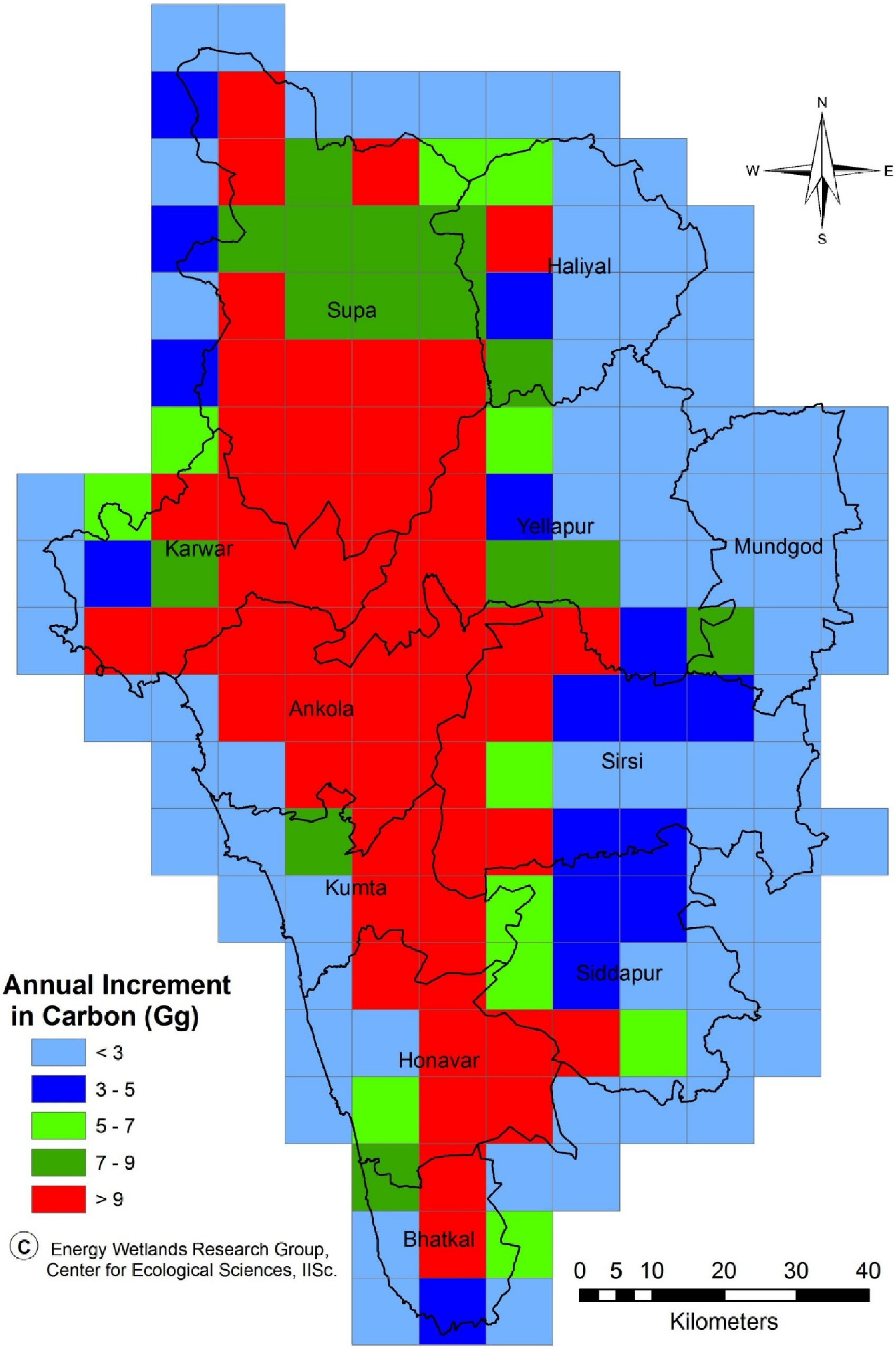


Figure 6.9: Annual increment in Carbon sequestration (Gg).

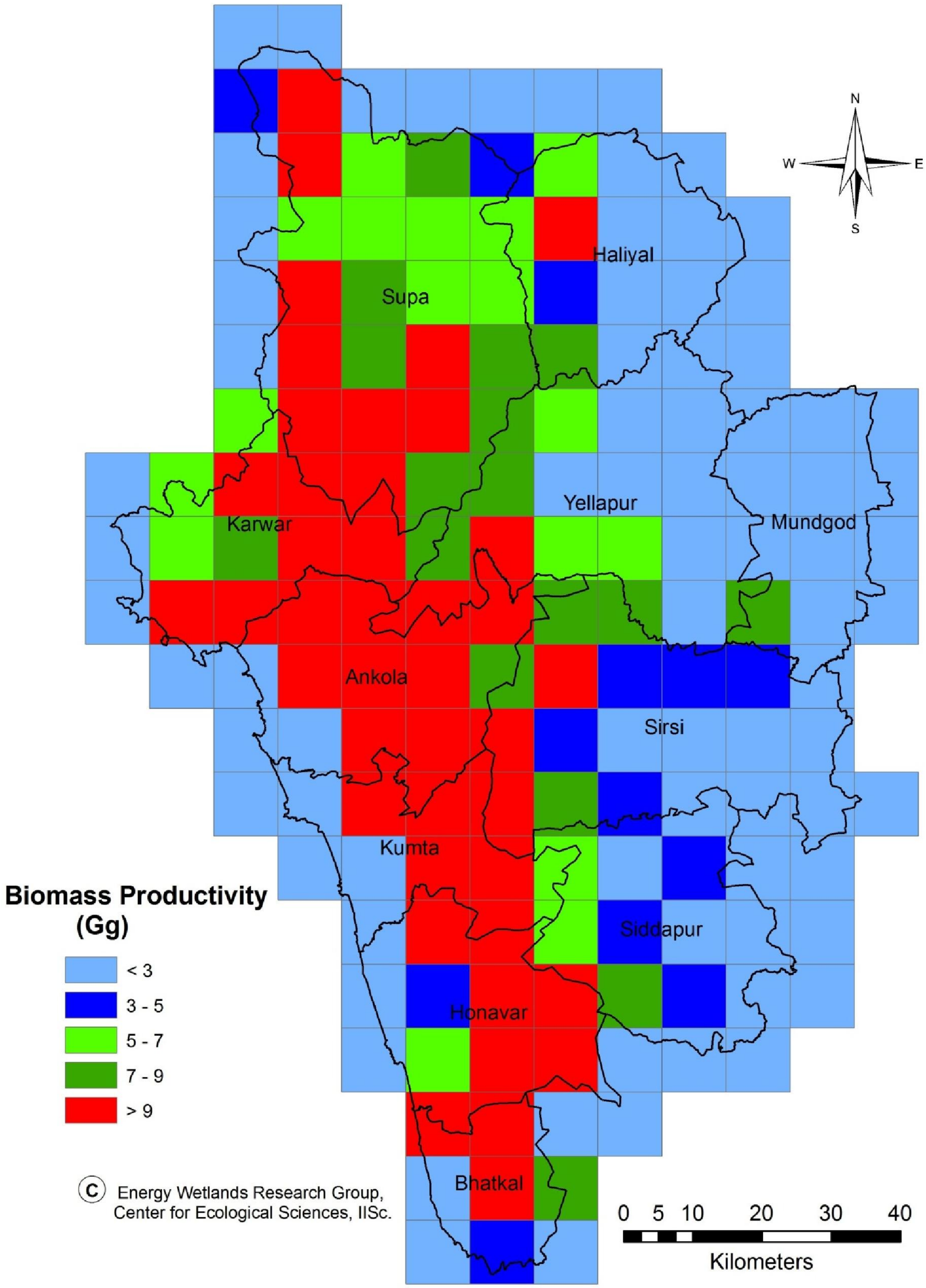


Figure 6.10: Annual biomass productivity (deadwood, twigs, fallen branches, etc.) in Uttara Kannada (Gg).

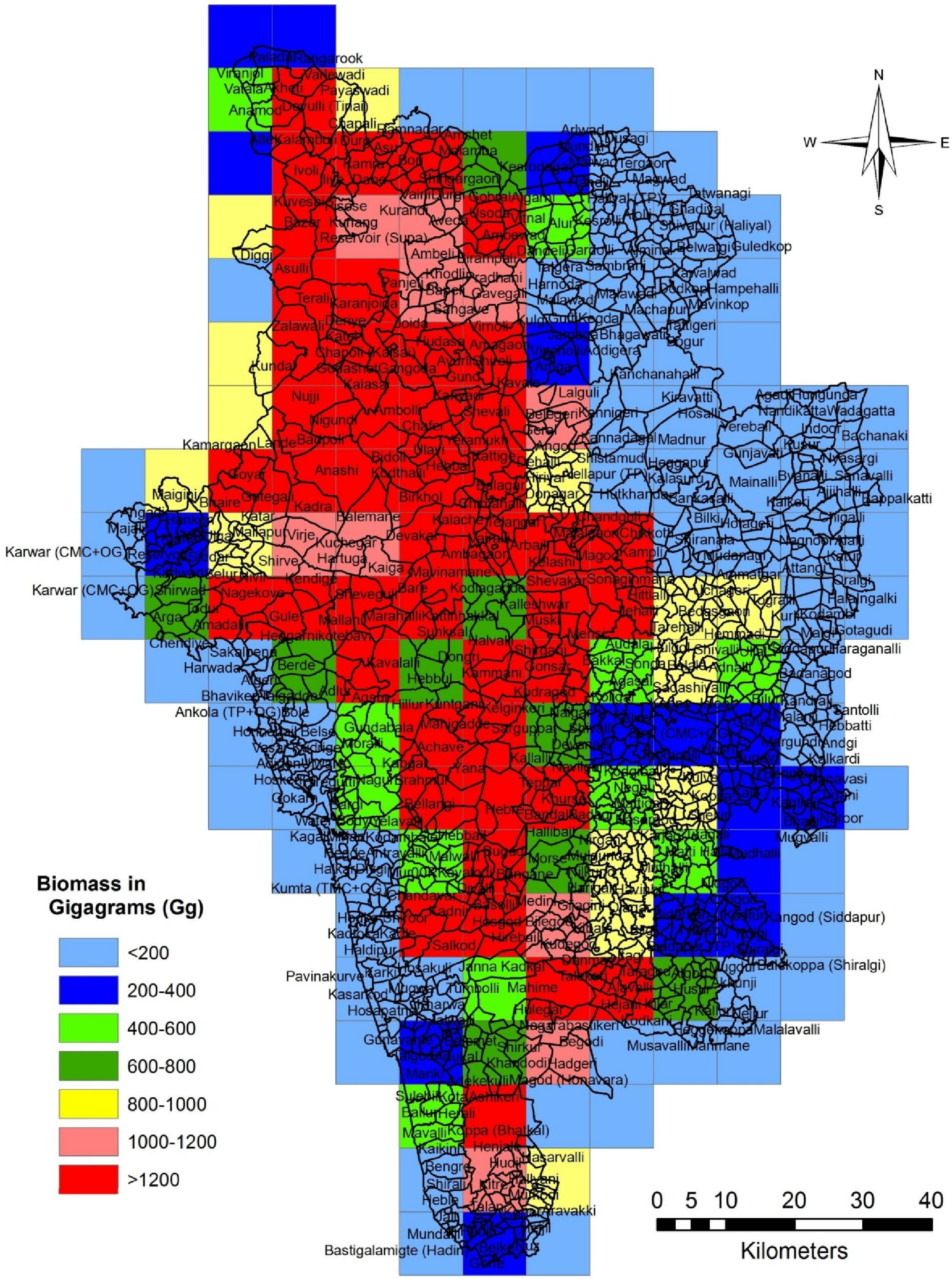


Figure 6.11a: Annual biomass availability in the villages of Uttara Kannada (Gg).

Figure 6.11 (b): Villages in Uttara Kannada

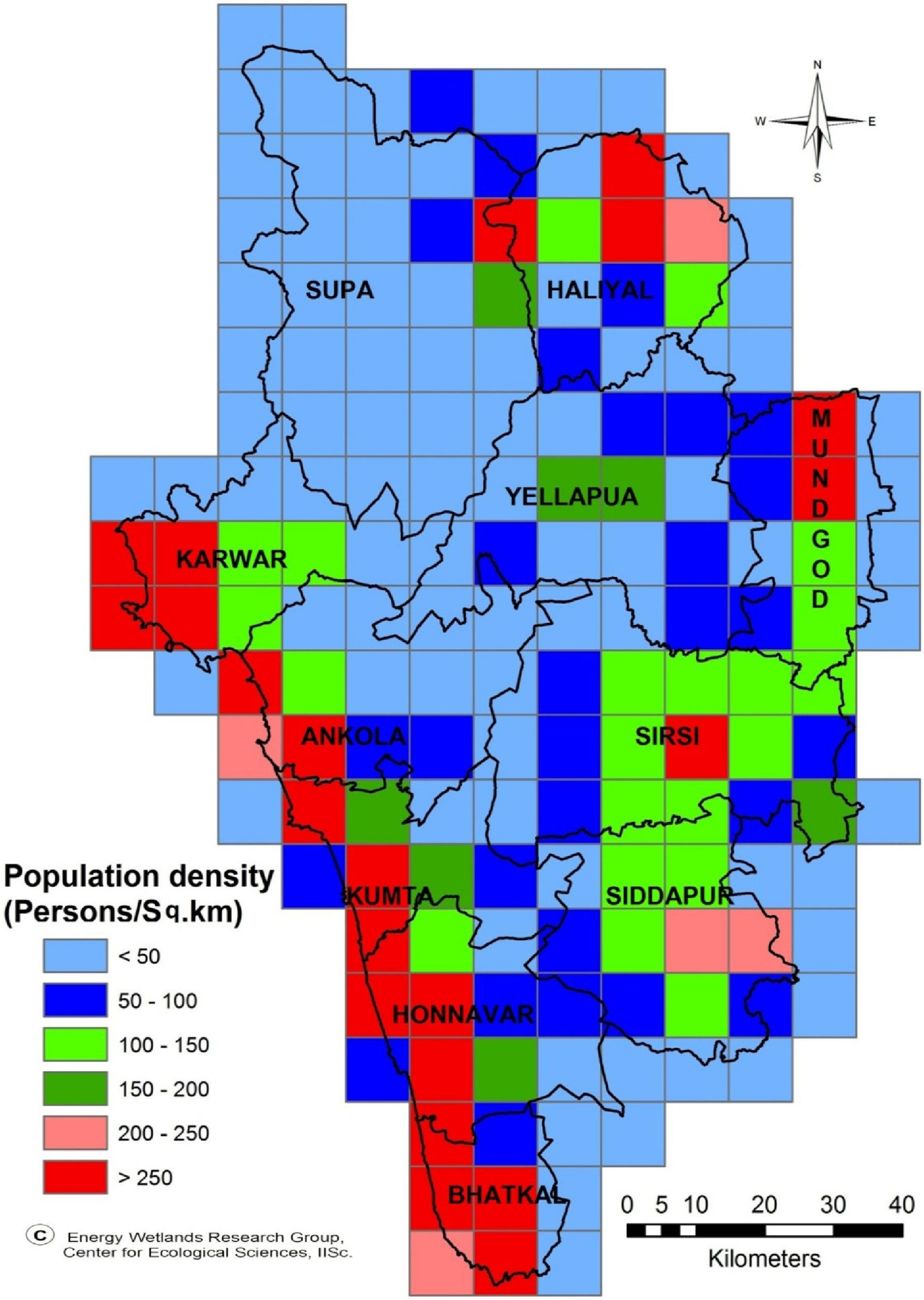


Figure 6.12 (a): Population density of Uttara Kannada.

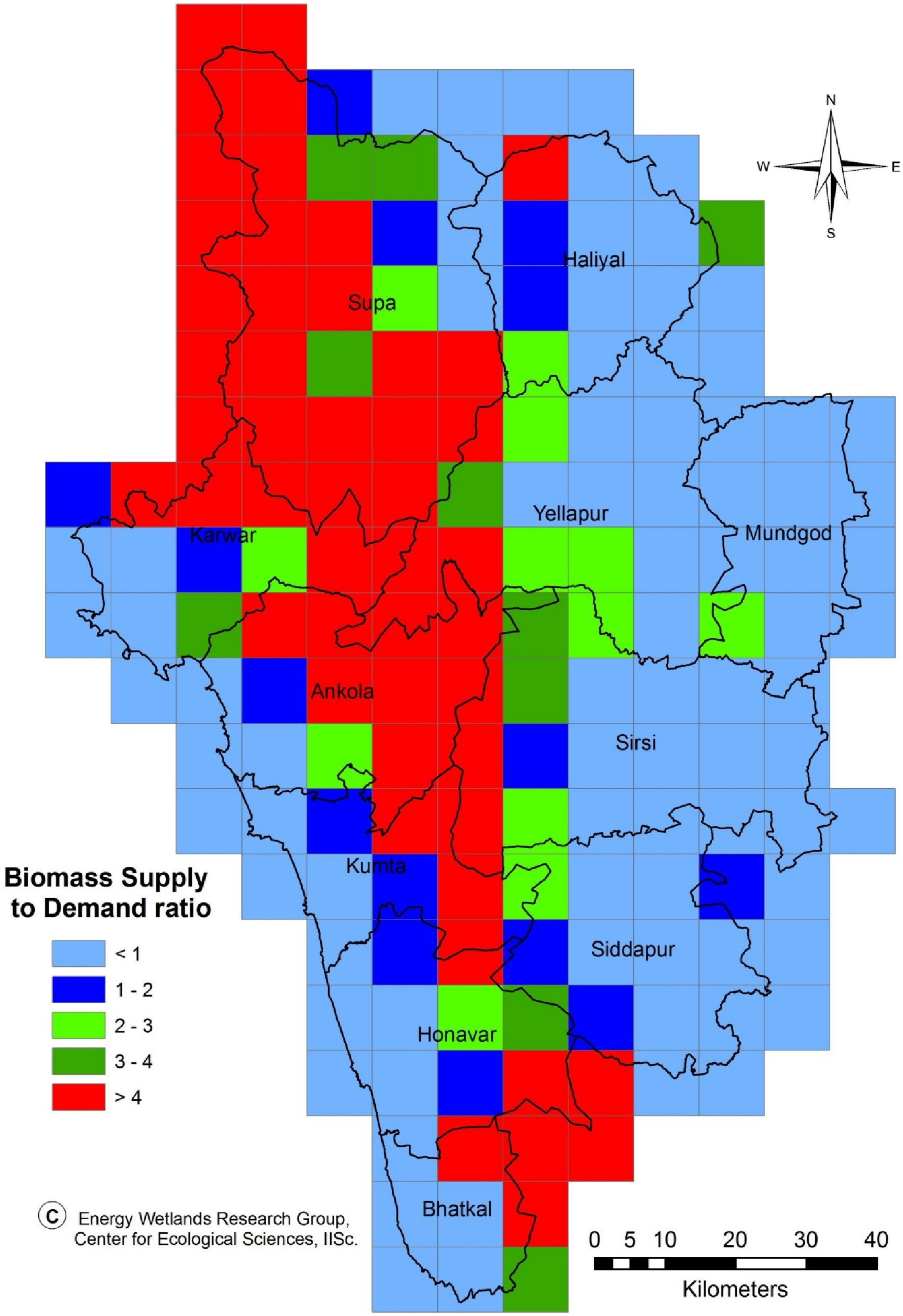


Figure 6.12 (b): Biomass supply to demand ratio of Uttara Kannada.

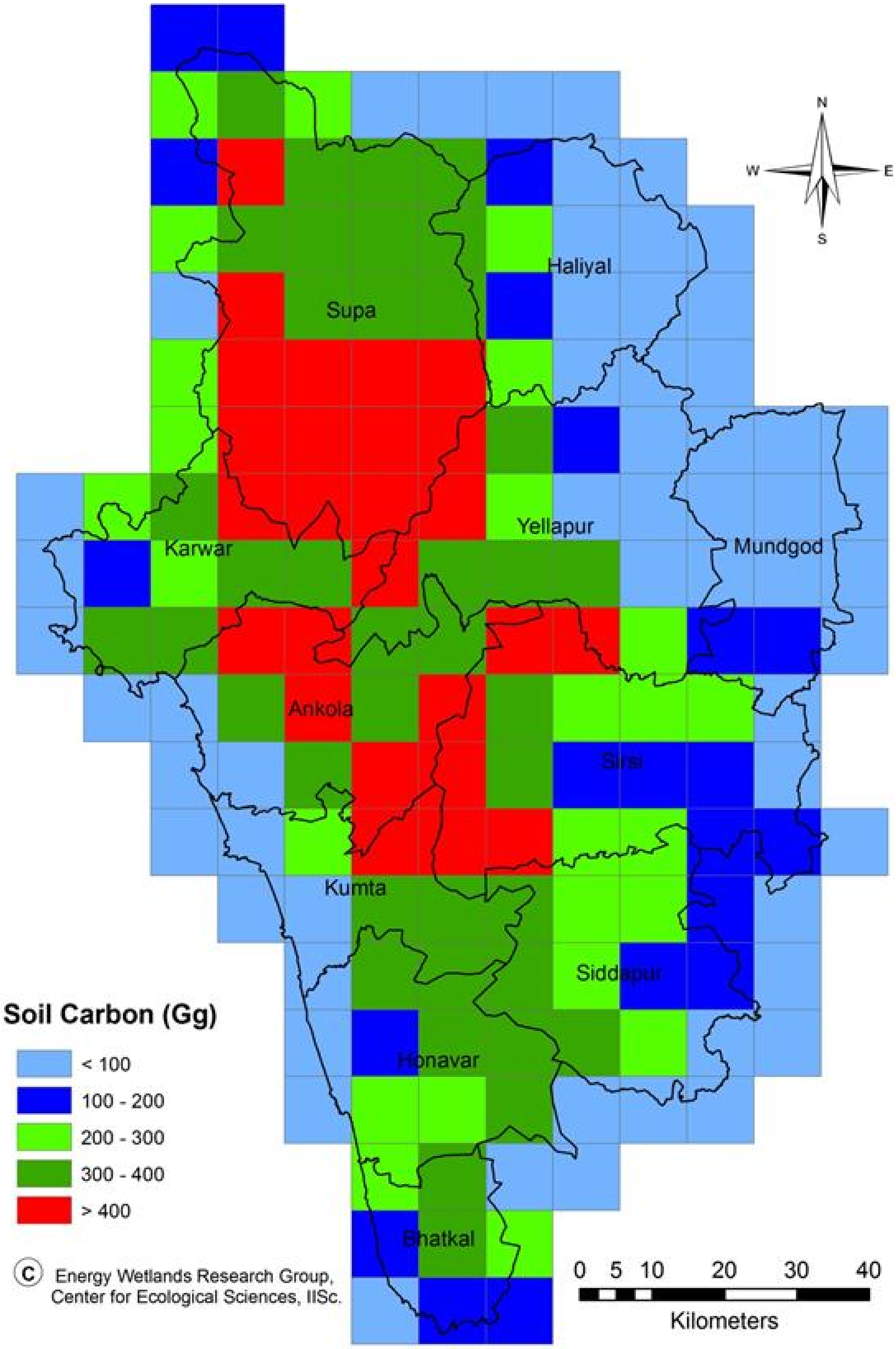


Figure 6.13(a): Soil carbon sequestration of Uttara Kannada.

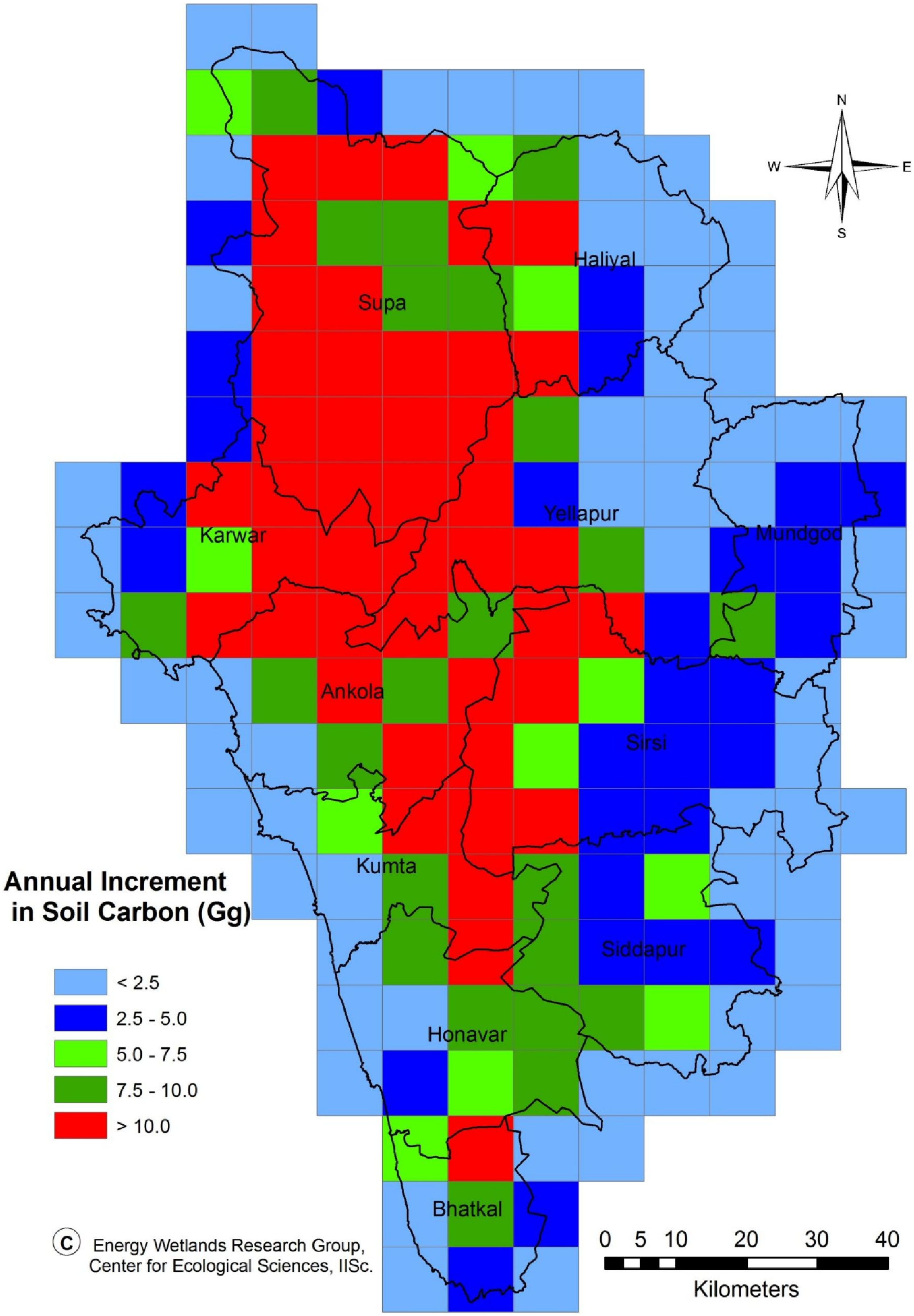


Figure 6.13(b): Annual carbon sequestration in soil of Uttara Kannada.

5.2 Estimation of Taluk wise Forest Biomass and Carbon Sequestration: Uttara Kannada district consists of 11 taluks. Taluk (tehsil) is a second layer of an administrative division consisting of agglomeration of gram panchayats/villages with a city or town that serves as its headquarters. Taluk wise standing biomass and carbon sequestration by forests were assessed to understand the micro level dynamics and their role in biodiversity and carbon storage. This approach also helped in visualizing the local hotspots of carbon sequestration and their significance/role in moderating the climate at local as well as at global levels. Table 9.5 lists talukwise forest cover, standing biomass and carbon stored. Figure 6.14 depicts taluk wise standing biomass and sequestered carbon in Gg (giga grams, thousand tons). Most forests in Supa, Honnavar and Siddapur taluks sequester higher amount of carbon due to forest cover of evergreen and semi-evergreen vegetation.

Table 5.5: Taluk wise biomass and carbon stored in forest vegetation

Taluks	Forest coverage type	Total standing biomass (Gg)	Total carbon stored (Gg)
Ankola	Semi evergreen to moist deciduous; evergreen forest (at central)	12856.41	6428.20
Bhatkal	evergreen to semi-ever green forest; moist deciduous towards coastline	2859.65	1429.82
Honnavar	Dominated by evergreen to semi-evergreen cover; moist deciduous found toward coastal line and disturbed regions	7592.32	3796.16
Karwar	Laterite thorn to moist deciduous and laterite evergreen to semi-evergreen	9135.00	4567.50
Kumta	Dominated by moist deciduous, semi-evergreen and evergreen towards west to east	6449.66	3224.84
Siddapur	Evergreen to semi evergreen and moist deciduous type towards east	7413.87	3706.93
Sirsi	Evergreen to semi evergreen and moist deciduous type towards east	15466.63	7733.32
Supa	Evergreen to semi evergreen, moist deciduous and disturbed moist deciduous (towards north and east)	35421.49	17710.72
Yellapura	Dominated by moist deciduous at central; evergreen cover to semi-evergreen towards Arabail Ghat	13158.49	6579.25
Haliyal	Dominated by dry deciduous; moist deciduous; evergreen cover found in Kali river valley	2701.31	1350.66
Mundgod	Dry deciduous and scrub type	768.76	384.38
Total		**113823.58**	**56911.79**

- **Ankola taluk:** Ankola taluk is most dominated by semi evergreen to moist deciduous forest cover from east to west. There are pockets of evergreen forests in the central part of Ankola. Towards the coastal side there is mainly mango, cashewnut, coconut and arecanut plantations. In Ankola taluk, as one goes from east to west, forest types changes from laterite thorn to moist deciduous, laterite semi-evergreen in tiny streams side pockets and interior depression. The Gangavali river valley area supports valuable teak forests having the most common under growth, bamboo. The greater biomass values (>1500 Gg) can be observed towards the eastern side (Arabail Ghat) and towards Sirsi taluk. Villages Mallani, Sheveguli, Kammani, Achave, Brahmur, Shevakar etc. have higher biomass and carbon storage. The forest coverage in these regions is evergreen to semi evergreen type. The Ankola town and its suburbs with more human interventions show less standing biomass and carbon (< 250 Gg) due to lower forest cover.

- **Bhatkal taluk:** Forests in Bhatkal taluk ranges from laterite thorn to laterite evergreen. This region is dominated by evergreen to semi evergreen forest cover, and very little moist deciduous forest cover. The evergreen forests near Koppa village (in the north-east) contain valuable timber. Laterite thin forests situated in the north-west and south-west of the taluk contain a large number of khair trees. These are bigger in the girth in the Balke forests in the south-west part of the border of the Dakshina Kannada District. The more dense paved surfaces in Bhatkal town reflects the urbanisation and has least biomass and carbon values (<250 Gg). The villages like Hudil, Kitre, Murukeri, Antravalli etc. with evergreen cover shows greater than 1500 Gg of biomass and >750 Gg of carbon content.

- **Honnavar taluk:** Honnavar forest landscape is one of relic rain forests of the central Western Ghats, where the high endemic vegetation exists till date. In Honnavar Taluk, the forest type changes from laterite to laterite semi-evergreen and evergreen. There is very little of the moist deciduous type which can be seen only on tops of small hills in the western part of the belt. The coastal strip of the forests is all denuded. These forests contain most valuable trees like *Dipterocarpus indicus*, *Syzygium travancoricum, Pterocarpus marsupium* (honne), *Calophyllum tomentosum*, *Machilus macrantha*, Caryota *urens* and *Aporosa lindleyana*. *Xylia xylocarpa* (jamba), *Lagerstroemia lanceolata* (nandi), *Hopea parviflora*, *Dalbergia* *latifolia*, *Dillenia pentagyna*, *Careya arborea*, *Emblica officinalis*, and other species. The laterite semi-evergreen forests and evergreen forests in the north-east corner, in the Mahime and Jankadkal villages of the taluk, contain tale palms. The belt of Acacia catechu is mostly confined to the south-west part of the taluk. The evergreen forests of Gerusoppa contain varieties of canes. Intensified coconut/ areca nut plantation activities can be observed in the district due to higher water availability. Forests at Kadnir, Chandavar, Salkod, Nilkod, Hodke Shiroor, Mallapur, Chandavar villages stores >750 Gg carbon.

- **Karwar taluk:** The forest type in Karwar taluk gradually changes from laterite thorn to moist deciduous and laterite evergreen to semi-evergreen from west to east. The deciduous forests have valuable timber of *Tectona grandis (teak)*, *Terminalia paniculata*, *Pterocarpus marsupium* (honne), etc. *Xylia xylocarpa* (jamba) is the predominant species of this tract. The upper slopes and lower valleys and banks of perennial streams contain patches of evergreen forests and large quantities of canes. Reserved forests of the moist deciduous type in the patches of laterite semi-evergreen in the interior situated on the steep hills. Forests in Lande, Kadra, Devakar villages has >1500m Gg of biomass and >750 Gg of carbon storage and higher standing biomass are towards Anshi-Dandeli tiger reserve (ADTR).

- **Kumta taluk:** Forests in Kumta taluk ranges from laterite thorn to moist deciduous, laterite semi-evergreen and evergreen towards west to east. The timber bearing high forests are confined to the south-east part of the taluk at the foot of the Nilkund and Dodmane Ghats round about the Soppinahosahalli village. Around Mirjan, the laterite thorn forests contain khair trees which yield valuable catechu. Bamboos occur in the Aghanashini valley around Soppinahosahalli. *Scleropyrum pentandrum* is available in this taluk along margin of evergreen to semi-evergreen forests between 600 and 1600 m. Villages Yana, Kalve, Chimmolli, Bellangi, Soppinohassalli, Kanakle, etc. have higher potential of carbon storage and lower value (<250 Gg) is in the forests closer to Kumta town.

- **Siddapur taluk:** Major part of Siddapur taluk is hilly and are with sandalwood trees towards the north-east, east and south-east. This sandalwood belt extends to Sirsi, Mundgod taluks also. The eastern part is drier and as one advances from east to west towards the Ghats, the forest type improves to semi-evergreen to evergreen. There are many large patches of evergreen forests called kans in this taluk, mostly confined to the west round about Dodmane, Nilkund and Malemane Ghats. The scared forest of Siddapur protecting endemic species like *Dipterocarpus indicus*, *Gymnacranthera canarica*, *Syzygium travancoricum* (in the swampy regions). *Aswatha* or *pipal* (*Ficus religiosa*), mango (*Mangifera indica*) are widely found. The rest of the trees are natural to the region, notable among them being *bakul* (*Mimusops elengi*), *Mesusa ferrea*, jackfruits (*Artocarpus heterophyllus*), *jamun* (*Syzygium cumini*), *saptaparni* (*Alstonia scholaris*), and *baini* (*Caryota urens*). Kathlekan swamps dominated by swamp species like *Gymnacranthera.* Forests in Malemane, Kathlekan, Keremane, Chandragatgi, Kudagund, Alavalli etc. villages, have higher biomass (> 1500 Gg). The region has more anthropogenic pressure due to higher water availability. Many natural areas were replaced with exotic plantations for higher timber yield.

- **Sirsi taluk:** The forest type of Sirsi taluk is semi-evergreen to evergreen types and moist deciduous patches are more towards east side. The belt of sandalwood forest of Siddapur taluk runs over this taluk and is mostly confined to the south-eastern part bordering Siddapur taluk and the Shimoga District. Endemic tree species like *Grangea maderaspatana, Fuirena uncinata, Schoenoplectus articulates, Drosera burmanni, Artocarpus heterophyllus, Syzygium cumini, Eriocaulon cuspidatum, Ischemum molle, Utricularia reticulate, Ammannia baccifera etc*. are found more in this taluk. Though, the human interventions are more, due to the sacred and reserve forests in this taluk endemic habitats are protected. Biomass is higher for *Dipterocarpus indicus* dominated areas of Karikan (Basal area 85.41 sq.m/ha) and in the nearby by other immense sized *Calophyllum tomentosum, Lophopetalum wightianum, Palaquium ellipticum.* Hill slopes (Devimane Ghat; Hebre; Kakkalli) and sacred groves have higher biomass (>1500 Gg). Places like Kanmaski-Vanalli and Bugadi of Sirsi, are characterised by *Diospyros candolleana, Tricalysia spearocarpa, Pterygota alata* with higher biomass.

- **Supa taluk:** Supa (Joida) taluk has higher forest cover in the district. Taluk has evergreen to semi evergreen forest and mixed with moist deciduous type. The greater part of the Supa tract is very hilly. Dense forests in south eastern part and scrub jungle in , northern part, near Castle rock, where the soil is very poor. Bamboo grows abundantly in this taluk. The region has experienced removal of natural vegetation for soft wood plantations to support forest based industries. Kushavali of Joida with species such as *Dysoxylum malabaricum, Holigarna grahamii* etc., have higher biomass (75.08 sq.m/ha). Lower biomass values (<250Gg) are found in deciduous and highly disturbed forests such Desaivada-Nandgadde in this taluk. ADTR conservation area and lower human population are the major reasons for higher carbon storage.

- **Yellapura taluk:** Central part of the Yellapura taluk basically comprises the semi-evergreen to moist deciduous type of forests. Arabail Ghat region is dominated with ever green forests. The eastern and northern part of the Yellapura taluk is a home for valuable forest of teak. Bamboo is also plentiful here, confined to the catchment area of Gangavali. The bamboo belt also extends to Ankola Taluk. Arabail Ghat covering villages of Marahalli, Mavinmane, Kodlagadde, Telangar, Kalache have higher biomass (>1500 Gg) and carbon (>750 Gg) storage. Eastern part of villages like Kirvatti, Hosalli, Madnur, Kannigeri etc. are with lower biomass (<250 Gg) due to intensified plantations activities.

- **Haliyal taluk:** The eastern and north-western parts of Haliyal taluk comprise a teak pole area tending to scrub type towards the border of the Dharwad District. There is sandalwood in drier parts of the area and patches of evergreen forest towards the western side in the lower portions of the valleys of rivers and perennial channels. Bamboo is considered as one of the most valuable constituents of economic forest produce in this taluk. The eastern part of taluk contains scrub and dry deciduous forest cover type. Forests at Kulgi, Vitnal, Dandeli have moderate biomass (>1250 Gg) and at Sambrani, Mundki, Malwad and Haliyal town have lower biomass due to the disturbed shrub forests.

- **Mundgod taluk:** Forests in Mundgod taluk varies from scrub in the south-west near the Sirsi Taluk boundary to a teak pole area in the eastern and deciduous forests towards the western half is in the high area. The deep valleys, in the south-west and near by the streams are covered with patches of moist deciduous forests. The drier parts of the teak pole arch, towards the border of the Dharwad district, contain sandalwood. Mundgod taluk village's forest cover was moist to dry deciduous in 1989, which had neglected by intensifying exotic plantations. Gunjavathi, Katur etc. Villages of Mundgod are with teak monoculture plantations of teak and are dominated with weeds such as *Eupatorium sp* and several thorny shrubs. This taluk has lower biomass (<250 Gg) except in villages towards Sirsi taluk.

Taluk-wise annual increment of biomass, carbon, net productivity from natural forest and carbon sequestered in forest soils are listed in Table 5.6. Total carbon uptake by forest as well as soil is about 2416.69 Gg/Yr considering annual increment in carbon, net productivity of carbon, annual increment of soil carbon. Supa taluk has higher standing biomass and carbon storage and least is in Mundgod (Figure 6.14). The forests of Supa taluk uptakes 610.67 Gg carbon and Ankola region stores 358.03 Gg. The least storage can be observed in Mundgod (43.71 Gg) and Bhatkal (82.65 Gg). Forests in Karwar, Sirsi, Yellapura taluks have higher (200 Gg) uptake of carbon per year, while Mundgod, Bhatkal and Haliyal have relatively lower carbon sequestration.

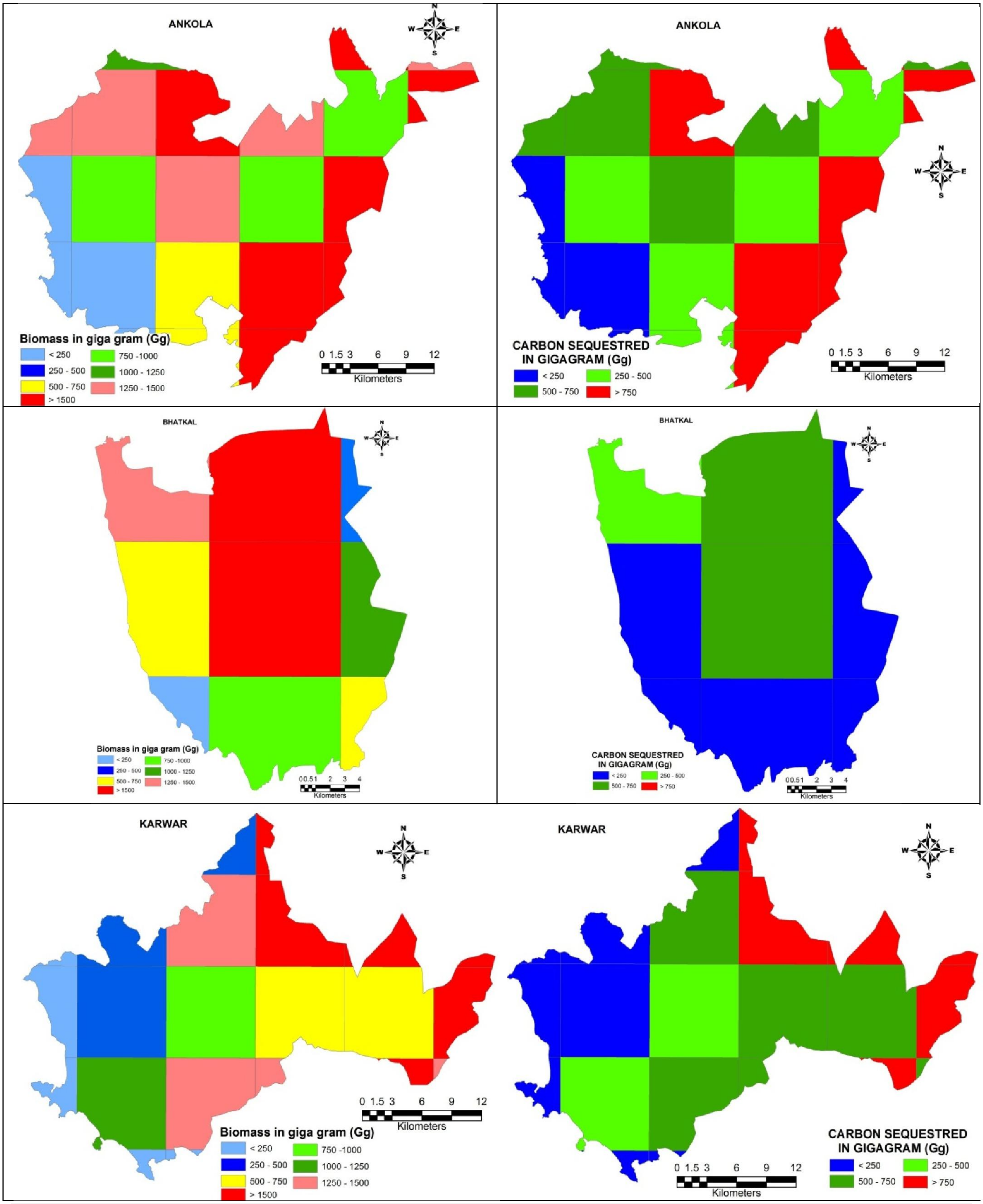
Table 5.6: Biomass and carbon stored in natural forests and soil at taluk level

Taluk	StandingBiomass Gg	Carbon Gg	Annual increment in Biomass Gg/Yr	Annual increment in Carbon Gg/Yr	Annual productivity of Carbon Gg/Yr	Soil Carbon Gg	Annualincrement Soil Carbon Gg/Yr	Carbon from Natural Forest cover Gg/Yr
Ankola	12856.41	6428.20	300.23	150.12	88.01	7460.48	119.90	358.03
Bhatkal	2859.65	1429.82	69.54	34.77	21.13	1637.00	26.75	82.65
Honnavar	7592.32	3796.16	147.05	73.53	44.53	3478.86	56.74	174.81
Karwar	9135.00	4567.50	214.94	107.48	63.28	5396.19	86.75	257.51
Kumta	6449.66	3224.84	128.07	64.03	36.53	3237.79	51.54	152.10
Siddapur	7413.87	3706.93	101.55	50.77	20.75	3739.44	54.64	126.15
Sirsi	15466.63	7733.32	209.23	104.61	42.03	7469.60	108.89	255.53
Supa	**35421.49**	**17710.72**	**483.93**	**241.98**	**97.61**	**18585.35**	**271.08**	**610.67**
Yellapura	13158.49	6579.25	195.52	97.76	42.42	6331.05	98.32	238.50
Haliyal	2701.31	1350.66	76.60	38.30	19.28	1762.19	59.47	117.04
Mundgod	768.76	384.38	24.93	12.46	6.51	595.49	24.73	43.71
District	**113823.58**	**56911.79**	**1951.61**	**975.81**	**482.07**	**59693.44**	**958.81**	**2416.69**

5.3 Biomass estimation in forest plantations: Absorption of CO_2 in the biomass directly depends on the productivity of tree species. Proper management plays an important role in biomass productivity. Field based estimates were carried out to compare the carbon sequestration potential in native forest and managed plantations in hilly regions of Uttara Kannada district. The spatial extent of forest plantations (land use analysis) are computed for each grids. The field based estimates of transact data provided the status of biomass (77.54 t/ha). This is compared with the earlier estimates and used to estimate biomass as well as carbon stored in each grid of the district. The estimate is compared with earlier literature and considered as. The annual increment in biomass is considered as 5.5 t/ha/yr and net productivity of biomass is considered as 1.5 t/ha/yr. (Ramachandra et al., 2000). The total accumulated biomass of Uttara Kannada district from forest plantation accounts to 14228.08 Gg (figure 6.15 and table 5.7). The spatial extent of forest plantations of Acacia, Eucalyptus, Teak, other hard and soft wood plantations ranges from 25957 hectares (Mundgod) to 27426 (Sirsi), 37007 (Haliyal) and 49703 hectares (Yellapura). Haliyal, Yellapura, Mundgod, Sirsi taluks are with higher biomass (>125 Gg) while Siddapur and Kumta have moderate biomass (75-125 Gg). The carbon sequestered in plantations is about 7441 Gg (figure 6.16). Higher carbon storage is in plantations of Haliyal, Yellapura, Mundgod, Sirsi (> 60 Gg) while native vegetation have carbon of 100 to 250 Gg. Annual increment in forest plantation biomass in the district is about 1055.55 Gg/yr (figure 6.17) and carbon is 527.77 Gg/yr (figure 6.18). Haliyal (Biomass > 12; carbon >9 Gg), Yellapura (> 12; >9 Gg), part of Mundgod (> 12; >9 Gg) have higher annual increment in biomass as well as carbon. Net productivity from forest plantations is about 277.88 Gg (figure 6.19). Taluk wise carbon sequestration in forest plantations soil is analysed and are given in figure 6.20. The soil sequestration potential of plantations is considered as 33 t/ha and annual increment as 1.5 t/ha (Ravindranath et al., 1996). Soil in plantations of Haliyal, Yellapura, Mundgod regions have higher (> 100 Gg) followed by Sirsi (50 to 100 Gg). The annual increment in carbon by soil of forest plantations given in figure 6.21 shows that Haliyal, Yellapura, Mundgod have greater than 6 Gg due to higher area under plantations.

Table 5.7: Biomass and carbon stored from forest plantations (FPL) and soil at taluk level

Taluk	Biomass (Gg)	Carbon (Gg)	Annual increment in biomass (Gg/Yr)	Annual increment in carbon (Gg/Yr)	Net productivity of carbon (Gg/Yr)	Soil_carbon (Gg)	Aninc_soilcarbon (Gg/Yr)	Carbon from forest plantations Gg/Yr
Ankola	575.37	287.68	40.80	20.39	11.11	244.88	7.41	38.91
Bhatkal	89.81	44.92	6.38	3.19	1.73	38.22	1.15	6.08
Honnavar	461.01	230.50	32.71	16.34	8.90	196.20	5.94	31.18
Karwar	234.70	117.35	16.66	8.33	4.55	99.88	3.03	15.92
Kumta	512.31	256.15	36.35	18.17	9.90	218.02	6.60	34.68
Siddapur	686.13	343.07	48.68	24.34	13.27	292.01	8.85	46.46
Sirsi	2056.24	1028.10	145.84	72.90	39.78	875.12	26.52	139.20
Supa	1056.46	528.23	74.94	37.49	20.46	449.63	13.64	71.58
Yellapura	3997.15	1998.58	283.50	141.76	77.31	1701.15	51.54	270.61
Haliyal	2655.05	1327.50	188.33	94.16	51.36	1129.96	34.24	179.77
Mundgod	1903.84	951.92	135.05	67.51	36.84	810.24	24.56	128.91
Uttara Kannada	**14228.08**	**7113.99**	**1009.23**	**504.58**	**275.22**	**6055.33**	**183.48**	**963.28**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500 - 750
> 1500
750 -1000
1000 - 1250
1250 - 1500
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Kilometers
ANKOLA
CARBON SEQUESTRED IN GIGAGRAM (Gg)
< 250
250 - 500
500 - 750
> 750
0 1.5 3 6 9 12
Kilometers
BHATKAL
Biomass in giga gram (Gg)
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500 - 750
> 1500
750 -1000
1000 - 1250
1250 - 1500
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Kilometers
BHATKAL
CARBON SEQUESTRED IN GIGAGRAM (Gg)
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250 - 500
500 - 750
> 750
0 0.5 1 2 3 4
Kilometers
KARWAR
Biomass in giga gram (Gg)
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500 - 750
> 1500
750 -1000
1000 - 1250
1250 - 1500
0 1.5 3 6 9 12
Kilometers
KARWAR
CARBON SEQUESTRED IN GIGAGRAM (Gg)
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> 750
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Kilometers
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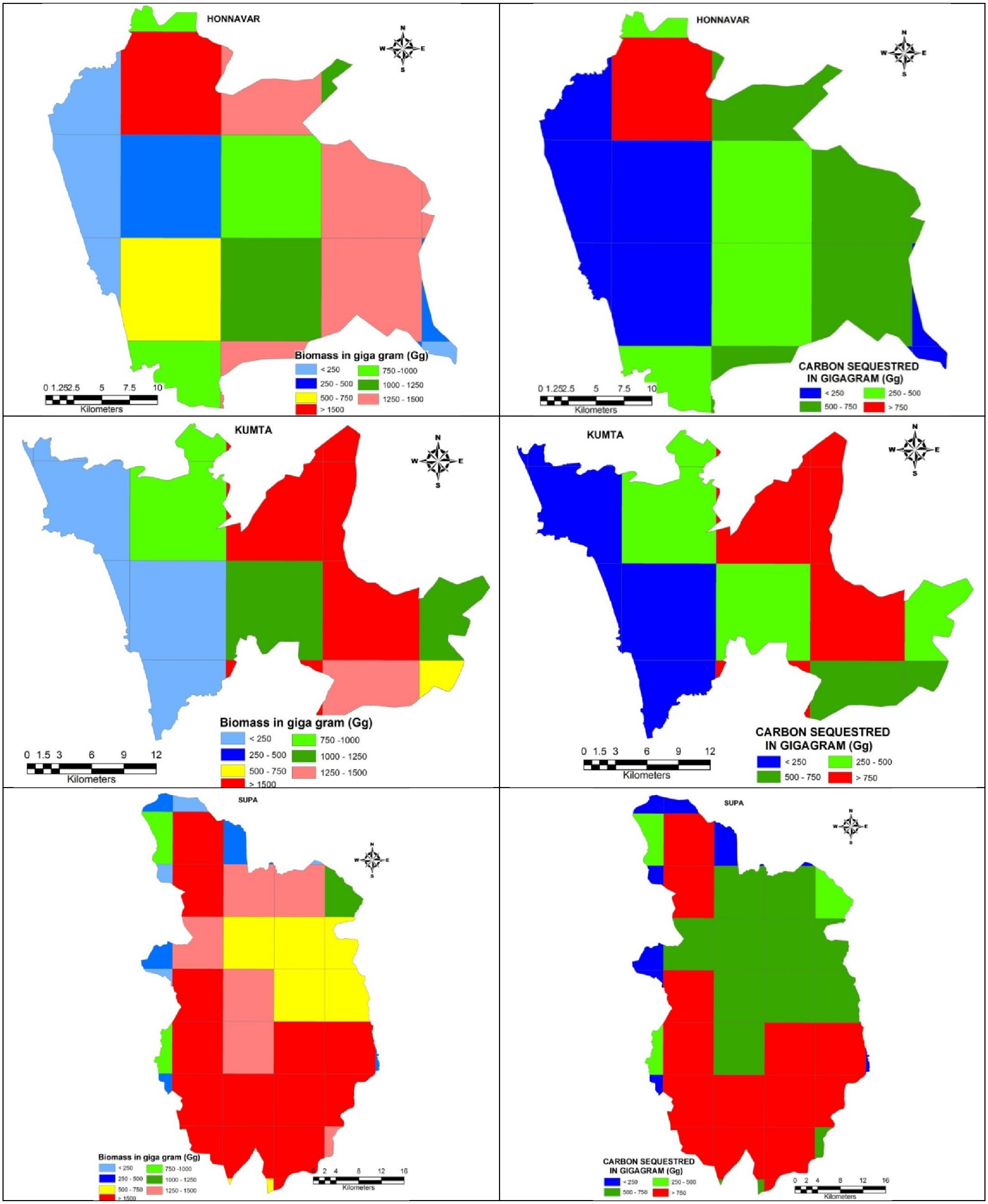
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IN GIGAGRAM (Gg)
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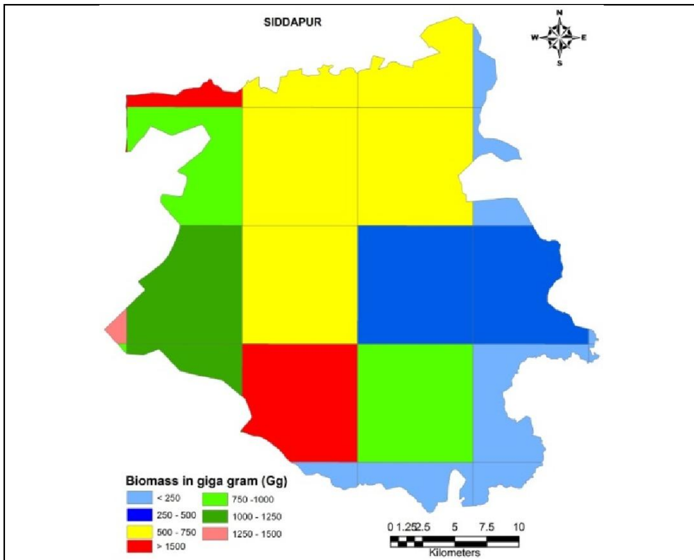
250 - 500
500 - 750
> 750
KUMTA
SUPA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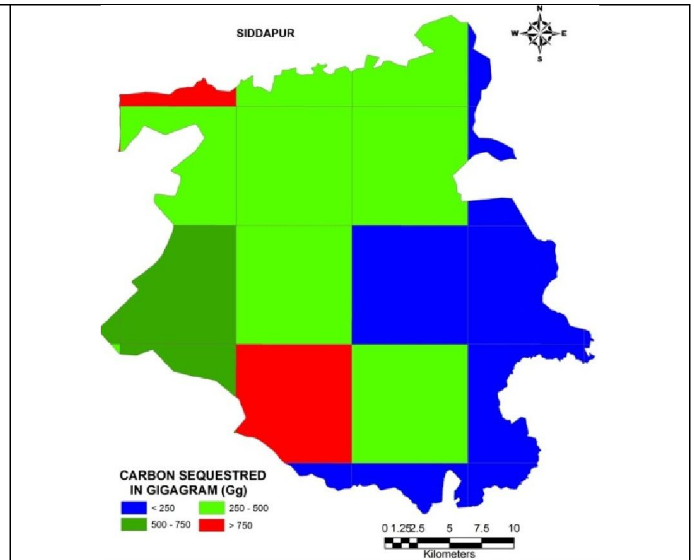
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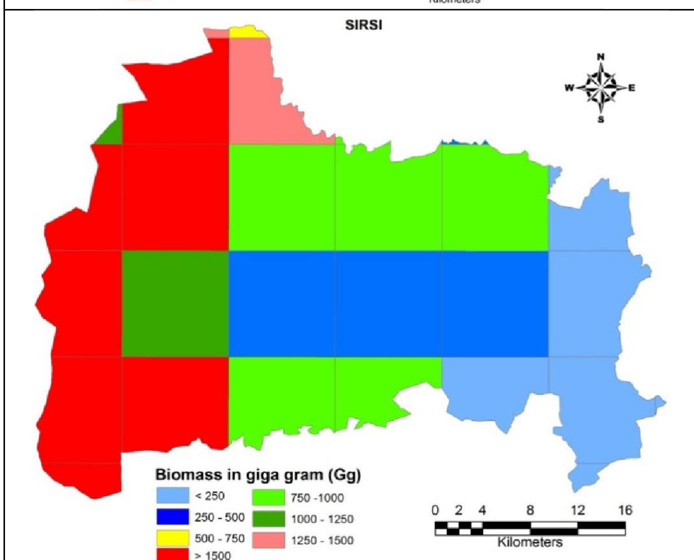
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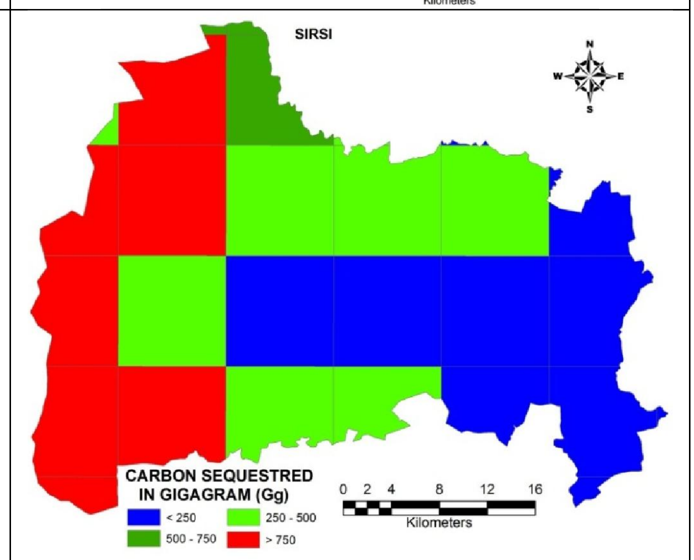
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IN GIGAGRAM (Gg)
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250 - 500
> 750
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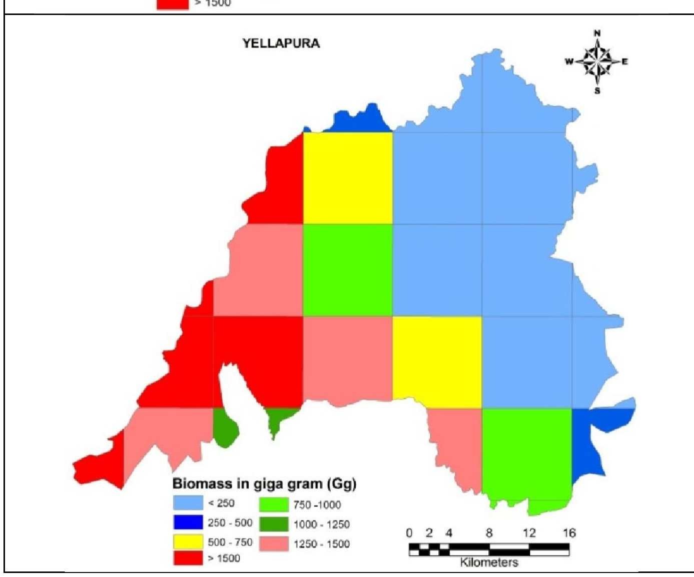
Kilometers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750 -1000
1000 - 1250
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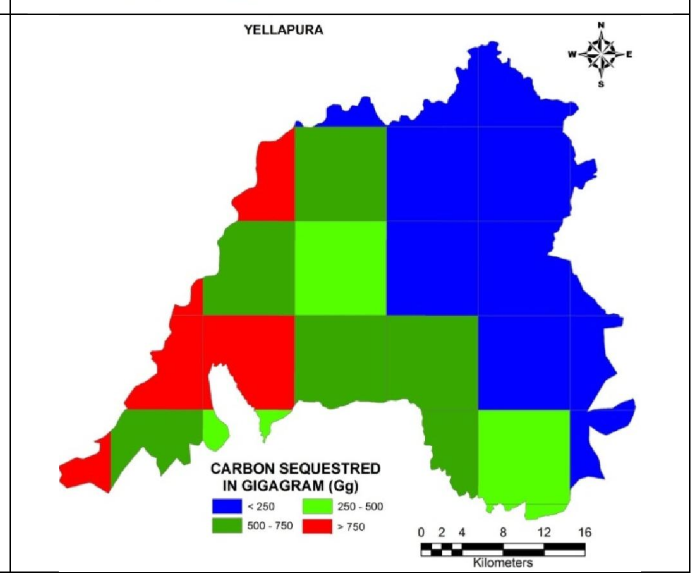
Kilometers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IN GIGAGRAM (Gg)
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250 - 500
> 750
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Kilometers

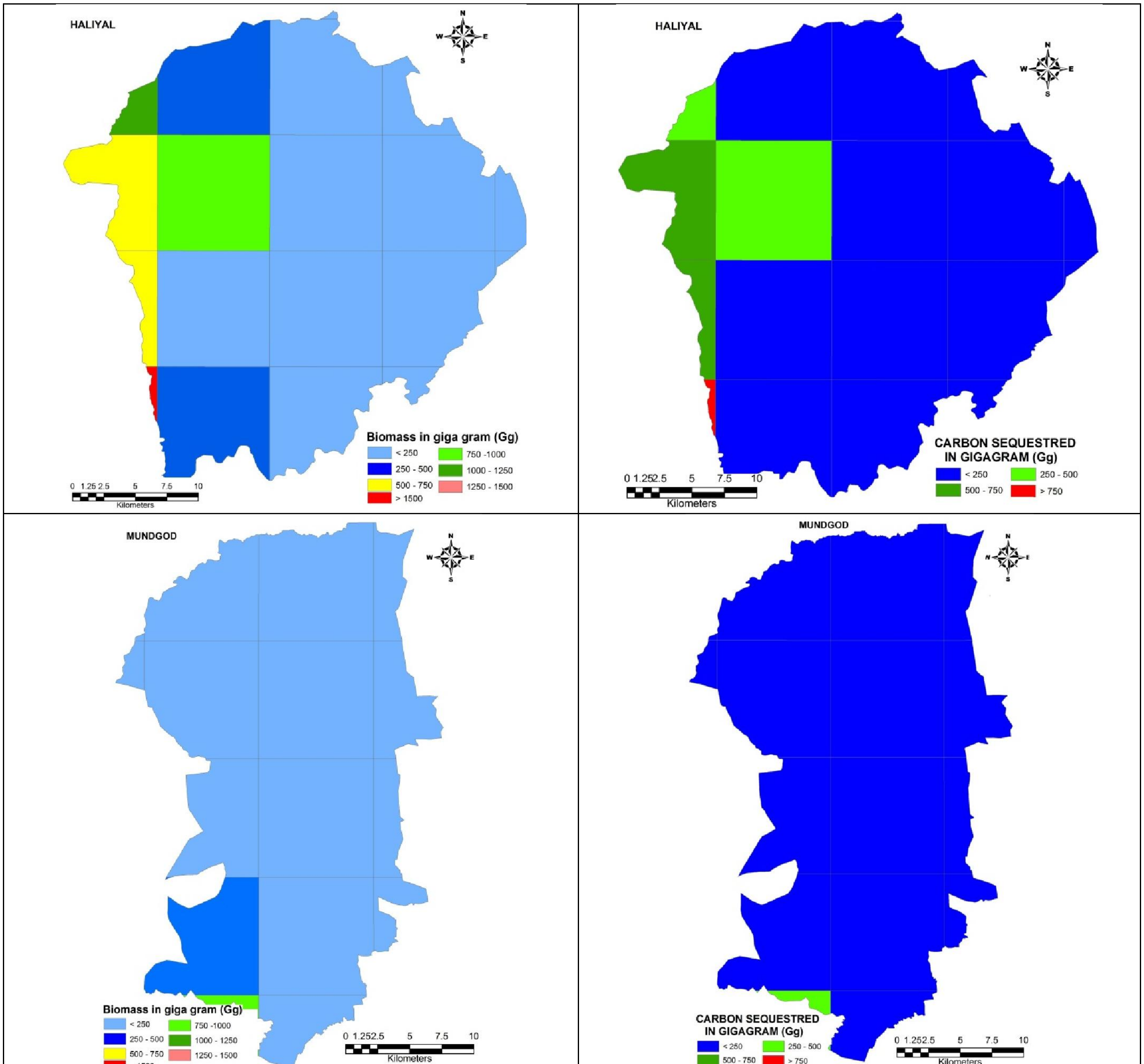

Figure 6.14: Taluk wise Biomass and sequestered Carbon estimated in Gg.

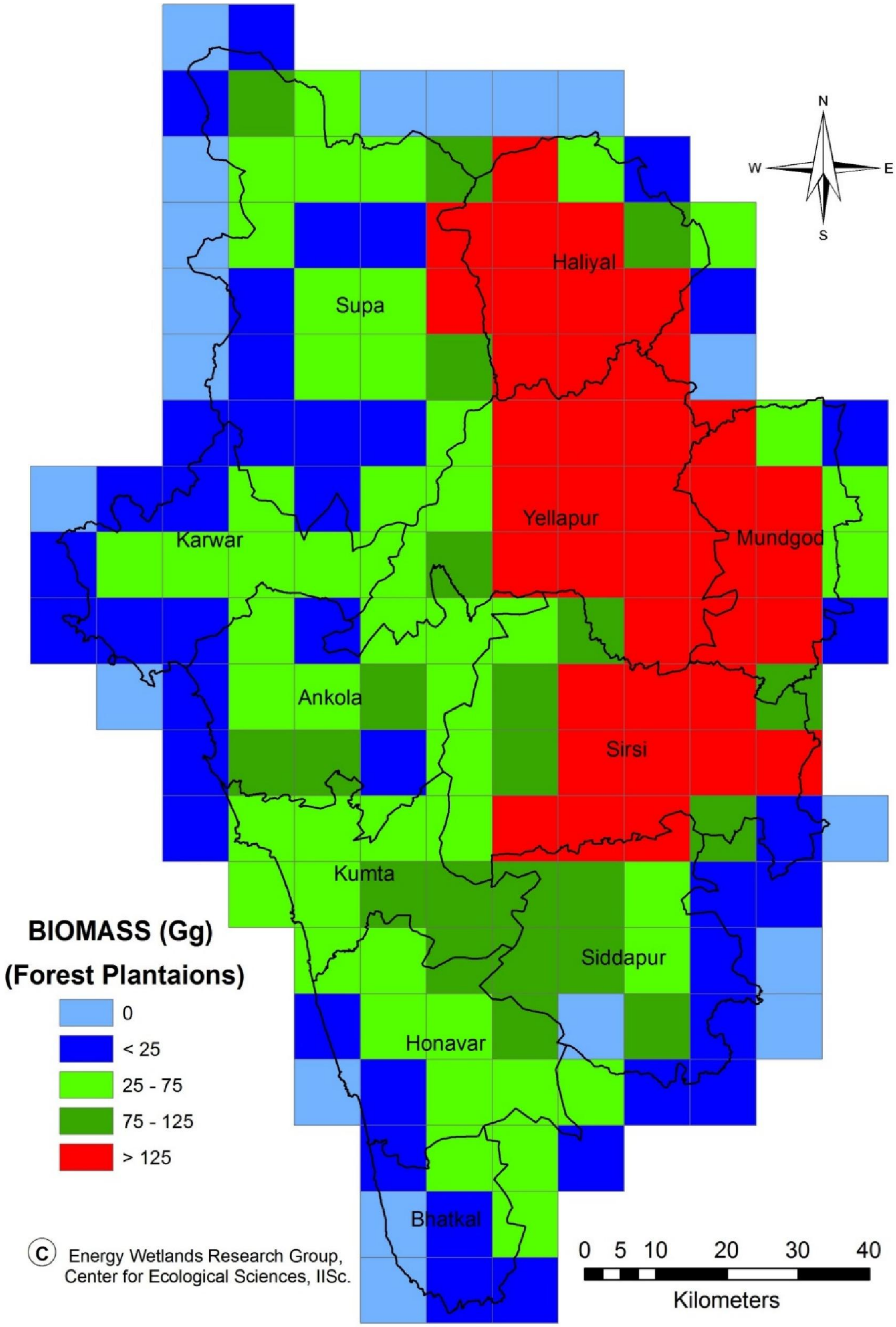

Figure 6.15: Biomass from forest plantations

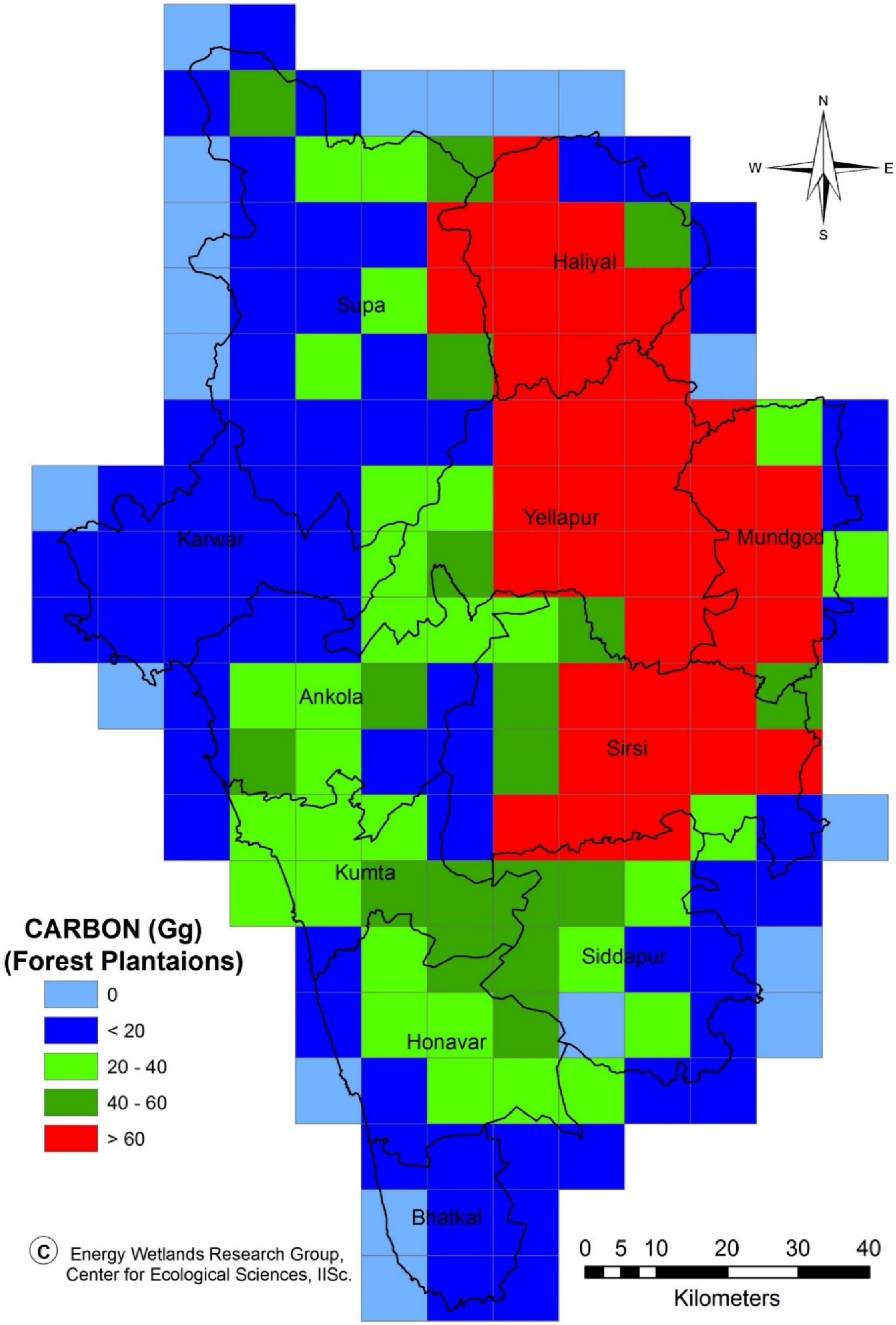

Figure 6.16: Carbon sequestered by forest plantations

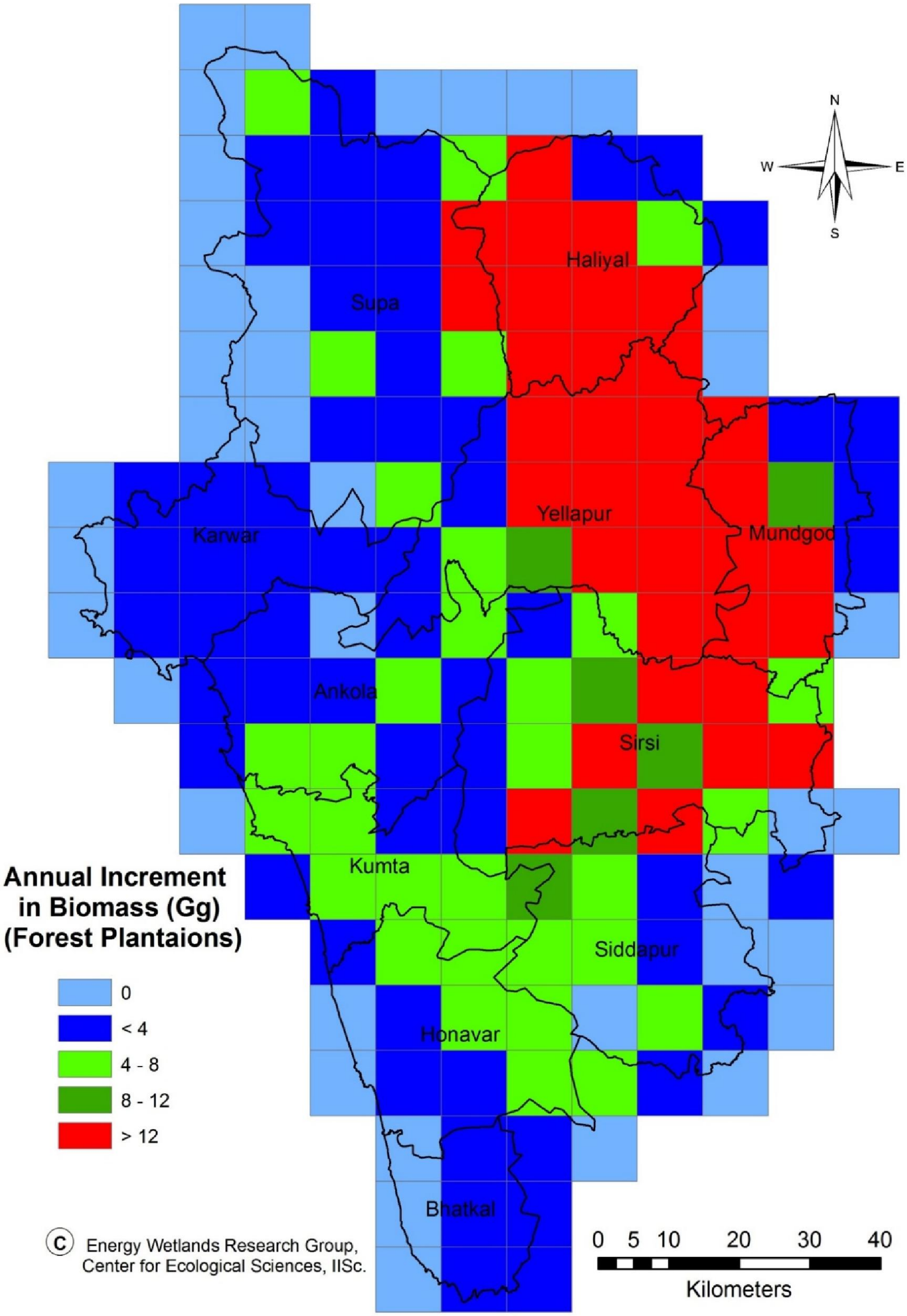

Figure 6.17: Annual increment in biomass of forest plantations

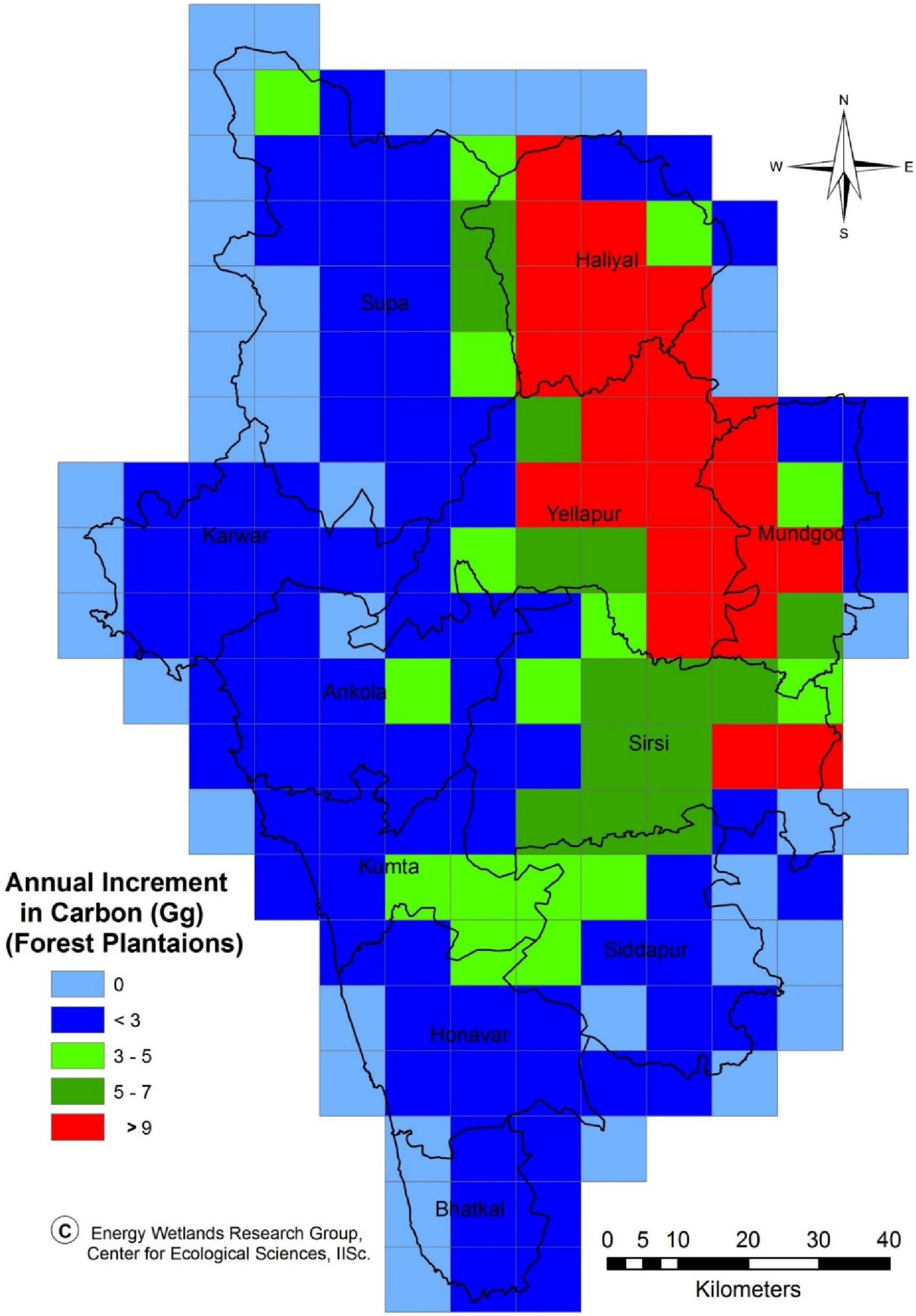

Figure 6.18: Annual increment in carbon sequestration of forest plantations

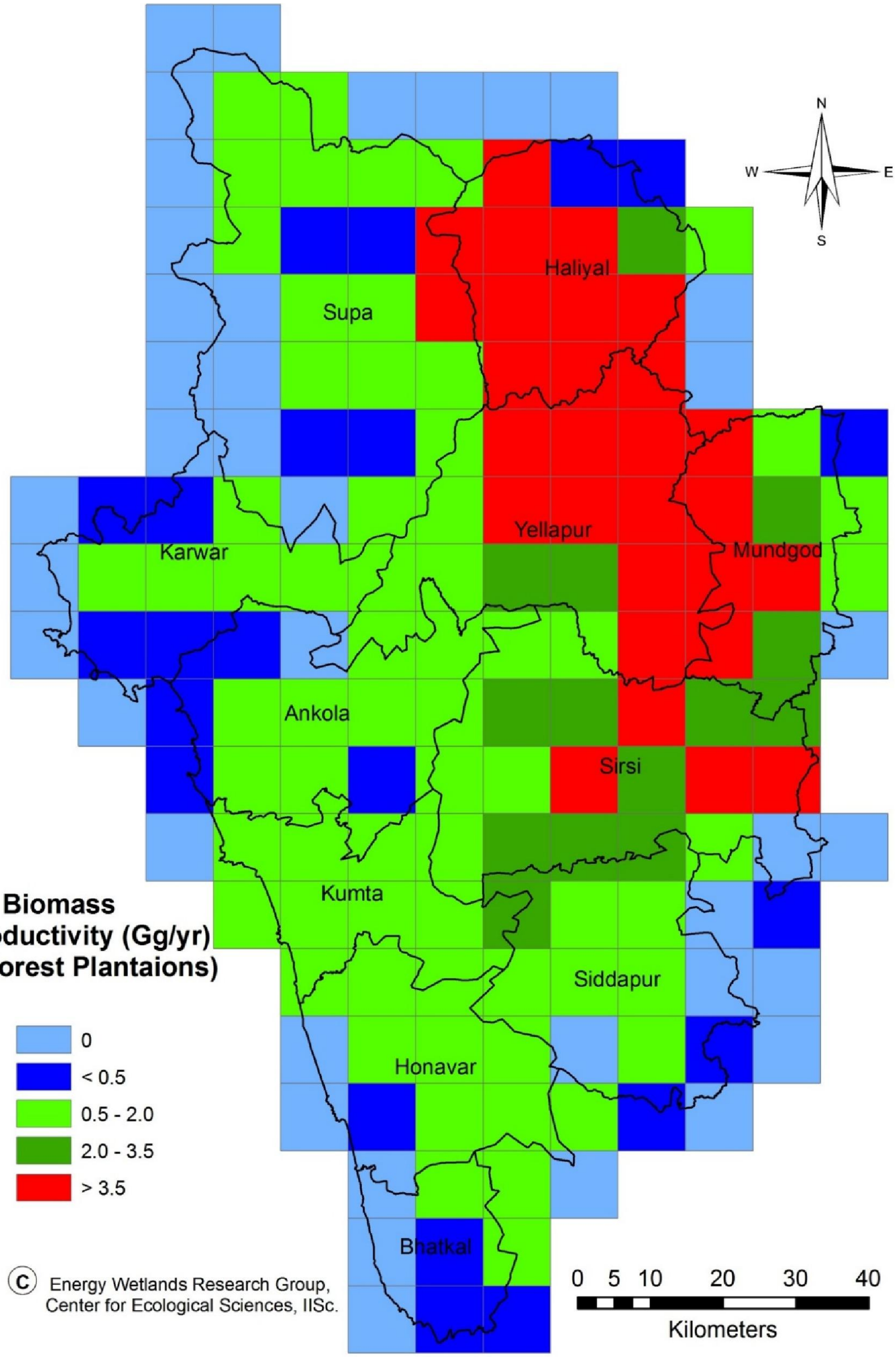

Figure 6.19: Net productivity from forest plantations

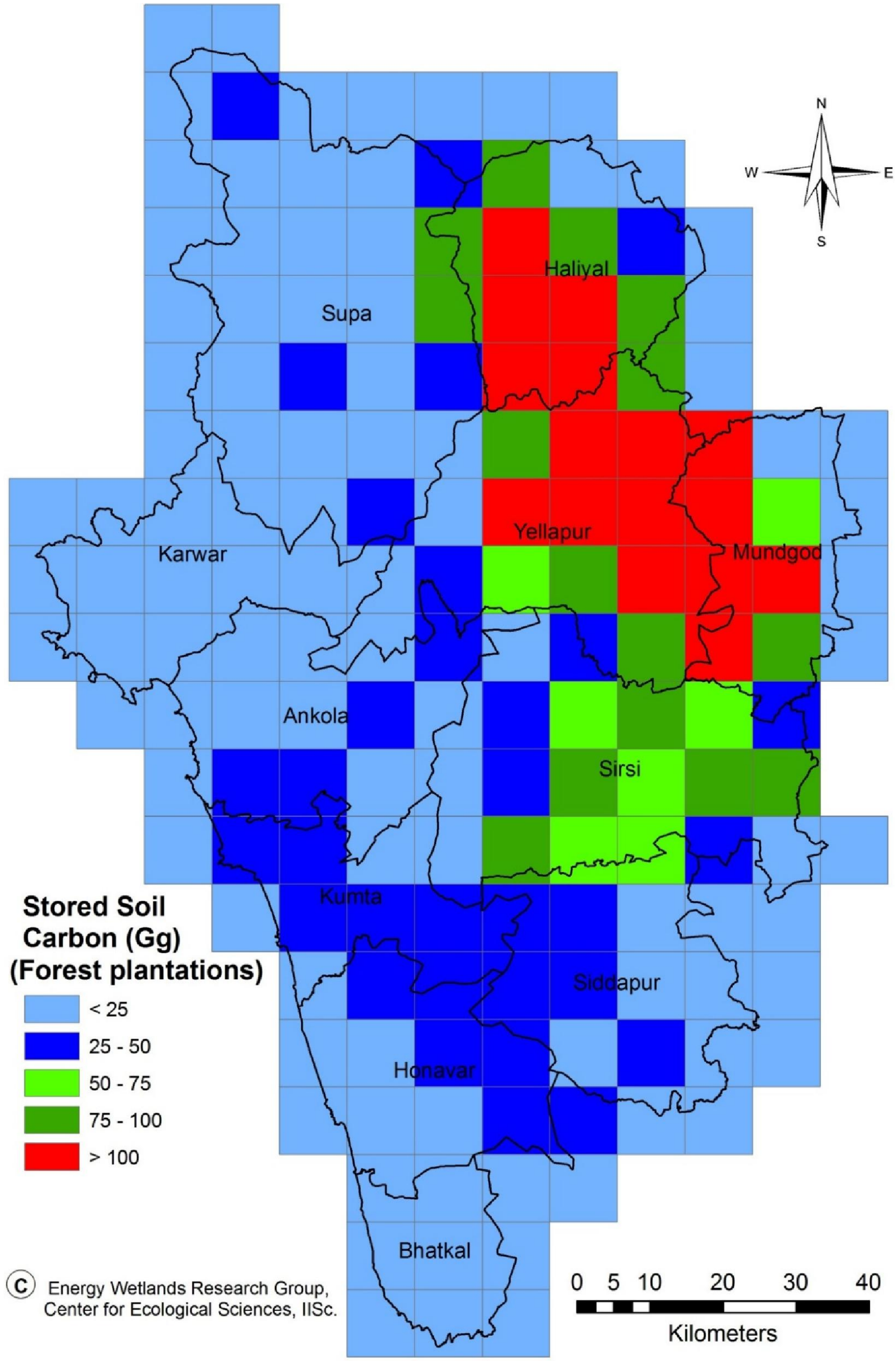

Figure 6.20: Carbon sequestration of soil from forest plantations

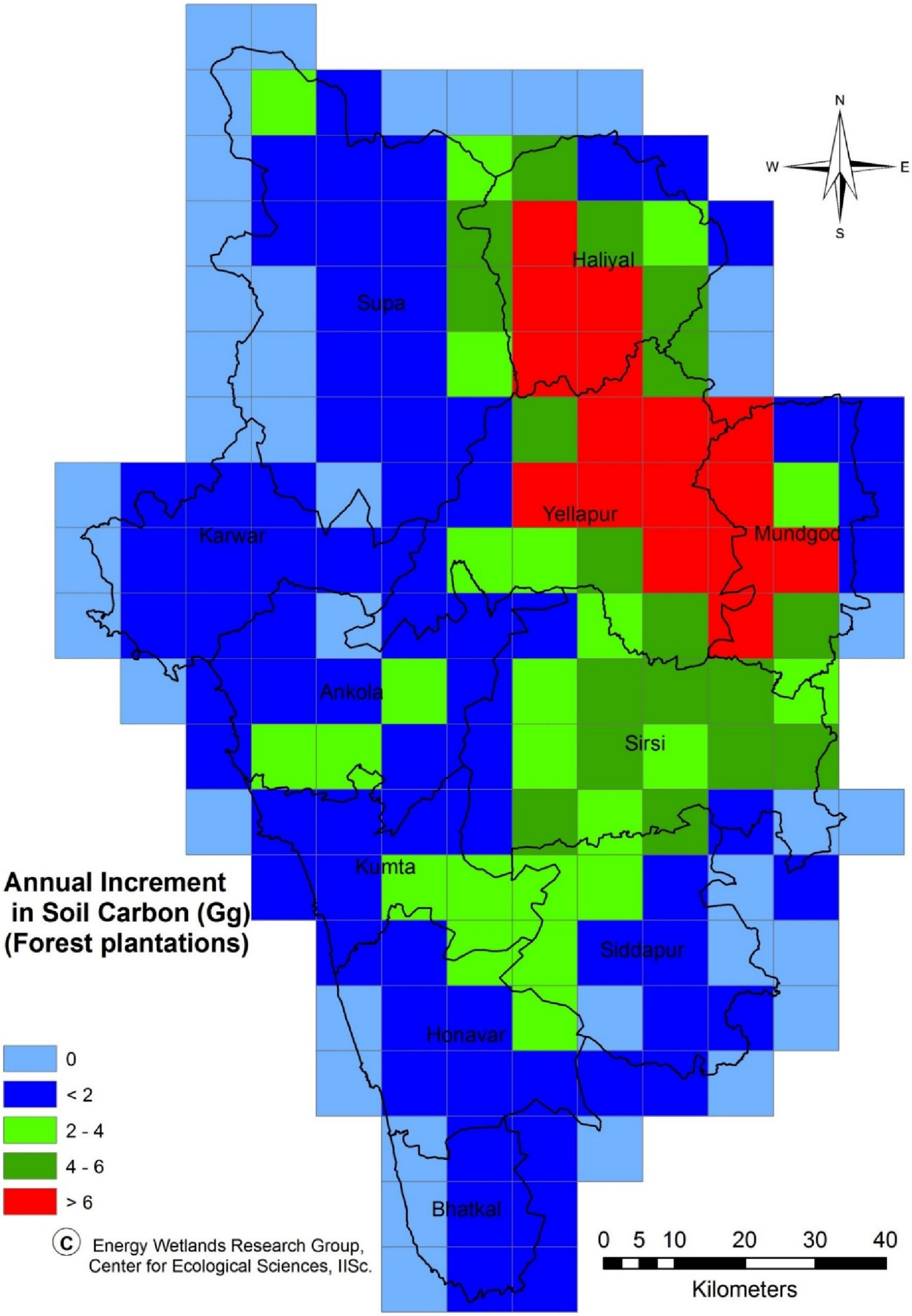

Figure 6.21: Annual increment in carbon sequestration of soil from forest plantations

5.4 Carbon emission: Livestock plays a prominent role in agrarian ecosystem. Livestock management in Uttara Kannada offers opportunities for reducing GHG emissions and the manures from confined cattle, bovines offer the most readily available source for biogas production to minimize methane emissions and replace fossil fuel / forest wood usage. Methane emissions from manure management tend to be smaller than enteric emissions. Two scenarios (Low and High) were considered to analyse potentiality of region considering taluk wise livestock. Figure 6.22 and table 5.8 depicts that Bhatkal with higher livestock density (105 animals/square kilometer) followed by Kumta (91), Haliyal (86), Honnavar (84). The lowest density is found in Supa (18) and Karwar (35) taluks.

Table 5.8: The livestock density of Uttara Kannada region

Taluks	No of Villages	Area (sq. km)	Total livestock population	Livestock density (per sq. km)
Ankola	79	904.79	44154	49
Bhatkal	60	355.5	37267	105
Haliyal	111	847.62	72908	86
Honnavar	92	756.15	64189	84
Karwar	51	724.12	25451	35
Kumta	112	590.45	53585	91
Mundgod	84	667.44	51829	78
Siddapur	195	847.27	71227	84
Sirsi	221	1322.32	88413	67
Supa	114	1910.44	33772	18
Yellapur	127	1298.75	52134	40

Anaerobic digestion of animal residues provides valuable cooking fuel, in the form of biogas and enhances the manure value of the waste. Methane from animal wastes is an alternative viable rural energy, provided sufficient feedstock is available. Energy and biogas potential of livestock residues of all major groups of animals were estimated based on the livestock population (2011). This disaggregated approach helps in accurate assessment of resources in a region, which would be useful in successful dissemination of biogas plants. It was seen that Sirsi, Honnavar and Siddapur had the highest biogas potential. Analyses reveal that the domestic energy requirement can be met by biogas option in 428 villages in Uttara Kannada district for more than 60% population. This highlights of optimal use of resources (animal residues) for energy (biogas generation) as well as manure.

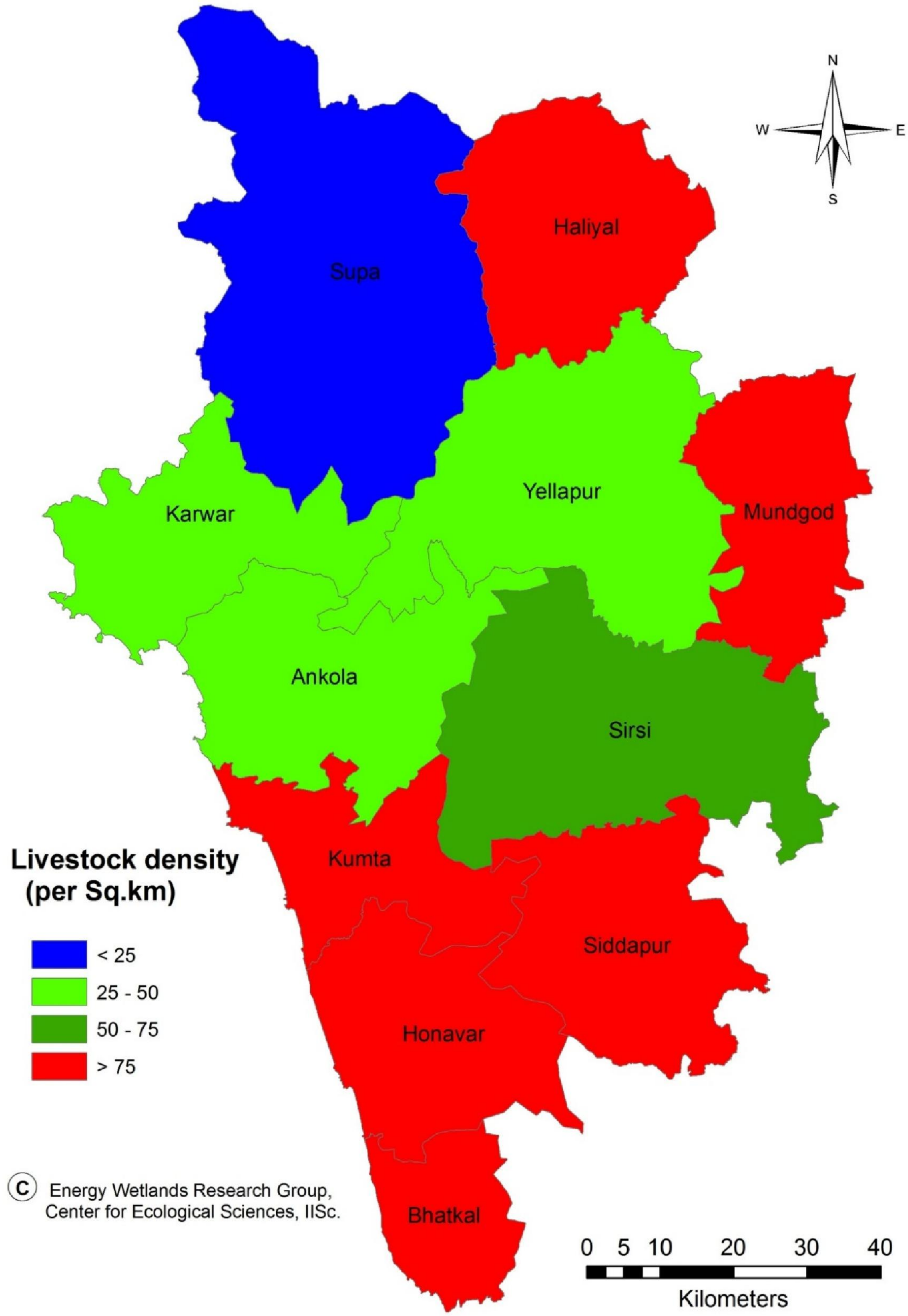

Figure 6.22: Livestock density of Uttara Kannada.

Tables 5.9 and 5.10 lists methane emissions from enteric fermentation and manure (under high as well as lower case scenarios). In high case emission factor for enteric fermentation is 16.408 kg/head/year and for manure it is 3.93 kg/head/year. In low case emission factor for enteric fermentation is 6.1 kg/head/year and for manure it is 0.92 kg/head/year. The high case scenario shows Sirsi (1450.68 t/yr), Siddapur (1168.69 t/yr), and Haliyal (1196.27 t/yr) taluks are with higher emission from entreric fermentation as well as from manure. The least values of emission from livestock can be seen in Karwar (417.60 t/yr) and Supa taluks (554.13 t/yr). Total emission from enteric and manure values shows Sirsi (1.8 Gg), Siddapur (1.45 Gg), Haliyal (1.48 Gg), Honnavar (1.31 Gg) and least values of emission seen in Karwar, Supa taluks. Simultaneously it was same under low case scenario lesser methane emissions from enteric, manure were found in Karwar, Supa with 0.18 and 0.24 Gg. In the lower case, values show Sirsi, Siddapur and Haliyal have the highest methane emissions from enteric as well as manure.

Table 5.9: Emissions from enteric fermentation and manure in Uttara Kannada district **(High case Scenario)**

Taluks	**Number of animals (B)**	**Emissions from enteric fermentation(t/yr) (Eef= B*EFT)**	**Emissions from manure (t/yr) Ema= B* EFT**	**Total emissions (Eef+Ema)**	
				(Tonnes/yr)	**Gg/ Yr**
Ankola	44154	724.48	173.53	898.00	0.90
Bhatkal	37267	611.48	146.46	757.94	0.76
Haliyal	72908	**1196.27**	**286.53**	1482.80	**1.48**
Honnavar	64189	1053.21	252.26	1305.48	**1.31**
Karwar	25451	417.60	100.02	517.62	0.52
Kumta	53585	879.22	210.59	1089.81	1.09
Mundgod	51829	850.41	203.69	1054.10	1.05
Siddapur	71227	**1168.69**	**279.92**	1448.61	**1.45**
Sirsi	88413	**1450.68**	**347.46**	1798.14	**1.80**
Supa	33772	554.13	132.72	686.85	0.69
Yellapura	52134	855.41	204.89	1060.30	1.06
Uttara Kannada	594929	9761.60	2338.07	12099.67	12.10

Table 5.10: Emissions from enteric fermentation and manure in Uttara Kannada district **(Low case Scenario)**

Taluks	Number of animals (B)	Emissions from enteric fermentation(t/yr) (Eef= B*EFT)	Emissions from manure (t/yr) Ema= B* EFT	Total emissions (Eef+Ema)	
				(Tonnes/yr)	Gg/ Yr
Ankola	44154	269.34	40.62	309.96	0.31
Bhatkal	37267	227.33	34.29	261.61	0.26
Haliyal	72908	**444.74**	**67.08**	511.81	**0.51**
Honnavar	64189	391.55	**59.05**	450.61	**0.45**
Karwar	25451	155.25	23.41	178.67	**0.18**
Kumta	53585	326.87	49.30	376.17	0.38
Mundgod	51829	316.16	47.68	363.84	0.36
Siddapur	71227	**434.48**	**65.53**	500.01	0.50
Sirsi	88413	**539.32**	**81.34**	620.66	0.62
Supa	33772	206.01	31.07	237.08	**0.24**
Yellapura	52134	318.02	47.96	365.98	0.37
Uttara Kannada	594929	3629.07	547.33	4176.40	4.18

Table 5.11: Taluk wise Carbon dioxide emissions from enteric fermentation and manure for high case scenario

Taluks	High case				
	Emissions from enteric fermentation(Gg/yr)	$GgCO_2$ equivalent (GWP=21)	Emissions from manure (Gg/yr)	$GgCO_2$ equivalent (GWP=21)	Total CO_2 emission
Ankola	0.72	15.21	0.17	3.64	18.86
Bhatkal	0.61	12.84	0.15	3.08	15.92
Haliyal	1.20	25.12	0.29	6.02	**31.14**
Honnavar	1.05	22.12	0.25	5.30	**27.41**
Karwar	0.42	8.77	0.10	2.10	10.87
Kumta	0.88	18.46	0.21	4.42	22.89
Mundgod	0.85	17.86	0.20	4.28	22.14
Siddapur	1.17	24.54	0.28	5.88	**30.42**
Sirsi	1.45	30.46	0.35	7.30	**37.76**
Supa	0.55	11.64	0.13	2.79	14.42
Yellapura	0.86	17.96	0.20	4.30	22.27
Uttara Kannada	**9.76**	**204.99**	**2.34**	**49.10**	**254.09**

Table 5.12: Taluk wise Carbon dioxide emissions from enteric fermentation and manure for low case scenario

Taluks	Low case				
	Emissions from enteric fermentation (Gg/yr)	**$GgCO_2$ equivalent (GWP=21)**	**Emissions from manure (Gg/yr)**	**$GgCO_2$ equivalent (GWP=21)**	**Total CO_2 emission**
Ankola	0.27	5.66	0.04	0.85	6.51
Bhatkal	0.23	4.77	0.03	0.72	5.49
Haliyal	0.44	9.34	0.07	1.41	**10.75**
Honnavar	0.39	8.22	0.06	1.24	**9.46**
Karwar	0.16	3.26	0.02	0.49	3.75
Kumta	0.33	6.86	0.05	1.04	7.90
Mundgod	0.32	6.64	0.05	1.00	7.64
Siddapur	0.43	9.12	0.07	1.38	**10.50**
Sirsi	0.54	11.33	0.08	1.71	**13.03**
Supa	0.21	4.33	0.03	0.65	4.98
Yellapura	0.32	6.68	0.05	1.01	7.69
Uttara Kannada	**3.63**	**76.21**	**0.55**	**11.49**	**87.70**

Table 5.12 and figure 6.23 shows CO_2 emission from fermentation and manure in low case. In this case also Sirsi, Siddapur Haliyal has the highest CO_2 emissions in both processes. The least values are in Karwar, Supa taluks.

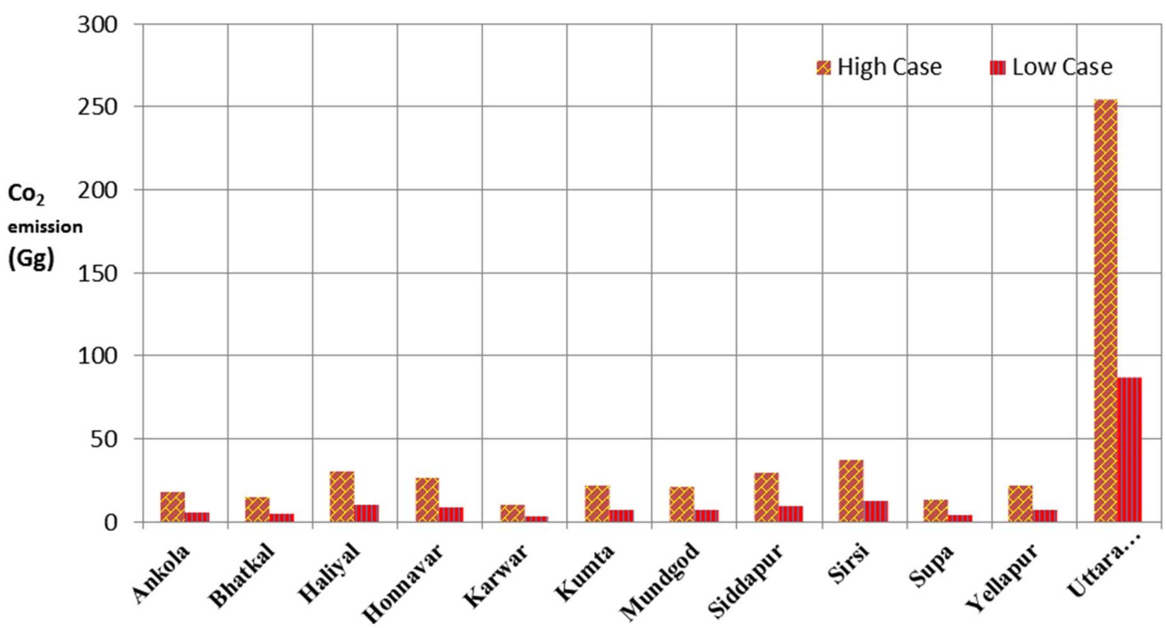

Figure 6.23: CO_2 emission from livestock in Uttara Kannada.

GHG emissions from enteric fermentation, manure were calculated by converting methane to carbon equivalent. Table 5.11 and figure 6.23 shows CO_2 emission from fermentation and manure (in high case scenario). Sirsi, Siddapur Haliyal has the highest CO_2 emissions in both processes, while lower values are in Karwar, Supa taluks.

Paddy is grown in two seasons, viz., kharif (June/July) and rabi or summer (January/February). In all the rice growing ecosystems, Kharif sowing is common while during summer season the crop is cultivated mainly in the irrigated areas and the tank-fed areas. The crop is taken up late in the season (August/September) depending upon the monsoon showers. In coastal area, one can see a specific situation where a second crop is sown in September/October and harvested in January/February and the third crop is cultivated between December/January and March/April. In each taluk, nearly 60-80 per cent of the total area is covered during Kharif (wet) season while the remaining area is occupied in late Kharif and summer (dry) season. The taluk wise area under paddy cultivation is being shown in table 5.13. The total methane emissions from Uttara Kannada paddy cultivation are estimated to be 4.84 Gg/year and its $C0_2$ equivalent is 101.57 Gg. Higher paddy cultivation can be seen in Haliyal, Mundgod, Sirsi taluks. The methane emission (Gg) is more in Haliyal (0.90), Mundgod (0.70) Sirsi (0.62) due to presence of both rain fed and tank based irrigations. The least can be seen in Karwar taluk (0.22) with an area of 3377 Ha under paddy.

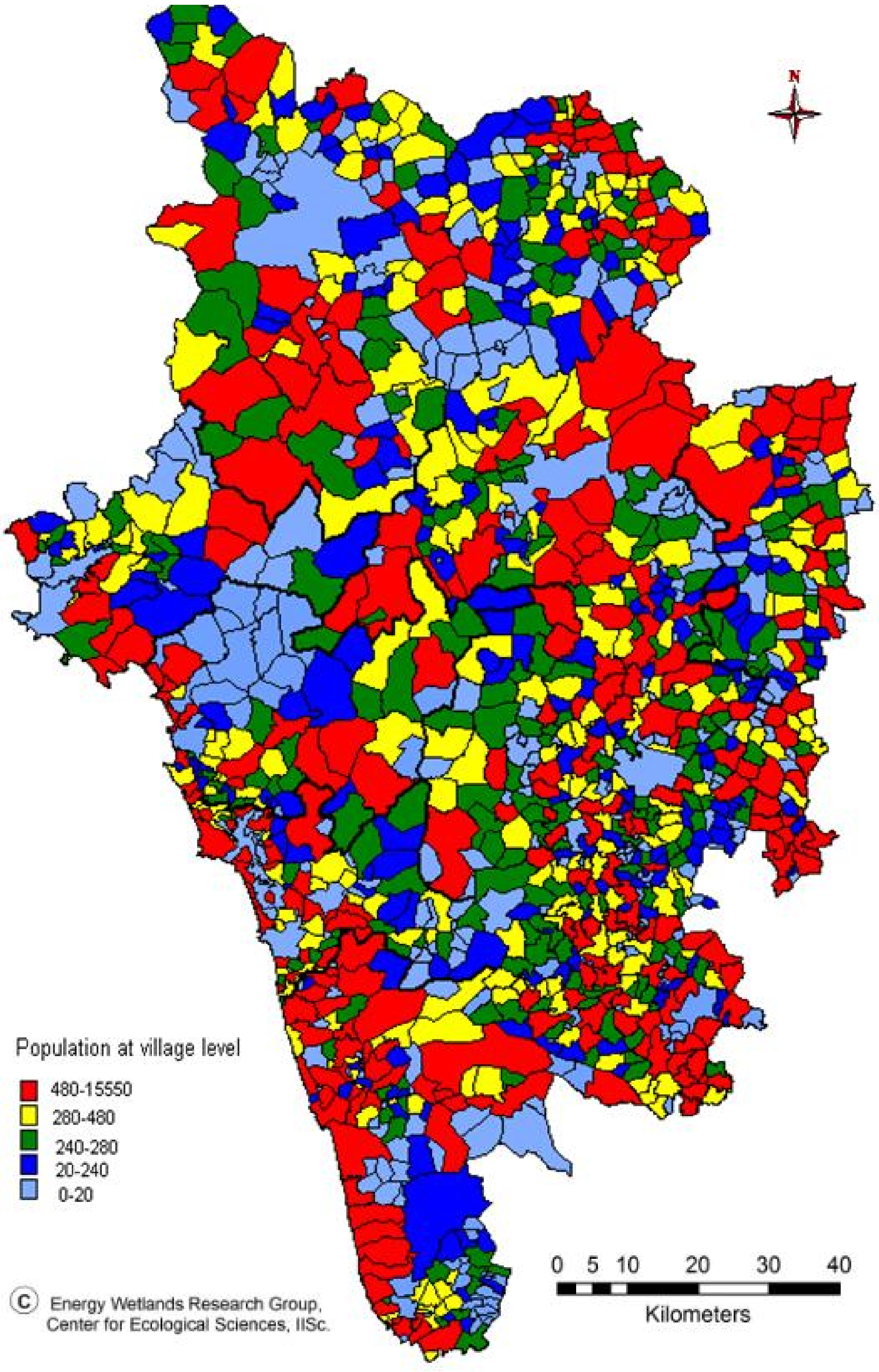

Figure 6.24: Village level population of Uttara Kannada district

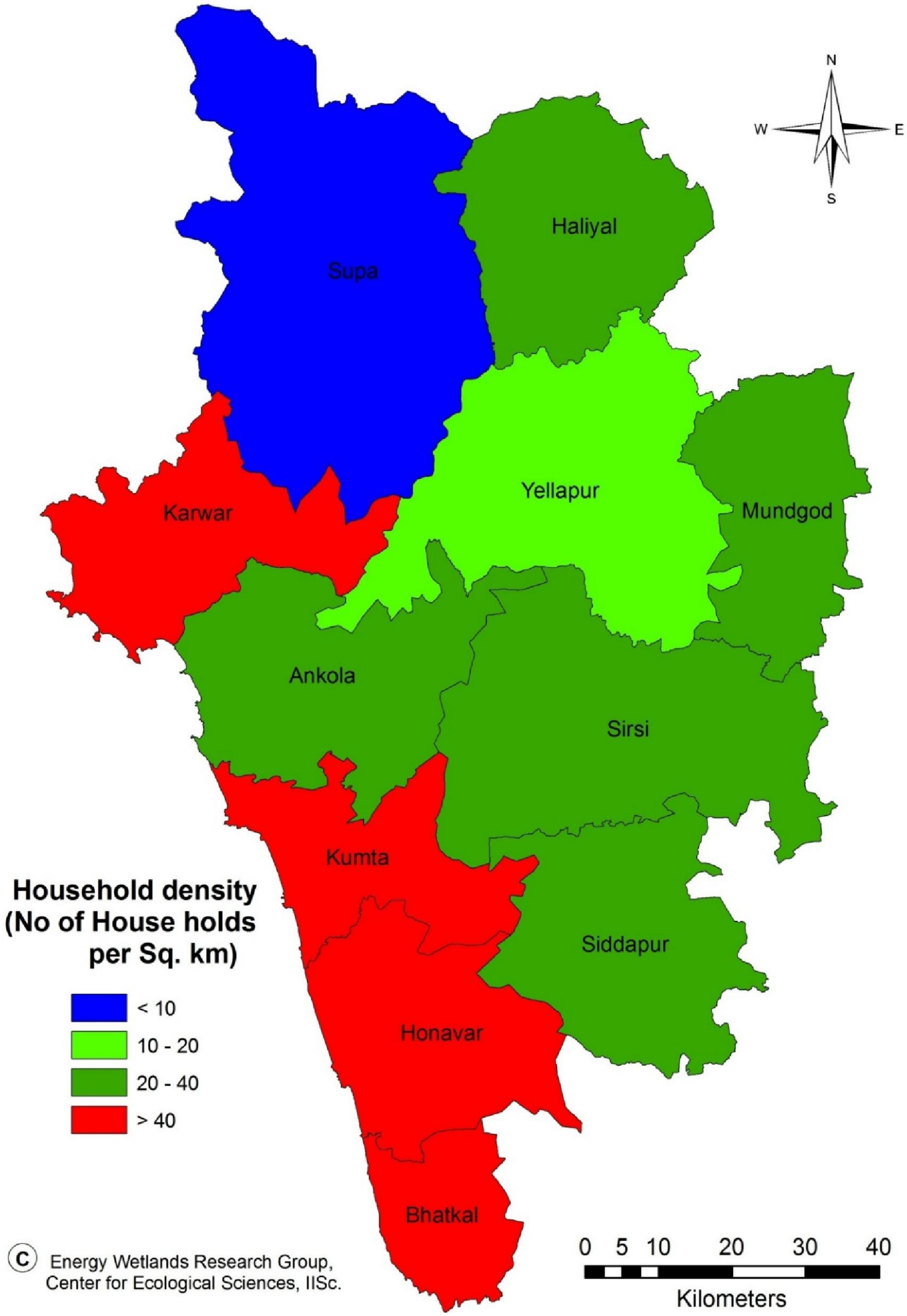

Figure 6.25: House hold density of Uttara Kannada district

Table 5.13: Taluk wise Carbon dioxide emissions from paddy fields

Taluks	Area under paddy cultivation (Ha)	Production in Tons	Methane emission		Gg CO_2 equivalent /Yr. (GWP=21)
			(T/Yr)	Gg	
Ankola	5900	17106	389.4	0.39	8.18
Bhatkal	4270	12380	281.82	0.28	5.92
Haliyal	**13705**	39736	904.53	0.90	**19.00**
Honnavar	4559	13218	300.894	0.30	6.32
Karwar	3374	9783	222.684	0.22	4.68
Kumta	5391	15706	355.806	0.36	7.47
Mundgod	**10631**	33117	701.646	0.70	**14.73**
Siddapur	6594	20029	435.204	0.44	9.14
Sirsi	**9401**	27898	620.466	0.62	**13.03**
Supa	5208	15100	343.728	0.34	7.22
Yellapura	4252	15549	280.632	0.28	5.89
UTTARA KANNADA	**73285**	**219622**	**4836.81**	**4.84**	**101.57**

Per Capita Fuel wood Consumption (PCFC) is computed to determine the fuel wood consumption pattern in various agro-climatic zones of the district. The village level population is estimated (figure 6.24) and fuel wood consumption based on the earlier field investigations (Ramachandra et al., 2000). Figure 6.24 shows that majority of villages in coastal taluks and plains have higher population and Sahyadri region has presence of moderate population. House hold density is estimated and is given in figure 6.25. It shows Coastal taluks Karwar, Kumta, Honnavar, Bhatkal are having number of households greater than 40. Plains are having moderate density and Supa has least household density. Fuel wood consumption (FC) is estimated based on population and PCFC in the respective agro zones. Table 5.14 shows agro-climatic region wise carbon emission from fuel wood usage in the district. The coastal Karwar, Honnavar, Kumta taluks are having higher emissions. Sahyadri taluks – Sirsi and Siddapura, and plains – Haliyal taluk has higher emissions of carbon. The overall emission from fuel wood consumption of district accounts to be 77.2 Gg. Supa taluk (2.97 Gg) and Yellapura (4.46 Gg) are having least emission values among all taluks (figure 6.26).

Table 5.14: Agro-climatic region Carbon dioxide emissions from fuel wood consumption

	Coastal region			
Taluk	No of households (NH)	NH*PCFC (PCFC=2.01 Kg/person/day)	Carbon emission	
			(T/Yr)	Gg of carbon /year
Ankola	21079	42368.79	5644.58	5.64
Bhatkal	25188	50627.88	6744.90	6.74
Honnavar	32808	65944.08	8785.40	*8.79*
Karwar	35273	70898.73	9445.48	*9.45*
Kumta	28251	56784.51	7565.12	*7.57*
	Sahyadri Interior			
Taluk	**No of households (NH)**	**NH*PCFC (PCFC=2.19Kg/person/day)**	**Carbon emission**	
			(T/Yr)	**Gg of carbon /year**
Siddapura	20598	45109.62	6009.73	*6.01*
Sirsi	36103	79065.57	10533.51	10.53
Supa	10186	22307.34	2971.90	2.97
Yellapura	15292	33489.48	4461.64	4.46
	Plains			
Taluk	**No of households (NH)**	**NH*PCFC (PCFC=2.32Kg/person/day)**	**Carbon emission**	
			(T/Yr)	**Gg of carbon /year**
Haliyal	31481	73035.92	9730.21	*9.73*
Mundgod	17163	39818.16	5304.77	5.30
	UTTARA KANNADA			**77.2**

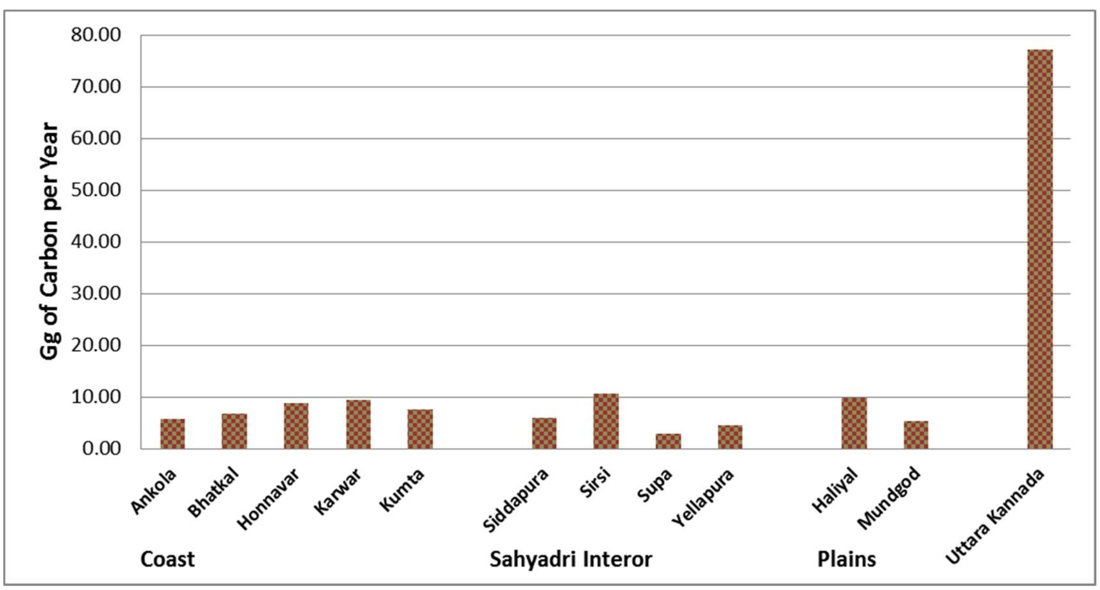

Figure 6.26: CO_2 emission from fuel wood consumption in Uttara Kannada.

Transportation is another major sector of CO_2 emission. The taluk wise vehicle details are analysed and emission from CO_2, CO, CH_4 is estimated and converted CO_2 equivalent. The distance travelled by each vehicle type and emission factors considered are shown in table 5.15. The total emission from transportation sector of Uttara Kannada accounts to be 424.9 Gg. The total Carbon dioxide (CO_2), Methane (CH_4), Carbon monoxide (CO), from Uttara Kannada transport is 396.93 Gg, 1.72 Gg and 3.19 Gg respectively (table 5.16). The taluk wise estimate shows Karwar (Gg), Sirsi (Gg) has higher CO_2 as well as CO emissions. The CH_4 emissions are more in Yellapura (29.31Gg) Sirsi (24.31Gg), Kumta (23.59 Gg).

Table 5.15: Distance and emission factor considered for computing GHG emissions from transportation sector

Vehicle type		Motor cycles	Car	Cabs	Auto rickshaws	Omni buses	Tractors and trailers	Ambul ance	Goods vehicle	Other
Distance travelled per year		6300	33500	12600	12600	100000	21000	6300	63000	12600
Emission factor (Gg)	CO_2	0.000000 027	2.236E-07	2.08E-07	0.0000000 6	5.152E-07	2.083E-07	2.083E-07	5.152E-07	2.236E-07
	CO	0.000000 002	0.000000 002	1E-09	0.0000000 02	3.6E-09	5.1E-09	1E-09	3.6E-09	0.000000 002
	CH_4	1.80E-10	1E-10	1E-10	1.80E-10	9E-11	1E-10	1E-10	9E-11	1E-10

Table 5.16: Taluk wise GHG emissions from transportation sector

Taluks	**Vehicle wise emission (CO2)**									
	Motor cycles	**Car**	**Cabs**	**Auto rickshaws**	**Omni buses**	**Tractors and trailers**	**Ambul ance**	**Goods vehicle**	**Other**	**Total (Gg)**
Ankola	1.38	5.81	0.14	0.26	6.39	0.14	0.01	19.21	1.14	34.49
Bhatkal	2.85	7.91	0.31	0.81	3.92	0.18	0.01	11.46	1.32	28.76
Haliyal	2.50	7.25	0.07	0.22	9.48	3.29	0.01	18.37	0.87	42.06
Honnavar	1.95	5.15	0.38	0.34	9.12	0.10	0.01	20.94	1.06	39.04
Karwar	3.70	11.99	0.36	0.77	16.74	0.37	0.02	36.64	2.11	72.71
Kumta	2.18	7.41	0.42	0.42	1.85	0.10	0.01	24.05	1.50	37.95
Mundgod	0.71	2.06	0.03	0.07	1.80	2.51	0.01	7.37	0.30	14.85
Siddapur	0.85	1.69	0.03	0.06	1.96	0.39	0.00	6.62	0.26	11.87
Sirsi	4.42	13.42	0.31	0.51	16.28	1.85	0.02	50.15	3.65	90.62
Supa	0.41	3.00	0.07	0.01	2.01	0.42	0.01	2.89	0.18	8.99
Yellapura	0.91	2.28	0.04	0.08	1.80	0.67	0.01	9.51	0.30	15.60
UTTARA KANNADA	21.88	67.9 6	2.16	3.55	71.36	10.01	0.12	207.21	12.68	**396.93**
Taluks	**Vehicle wise emission (CO)**									

	Motor cycles	Car	Cabs	Auto rickshaws	Omni buses	Tractors and trailers	Ambulance	Goods vehicle	Other	Total (Gg)	Gg CO_2 equivalent
Ankola	0.01	0.05	0.00	0.01	0.04	0.00	0.00	0.13	0.01	0.26	0.39
Bhatkal	0.02	0.07	0.00	0.03	0.03	0.00	0.00	0.08	0.01	0.24	0.36
Haliyal	0.02	0.06	0.00	0.01	0.07	0.08	0.00	0.13	0.01	0.37	0.56
Honnavar	0.01	0.05	0.00	0.01	0.06	0.00	0.00	0.15	0.01	0.29	0.44
Karwar	0.02	0.11	0.00	0.03	0.12	0.01	0.00	0.26	0.02	0.56	0.84
Kumta	0.01	0.07	0.00	0.01	0.01	0.00	0.00	0.17	0.01	0.29	0.44
Mundgod	0.00	0.02	0.00	0.00	0.01	0.06	0.00	0.05	0.00	0.15	0.23
Siddapur	0.01	0.02	0.00	0.00	0.01	0.01	0.00	0.05	0.00	0.09	0.14
Sirsi	0.03	0.12	0.00	0.02	0.11	0.05	0.00	0.35	0.03	0.71	1.07
Supa	0.00	0.03	0.00	0.00	0.01	0.01	0.00	0.02	0.00	0.08	0.11
Yellapur	0.01	0.02	0.00	0.00	0.01	0.02	0.00	0.07	0.00	0.13	0.19
UTTARA KANNADA	0.15	0.61	0.01	0.12	0.50	0.25	0.00	1.45	0.11	3.19	**4.78**

Taluks	**Vehicle wise emission (CH_4)**										
	Motor cycles	**Car**	**Cabs**	**Auto rickshaws**	**Omni buses**	**Tractors and trailers**	**Ambulance**	**Goods vehicle**	**Other**	**Total (Gg)**	**Gg CO_2 equivalent**
Ankola	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	2.33
Bhatkal	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	4.64
Haliyal	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	4.12
Honnavar	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	3.23
Karwar	0.27	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.29	6.14
Kumta	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	3.61
Mundgod	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	1.19
Siddapur	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.37
Sirsi	0.33	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.35	7.34
Supa	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.69
Yellapur	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	1.49
UTTARA KANNADA	1.62	0.03	0.00	0.01	0.01	0.00	0.00	0.04	0.01	1.72	**36.16**

Figure 6.27 explains taluk wise CO_2, CO, CH_4 emissions and total CO_2 equivalent values (Gg). The Sirsi, Karwar, Haliyal taluks have higher CO_2 while Supa, Siddapur taluks have least CO_2. Sirsi, Karwar regions having national highways and more vehicle density and Supa is having least vehicle density in the district.

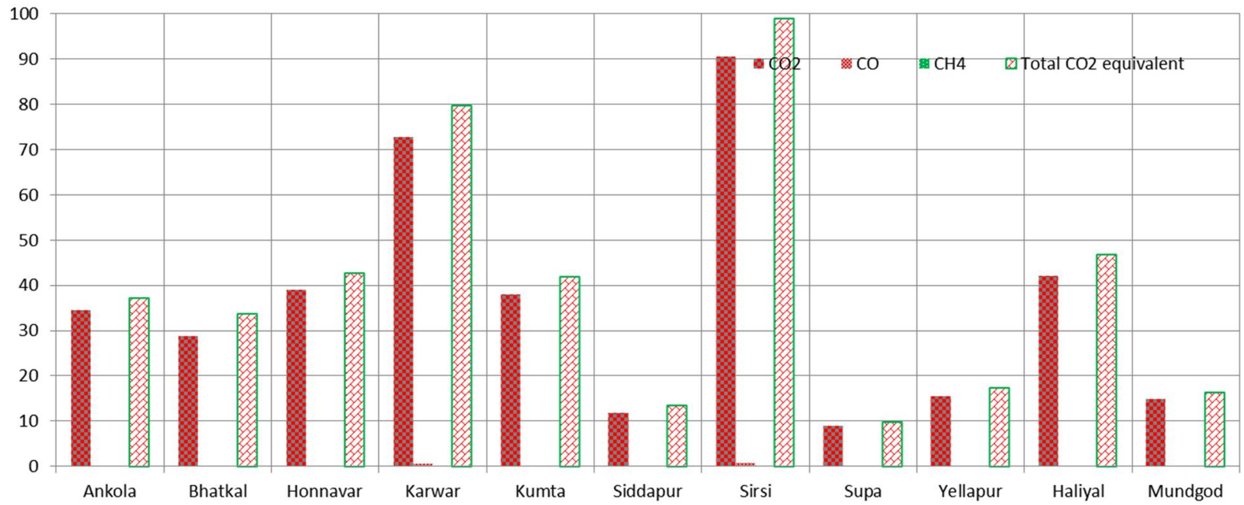

Figure 6.27: CO_2 emission from transportation in Uttara Kannada

6. CARBON STATUS IN UTTARA KANNADA

Carbon budgeting would provide information of Greenhouse Gas (GHG) emissions (especially carbon dioxide (CO_2) in the atmosphere, and on the carbon cycle in general), which helps in implementing strategies to mitigate carbon emissions and manage dynamics of the carbon-climate-human system. Budgeting of carbon was done by quantifying carbon sources as well as sinks. The ratio of carbon sinks to sources would provide the carbon status in the region. Sources include livestock, agriculture, fuel wood consumption, transport, etc. Sinks include forest vegetation and soil.

Table 6.1 shows various sources and sinks of carbon in the region. The emission from agriculture (paddy cultivation) is more in Haliyal (19.00 Gg), Mundgod (14.73Gg), Sirsi (13.03 Gg) and least in Karwar (4.68 Gg). The horticulture residue is a major source in Sirsi, Siddapur taluks. Transport and communication sector shows Sirsi (99.02 Gg), Karwar (79.70 Gg) taluks are having higher values due to higher population, vehicle density and transportation connectivity. The higher emissions from livestock sector are in Sirsi, Haliyal, Siddapur and Honnavar taluks due to greater density of livestock. The emission from fuel wood consumption is more in Sirsi, Haliyal, Karwar taluks. The total emission from transportation sector accounts to be 437.87 Gg and from livestock it is 87.70 Gg. The emission from paddy fields shows 101.57 Gg and fuel wood consumption shows 77.20 Gg.

Forest vegetation and soil play a pivotal role in sequestering carbon. Quantifications show that higher sequestration in Supa (610.67 Gg), Ankola (358.03 Gg) and Karwar (257.51 Gg). The Karwar taluk has higher sequestration of carbon (4567.5 Gg) due to ADTR and its buffer region. Yellapura taluk also shows 238.50 Gg carbon stored due to thick and moderately disturbed evergreen forest cover presence. The forest types can be seen in these regions ranges from evergreen to semi evergreen followed by large patches of moist deciduous forests. The least sequestration from natural forest is seen in Mundgod and Bhatkal. The total carbon sequestered from natural vegetation and soil at district level is 2416.69 Gg. The forest plantation accumulates 963.28 Gg at district level. The higher accumulation can be seen in Yellapura, Haliyal, Sirsi and Mundgod covering major part of the region under plantations. Bhatkal, Karwar taluks are showing least values.

Table 6.1: Taluk wise carbon emission and sequestration from various sectors

Taluks	Emission (CO_2 equivalent per year)				Carbon uptake (per year)	
	Transport & Communication (Gg)	Livestock (Gg)	Agriculture (Gg)	Fuel wood consumption (Gg)	Natural forest (Vegetation+Soil) (Gg)	Forest plantations (Vegetaion + Soil) (Gg)
Ankola	37.22	6.51	8.18	5.64	358.03	38.91
Bhatkal	33.76	5.49	5.92	6.74	82.65	6.08
Honnavar	42.71	9.46	6.32	8.79	174.81	31.18
Karwar	79.70	3.75	4.68	9.45	257.51	15.92
Kumta	42.00	7.90	7.47	7.57	152.10	34.68
Siddapur	13.39	10.50	9.14	6.01	126.15	46.46
Sirsi	99.02	13.03	13.03	10.53	255.53	139.20
Supa	9.80	4.98	7.22	2.97	610.67	71.58
Yellapura	17.28	7.69	5.89	4.46	238.50	270.61
Haliyal	46.74	10.75	19.00	9.73	117.04	179.77
Mundgod	16.27	7.64	14.73	5.30	43.71	128.91
Uttara Kannada	**437.87**	87.70	**101.57**	**77.20**	**2416.69**	**963.28**

The taluk wise total carbon emission and sequestration is shown in table 6.2 & figure 6.1. The carbon status is computed as a ratio of sink and emissions (figure 6.2). The total carbon emission of didtrict is 704.35 Gg and sink is 3379.97 Gg. The major emission can be seen in Sirsi (135.63 Gg), Karwar (97.57 Gg), Haliyal (86.21 Gg) due to various anthropogenic factors. These regions have higher vehicle density, livestock density, higher emission from paddy fields, fuel wood consumption. The Supa (682.25 Gg), Yellapura (509.11 Gg) and Ankola (396.94 Gg) taluks are acting as a major sink of the district. Carbon status computation shows Supa (27.33), Yellapura (14.41), Ankola (6.90) are having higher values revealing the taluks are aiding in higher carbon sequestration as area under forest cover. The net carbon balance calculated as the net source or sink of the forest sector to provide a base for UNFCC. United Nations Framework Convention on Climate Change (UNFCCC) emphasis on the signatory nations to provide a periodic update of carbon budget in the atmosphere. This endevour provides a frame work for carbon budgeting in the region.

Table 6.2: Carbon status at taluk wise of Uttara Kannada district

Taluks	Total carbon emission (Gg)	Total carbon uptake (Gg)	CBR
Ankola	57.55	**396.94**	**6.90**
Bhatkal	51.92	88.72	1.71
Honnavar	67.28	205.99	3.06
Karwar	**97.57**	273.42	2.80
Kumta	64.93	186.78	2.88
Siddapur	39.04	172.61	4.42
Sirsi	**135.62**	394.73	2.91
Supa	24.96	**682.25**	**27.33**
Yellapura	35.32	**509.11**	**14.41**
Haliyal	**86.21**	296.81	3.44
Mundgod	43.95	172.62	3.93
Uttara Kannada	704.35	3379.97	4.80

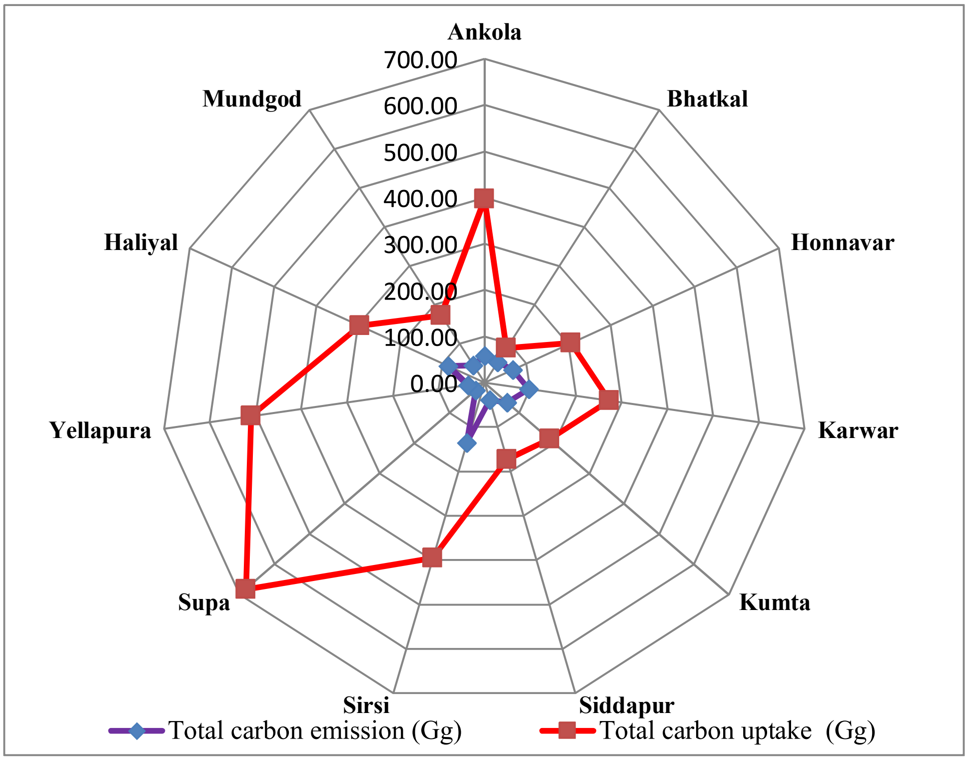

Figure 6.1: Taluk wise estimates of carbon sink and sources

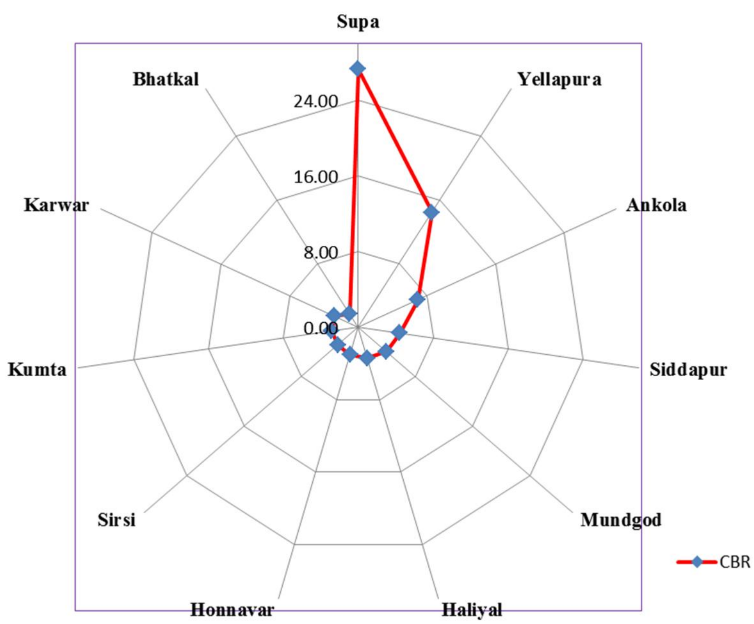

Figure 6.2: Carbon status - taluk wise

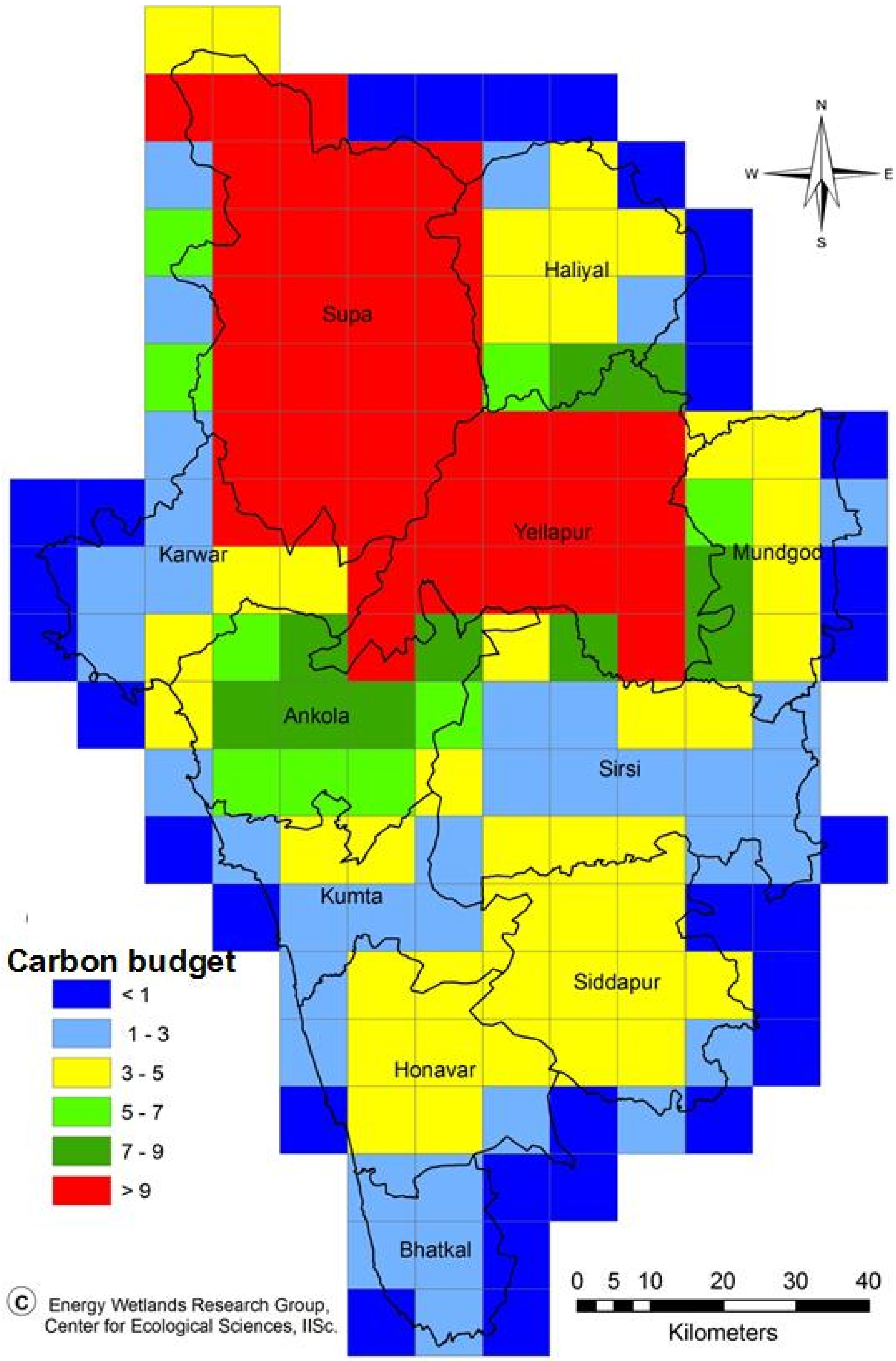

Figure 6.2: Carbon status in Uttara Kannada district

7. MITIGATION OF CARBON EMISSIONS:

The impact of anthropogenic activities on climate changes in the absence of mitigation measures is sufficiently large, and the time scales of natural intervention for climate change response are sufficiently long, necessitating prudent immediate mitigation actions. Figure 7.1 outlines the strategies to be adopted to reduce CO_2 emission towards the reduction of global climate change. Two courses of strategies are available to address the challenges associated with climate change: 1) adapting to the consequences of climate change and 2) mitigating climate change through reduction of GHG concentrations. Adaptation focuses on implementing measures that enable people to alter their lifestyles to minimize impact of climate change by promoting reducing use of fossil fuels; efficient use of water resources; developing low-cost technologies; improving health care and pest control; developing and using drought-resistant crops; and constructing disaster-resistant buildings and infrastructures. Although policies to implement adaptation measures may be established at a global, national, or regional levels, the consequences of climate change and the necessary adaptation to it must be undertaken locally. By prompting the long-term cost minimization the magnitude of action needed to respond to climate change through well-designed adaptation measures. Renewable energy technologies generate near-zero emissions of GHGs compared with fossil fuels. Renewable technologies include hydropower, wind, solar (concentrating solar thermal power and photo voltaic), waste-to-energy and combustion of renewables and waste. Expanding of renewable incentives to local authorities will drive down costs of renewable electric technologies in the achievement of mass production through cost reductions.

The adaptation task is a reactive approach and it is a burden because the challenges in infrastructure, societal changes that might economically limit. The proactive is considering mitigation by addressing the consequences of climate change with long term implementation by addressing many dimensions ranging from reducing emissions to increasing natural processes for GHG removal and long-term sequestration. Forest ecosystem includes three carbon pools: live biomass, dead biomass and mineral soils. The live biomass carbon represents all living tree and plant biomass. The dead biomass pool consists of carbon in detritus, forest floor, standing dead trees and coarse woody debris. The mineral soil pool consists of soil organic matter in the top 30 cm^3. Hence, forest regeneration is an effective mitigation measure for carbon emission, since vegetation, soil have enormous capacity of reducing emission of atmosphere. At the global level, the IPCC Third Assessment Report estimates that ~100 billion metric tons of carbon over the next 50 years could be sequestered through forest preservation, tree planting and improved agricultural management. So mitigation measures will play significant role in long term planning and the reduction of cost. The mitigating global climate change has become one of the nation's most significant policy challenges. Increased greenhouse gases, particularly carbon dioxide (CO_2), in the atmosphere are changing regional climates throughout the world. The magnitude of such damage remains highly uncertain, but there is growing recognition that mitigation measures will substantially overcome the problem in long term. Reducing the risk would require preventive the growth of CO_2 emissions and ultimately limiting those emissions to a level that would stabilize atmospheric concentrations which would involve costs but could be substantial. Many organisations, initiatives are created and designed programs to begin lowering CO_2 emissions would produce greater benefits than costs. United Nations Framework Convention on Climate Change (UNFCCC) is one of such initiative started in 21 March 1994. The ultimate objective of the Convention is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." It states that "such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner." The Convention acknowledges the vulnerability of all countries to the effects of climate change and calls for special efforts to ease the consequences. The UNFCC also provides monitory support for developing countries which lack the resources to do mitigation. The organisation also started active funding arrangements for adaptation under different Convention bodies after the guidelines of IPCC's third assessment report.

The Global Environment Facility (GEF) is another initiative from the World Bank to assist in the protection of the global environment and to promote environmental sustainable development, which unites 183 countries in partnership from 1991. It is an independent financial organization providing grants for projects related to biodiversity, climate change, international waters, land degradation, the ozone layer, and persistent organic pollutants. Since 1991, GEF has achieved a strong track record with developing countries and countries with economies in transition, providing $11.5 billion in grants and leveraging $57 billion in co-financing for over 3,215 projects in over 165 countries. Through its Small Grants Programme (SGP), the GEF has also made more than 16,030 small grants directly to civil society and community based organizations, totaling $653.2 million. The GEF also serves as financial mechanism for the **Convention on Biological Diversity (CBD); United Nations Framework Convention on Climate Change (UNFCCC); Stockholm Convention on Persistent Organic Pollutants (POPs); UN Convention to Combat Desertification (UNCCD).** The Kyoto Protocol (adopted in Kyoto, Japan, on 11 December 1997) is an international agreement linked to the UNFCC, which commits by setting internationally binding emission reduction targets. Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of "common but differentiated responsibilities." The Kyoto mechanisms are International Emissions Trading; Clean Development Mechanism (CDM); Joint implementation (JI).

Incentive based approaches can reduce emissions at a lower cost than more restrictive command-and control approaches because they provide more flexibility about where and how emission reductions are achieved. Reducing Emissions from Deforestation and Forest Degradation (REDD) is one such prime global initiative to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low carbon paths to sustainable development. "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks thus contributing to the global fight against climate change. REDD+ will benefit local communities as it explicitly safeguards their rights and those of indigenous peoples. India is committed that monetary benefits from REDD+ will flow to local, forest dependent, forest dwelling and tribal communities. India's stand was accepted in 13th Meeting of the Conference of the Parties (COP 13) at Bali 2007 with the focus of elements of conservation, sustainable management of forests and enhancement of forest carbon stocks. The government has put in place a National Mission for a Green India as part of the country's National Action Plan for Climate Change with a budget of Rs 46,000 crore (approx. USD 10 billion) over a period of 10 years. The overarching objective of the Mission is to increase forest and tree cover in 5 million ha and improve quality of forest cover in another 5 million ha.

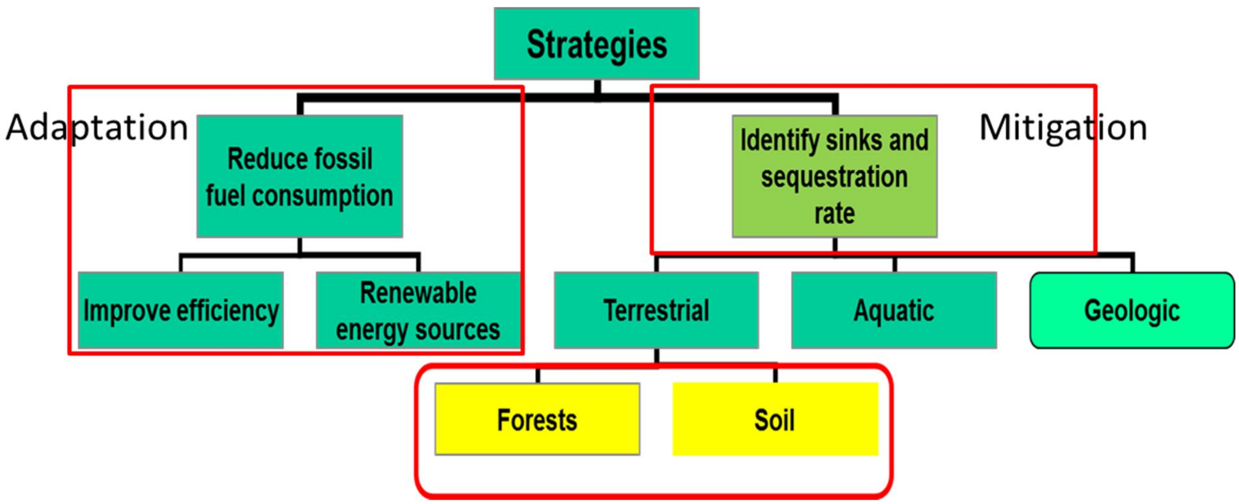

Figure 7.1: Frame work of strategies for reducing emission

Since the region has higher potentiality as a sink prompting for enrichment further with effective management to attain more incentives as stated above. The following are the recommendations provided to enrich the carbon sequestration potential of region and reducing emission.

i. The region has higher rainfall (upwards of 3000 mm/per annum) in most places, a dense forest cover is required to check soil erosion and increase infiltration. Enriching degraded forest patched with the location specific native species (except grasslands or grassy blanks, critical resources for grazing ecosystems) to enhance the carbon sequestration potential of the region.

ii. The forest department, for its administrative/practical convenience would prefer afforestation of large blocks of land than carrying out the process in a diffused fashion in the small blanks and degraded forest patches, which are dispersed widely almost everywhere, except in the steep areas of the ghats. This is understandable because saplings raised in centralized nurseries have to be transported, through the roads in bulk to the planting areas. The labour management will be easier and less expensive than if small planting areas are dispersed here and there, even in the interiors without proper road facility. The model that we suggest here is one of **decentralized local farmer-centric nurseries**, raised in small scale closer to the areas to be planted. This gives scope for sector-wise selection of plant species that are suitable for the local conditions of the respective areas.

iii. We recommend **peoples' nurseries** to get ready saplings instead of centralized nurseries of forest department. This will generate more of rural employment potential, all along the proposed alignment areas, for the same people who might as well be important stakeholders in the future on the very vegetation wealth they create. It is notable that several habitually forest dwelling communities here, such as Gowlis, Siddis, Kunbis, Karivokkaligas, Halakkivokkals etc. who live in these parts can be associated as partners in conservation efforts and benefit sharing in accordance with the various forest regulations and provisions and Forest Dwellers' Act, 2006. Year-wise progress achieved in these afforestation activities has to be recorded. In addition we also recommend **fencing of blocks of forest lands** with basal areas of less than 15 sq. m each, for minimum periods of 8-10 years, will prevent the entry of domestic cattle and humans into these protected blocks and pave the way for natural regeneration of especially native species of plants.

iv. Biomass enrichment is an urgent necessity and poor grade tree plantations of Haliyal, Mundgod, Kirvathi division of Yellapura regions need to be restored with natural forest species through planting of saplings and seeds to enhance eroded soils.

v. The betta and hakkal lands should be fenced and natural regeneration, enriching grassy blocks can be promoted. The degraded regions such as betta and hakkal lands should be reforested by public private partnership.

vi. Create incentives for adopting energy-efficiency measures in industry that accommodate changing market conditions and pressures, energy prices and business concerns that affect the ability and willingness of industry to pursue energy efficiency opportunities.

vii. Promote increased levels of recycling and remanufacturing to recover the energy invested through virgin material processing.

viii. Various plant species of the district are sources of bio pesticides. Preparation of bio-pesticides, harmless to humans and domestic animals, may be promoted as a cottage industry using local plant resources, especially from village peripheral forests/VFC managed areas.

ix. This approach can further improve organic farming in the district while also earning extra income to the locals from production of marketable, homemade bio pesticide formulations, under an assisted programme from the Government.

x. Forest range wise river-stream-swamp protection action plans should be framed which incorporating adequate amount of inviolate vegetation growth for protection of ecology. River and stream bank forests, including inland swamp area forests are to be considered as endangered ecosystems for their high accumulation of biomass, presence of endemic species and higher levels of carbon sequestration.

xi. Investments in research to develop cost effective renewable and efficient energy technologies, improve the performance of carbon energy systems is recommended for clean energy systems.

xii. Increased emphasis and investment in education and training of the employees, NGOs in all advanced energy technologies and their deployment is required for reducing emission by public private participation.

8.0 CONCLUSION

Forest ecosystems are one of the pivotal factors in the global carbon cycle, vital habitats of many animal and plant species. Based on the detailed investigation of biomass resource availability and demand, the study categorises the Uttara Kannada District into two zones i.e. biomass surplus zone (consisting of taluks mainly from the Sahyadri Interior) and biomass deficit zone, (consisting of thickly populated plains and coastal taluks such as Bhatkal, Honnavar, Kumta, Mundgod, Haliyal). Total accumulated biomass of natural forest of district is 118627.54 Gg. The major sources of carbon emissions are deforestation, burning of fossils fuels, agriculture (livestock, paddy cultivation) and transport. Similarly major sinks are forest vegetation, soil, plantation, aquatic system (phytoplankton). Carbon emission and sequestration were quantified based on data available in published literatures (reports, scientific papers) and government agencies. Carbon status of each taluk was calculated based on quantification of carbon sinks and sources. The present study reveals the total carbon emitted from major sectors (livestock, paddy cultivation, transportation and fuel consumption) was 704.35 Gg/yr and carbon sequestered is 3379.97 Gg/yr. The taluk wise assessment shows Supa (682.25 Gg/yr), Yellapura (509.11 Gg/yr), Ankola (396.94 Gg/yr) of carbon stored. Least values can be seen in Mundgod, Bhatkal taluks. Supa taluk has higher carbon status (of 27.33) due to the presence of higher protected forests and moderate disturbance. The least values are in Mundgod, Bhatkal, Haliyal due to higher anthropogenic activities and disturbed forests. The effective forest management with forest regeneration activities with native species would help in further enhancing carbon status of a region.

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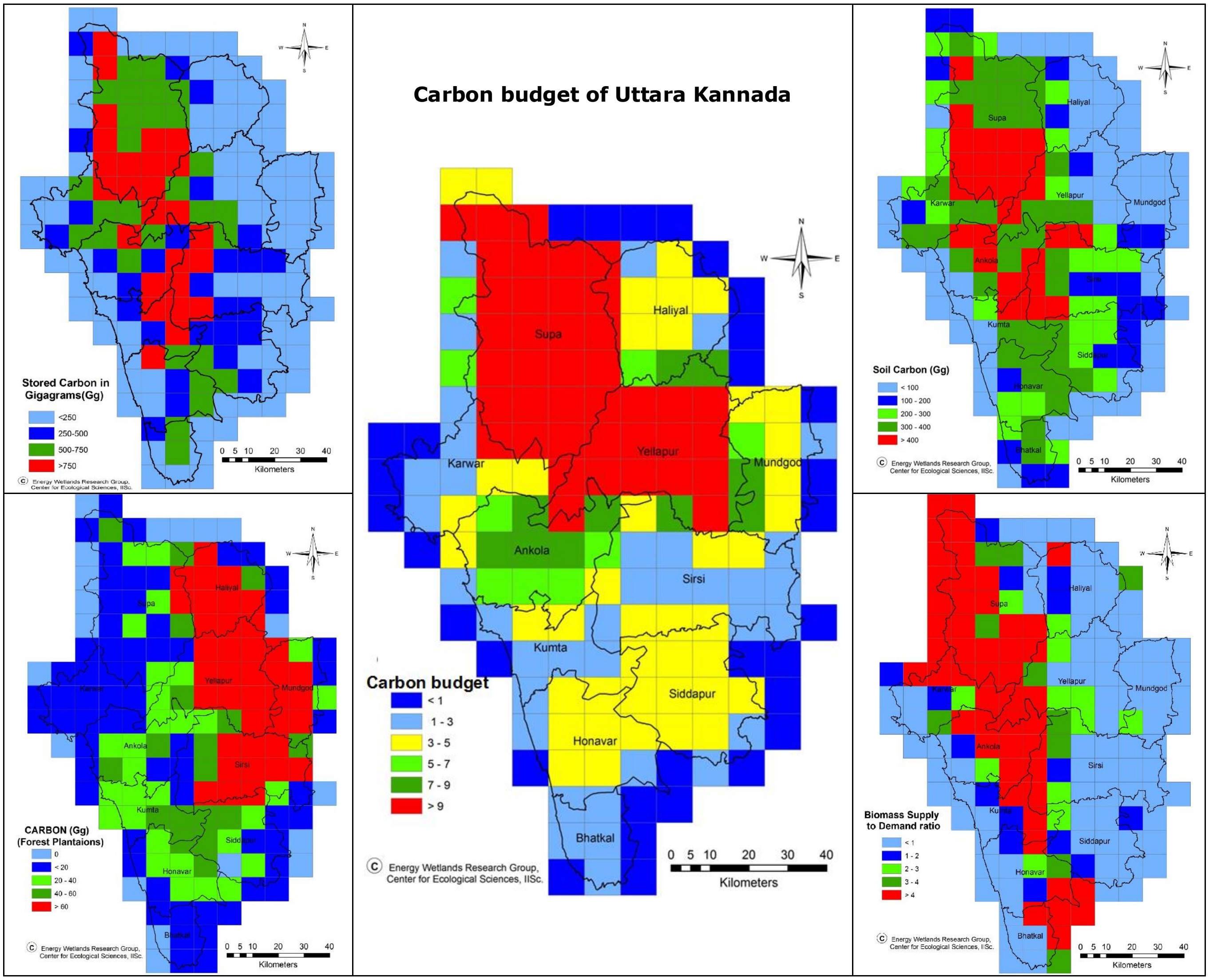

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