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Monitoring Vegetation with GIS and Remote Sensing Techniques and Carbon Stock Assessment of Mangroves of South Gujarat, Gujarat

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Abstract

The carbon dioxide which is emitted from anthropogenic activities stay into the atmosphere and takes centuries to remove. Carbon present in many ecosystems like ocean, biosphere, terrestrial and atmosphere (IPCC 2001a, Grace, 2004). The Ocean is the biggest carbon sink while 20-40% will be remaining in the atmosphere for the longer period. Mangrove ecosystem can sequester three times more carbon than any other ecosystem. To keep atmospheric carbon dioxide level below 450 ppm carbon dioxide reduction is required at 7% which can be achieving by restoring mangrove forest (Nellemann et al., 2009). Around 22.5 million tons of carbon is sequester by mangrove per year (Dittmar et al., 2006)

Recent Studies have emphasized the valuable role played of mangrove forest on carbon storage. Gujarat possess second largest mangrove cover in India and shows increasing trend since 1987. Many conservation measures are taken by the state by plantation activities, involvement of local community for conservation and various awareness programs that are why mangrove area is increased in the state. Total 15 mangrove species are reported from Gujarat out of them Avicennia marina is dominant species. Two carbon pools were measured to calculate mangrove forest: Biomass carbon (Above ground and roots) and sediment carbon.In present study carbon sequestration carried out by non-destructive methodology. To calculate above ground and root biomass allometric equations are used which were development by Komiyama et al. (2006).

The vegetation cover was mapped by GIS and Remote Sensing technique using LISS III and IV images.Present study data reveal that highest AGB is reported in Navsari (14.2mg/ha) followed by Surat (9.707 mg/ha), Bharuch (3.39 mg/ha), and Valsad (0.606 mg/ha).Results on the productivity of mangrove forests showed an overall carbon increment of 32.0915 mg/ha (aboveground and below ground carbon), 278.759 mg/ha (Soil Organic Carbon) and 301.85 mg/ha (total carbon). The result showed that the maximum carbon has been reported in Surat District (148.8645 Mg/ha) while least is in Valsad District (12.247 Mg/ha). The Carbon Stock assessment study revealed that the soil has sequestered more carbon (278.75 Mg/ha) than biomass (32.09 Mg/ha).The results further demonstrated the importance of the oceanic mangrove in carbon storage and the mangrove plants in contributing OC to their biomass and soils.

Key Words: Mangroves, GIS and Remote Sensing, Carbon Stock, Gujarat

Introduction

Mangrove plants can survive on high salinity, high temperature, tidal regimes, and strong wind velocity. Mangrove ecosystem is one among the most productive ecosystems on the earth. This ecological group of plant provides a wide range of ecological and economic products and services, and also supports a variety of other coastal and marine ecosystems. Globally, mangroves are present in 118 countries and globally, total mangrove cover is 18 million hectares (0.45%) and 1% of the entire area of tropical forest and less than 1% global forest cover (Spalding et al., 2010). Out of

75% of world's mangrove only 6.9% are protected under the existing protected areas network. India, having longest coastline of about 7516 km long. In India mangrove occupy about 5% of global mangrove vegetation and area occupy 4,500 km2; fourth largest area in the world.

The carbon dioxide which is emitted into the atmosphere takes centuries to remove. Carbon circulates in many ecosystems like ocean, biosphere, terrestrial and atmosphere (IPCC 2001a, Grace, 2004). The biggest sink for the carbon is ocean while 20-40% will be remaining in the atmosphere for the longer period. According to many scientists the emitted Carbon dioxide remains into the atmosphere for longer period of time. Terrestrial ecosystem sequesters around 500 peta grams plant biomass carbon and 200 peta gram sediment carbons. For oceanic carbon cycle, high primary productivity and nutrient concentration and earth surface coverage, coastal margins are very important component (Berg, 1996, Bergheim, 1998). There should be net balance between release and sequester carbon. The net effect of photosynthesis and respiration is comparatively lesser increment in sequestered carbon in most years.

Mangrove ecosystem can sequester three times more carbon than any other ecosystem. To keep atmospheric carbon dioxide level below 450 ppm carbon dioxide reduction is required at 7% which can be achieving by restoring mangrove forest (Nellemann et al., 2009). Around 22.5 million tons of carbon is sequester by mangrove per year (Dittmar et al., 2006). Mangrove cover only 0.1% of earth's continental surface and account for around 11% of the total input of terrestrial carbon into the and 10% terrestrial dissolved organic carbon exported to the ocean (Dittmar et al., 2006). Increasing greenhouse gases concentration in the atmospheres is the main causes for manmade climate change. The chief greenhouse gas is anthropogenic carbon dioxide and it emit majorly from energy use and industries and effect temperature and climate; that emission is called as brown carbon for greenhouse gases and black carbon for particles from combustion like soot and dust. Fossil fuel burning adding greenhouse gases such as CO2 (Brown Carbon) and dust particles (Black Carbon). Trumper has explained the definition of carbon sequestration; it is a process by which CO2 uptake into reservoir over long period of time. The ocean has sea grasses, marshes, mangroves stored carbons in marine sediments that is called blue carbon. Around 55% carbon in all living organisms is stored in the ocean. This ecosystem is degraded faster than any other ecosystem. In lacking of important green carbon biofuel cropping become incentivized and leads to emission of carbon. According to Bouillon et al. (2008), the average biomass carbon density of mangroves is 78 t C/ha, foremost to an estimate of global biomass carbon stock of 1.21 Gt Carbon. Marine habitat accumulates carbon in the biomass as well as in sediment but it varies between site and range of environment conditions.

Tropical forest stored more above ground carbon per unit area than any other land cover type. Net carbon can be estimated by calculating increase or decrease terrestrial carbon. The tree biomass absorbs carbon dioxide from the atmosphere and stored into plant tissue (Mathews et al, 2000). The active absorption of carbon dioxide from the atmosphere and storage in biomass of growing tree is carbon sequestration (Baes et al., 1977). Many scientists estimated that carbon sinks are originated from land ecosystem and major part is sinking in forest in the northern latitude (White et al., 2000). It has been estimated that half of the carbon sink instigates from the land ecosystem of the earth and major part of the sink is placed within forest in the northern latitudes (White et al., 2000). It has been implicated that mature forests act as a carbon sink in which net exchange is close to nil, although this hypothesis has been questioned recently (Carey et al., 2001; Pregitzer and Euskirchen, 2004).

In forest key carbon pools are biomass, wood debris, litter and soil (SCOPE, 1984, Schlesinger, 1997, Richards and Evans, 2004). It is reported that when forest expansion is distressed or forest is devastated greenhouse gases like CO2, CH4 etc. are coming back to the atmosphere via respiration, decomposition or combustion process (IPCC, 2003, Richards and Evans, 2004). It is accomplished that the forest has ability to sequester and emit greenhouse gases with permanent extensive deforestation (Kyoto 1997; UNFCCC 1992). It reported that the 90% carbon is stored in the plant biomass rather than emitted atmosphere. This point outs the important of forest ecosystem in global carbon cycle. Hence, it is important to estimate forest carbon sequestration (Körner, 2006).

The 18% global carbon emission is from the deforestation activities and is the third source of the greenhouse gases emission. Currently, REDD, Reducing Emission from Deforestation and Degradation is accepted as a main component of climate change mitigation. The importance of carbon stock assessment of forest is that it provides how the carbon varies in different environment conditions and anthropogenic activities. Initially, Kyoto protocol rule for accounting carbon stock of different sectors was in demand for natural forest and planting forest modifications.

Resent research findings said that three major forest namely; tropical, boreal and temperate biome have capacity to sink carbon. The newly planting trees take more time to sequester carbon than already present old mature tree. It is very useful to discriminate between carbon sequestration capacity of ecosystem and current carbon stock. The carbon carrying capacity means ability of forest to sequester carbon under predominant environmental condition and natural disturbance systems. Carbon carrying capacity excludes man made disturbances. It provide baseline in contradiction of current carbon stock to be compared. The difference between these two activities allows carbon sequestration potential of particular ecosystem and calculate the lost carbon as a result of land use activities.

Carbon estimation study give world's major forest biomes by publically available peer reviewed articles and reputed publications. Mature old forest data provide the carbon varying capacity of forest. From the field measurement technique of tree and dead biomass can be called as structural biomasses are the reliable non-destructive source of biomass carbon. The structural measurement can be converted to biomass carbon density by allometric equations. All these results provide framework for identifying forest which have high carbon stock and help elucidate average forest biome values, published by inter-governmental panel on climate change and update policy about role of forestry in mitigating climate.

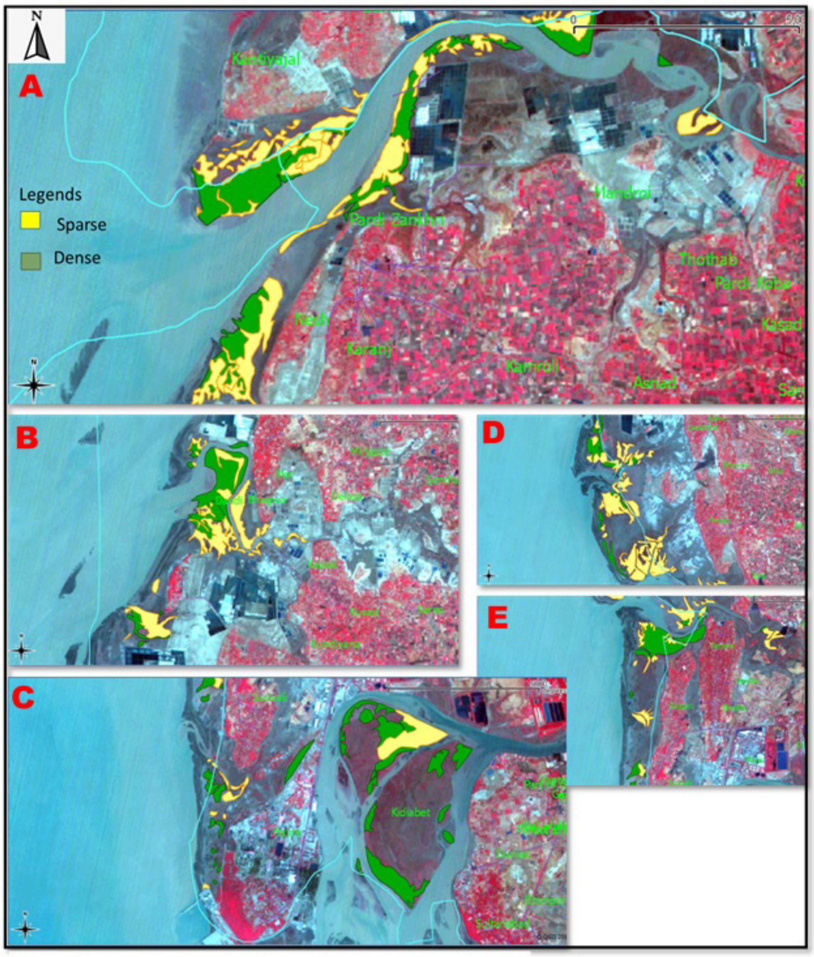

Figure 3 A to E Surat Mangroves Mapping

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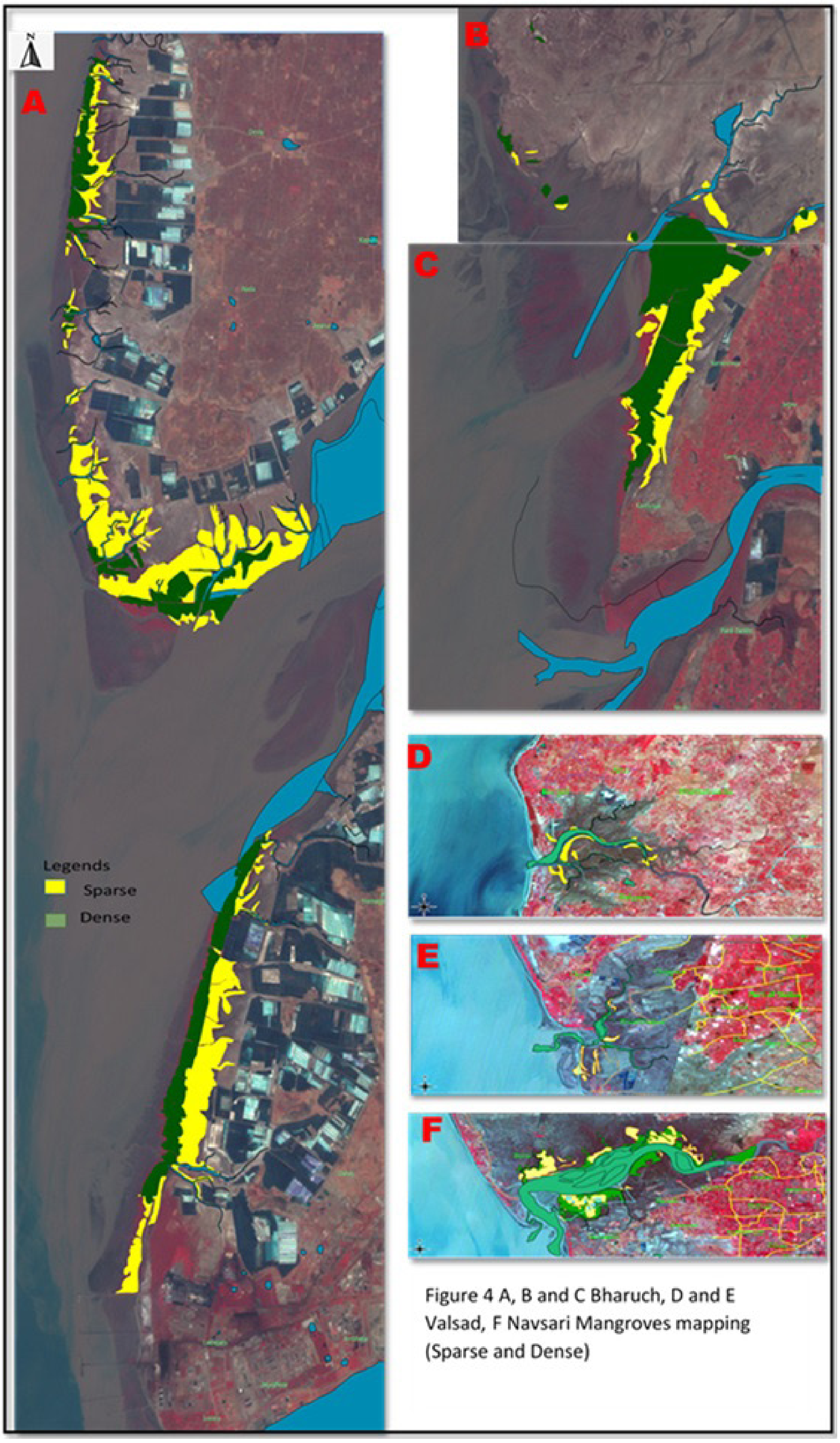


Figure 4 A, B and C Bharuch, D and E Valsad, F Navsari Mangroves mapping (Sparse and Dense)

Material and Methods

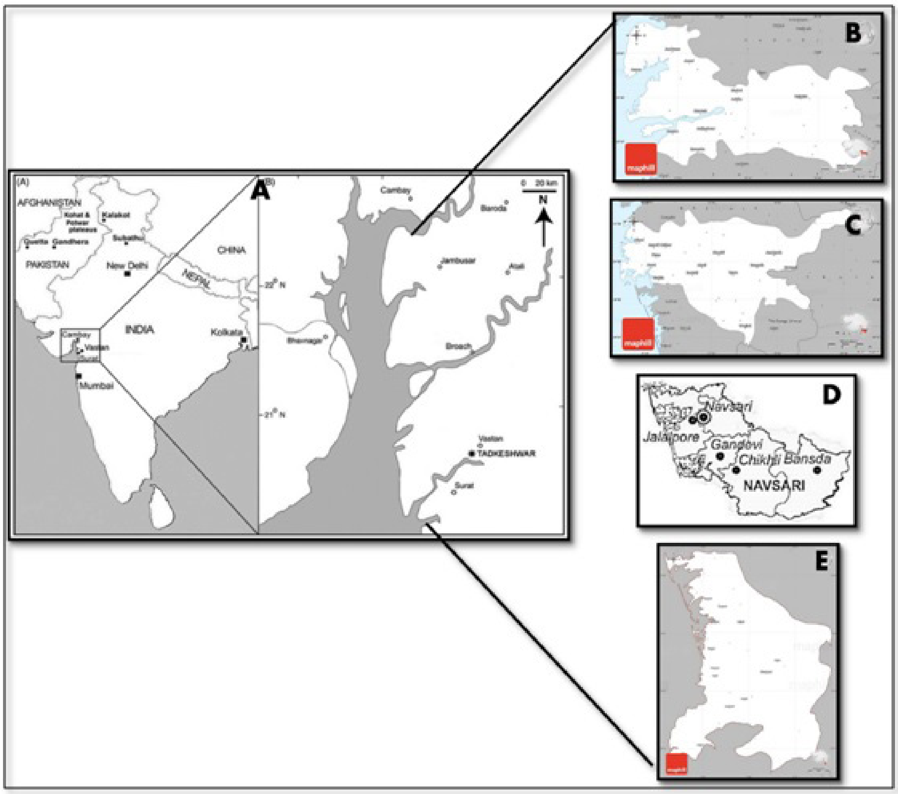


Figure 1 Study area

Description of Study site

The study site is located in Gujarat. (Figure 1) Gujarat gifted with about 1600 km long coastline which is approximately 21% of the entire Indian coastline. It has been broadly divided into four geo-morphologically and oceanographically distinct sub regions. These include Saurashtra coast, South Gujarat Coast and two gulf viz. Gulf of Kuchcch and Gulf of Khambhat (Cambay) covering about 60% of state's coastline. Importantly, out of three Gulfs in the country, two are situated in the Gujarat coast. Gujarat possess second largest mangrove cover in India and shows increasing trend since 1987. Many conservation measures are taken by the state by plantation activities, involvement of local community for conservation and various awareness programs that are why mangrove area is increased in the state. Total 15 mangrove species are reported from Gujarat out of them Avicennia marina is dominant species.

The graph (Figure 5 A & B) shows average amount of days (24h) with precipitation during a month. The mean period is 1961–2018 Temporal and spatial variations of monsoon rainfall, especially intense rainfall have been reported in the graph. Annual temperature anomaly with respect to the mean temperature at (Gujarat) region for the period 1901-2014 is shown in Figure 5 A &B. Annual temperature and average clearly show an increasing trend. The linear trend for the whole data period 1901-2014 is statistically significant at 99.9% level with an increase of 0.14°C/decade.

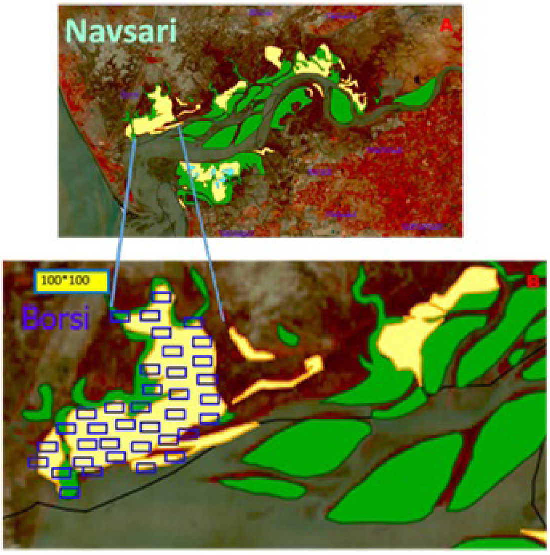


Figure 2 Methodology used to study vegetation; Navsari district map

The study area is geomorphologic regime with extensive mudflats and rapidly changing shoreline geomorphology. Heavy influxes of sediments are received from the major perennial rivers of South Gujarat like Purna, Ambika, and Kolak on the north side Sabarmati and Mahi etc. draining mainly from into the Arabian Sea. However, the coast of South Gujarat characterizes the drowned alluvial coastline (Ahmed, 1972).The wetlands of the study area comprise of intertidal mudflats, mangroves, salt marsh, sand beach, dunes, tidal creeks, etc. The lower most reaches of the river form extensive mudflats. The cross profile across the coast is made up of lower foreshore, upper foreshore, backshore, Paleoridgea, coastal dunes resting over the ridge, tidal flats, raised mudflats, alluvial plain and hilly terrain (Kulkarni, 1985). The river mouths support numerous small islands (Ahmed, 1972). Tidal waters reach the mudflats through a dense creek network. It experiences semi-diurnal tides, with two high and two low tides daily.

Carbon Sequestration Calculations

Samplings were carried out during low tide period. The random transects (100 km2) were laid down on field for study. (Figure 2) Satellite data were used for site identification. (Figure 3, 4)Two carbon pools were measured to calculate mangrove forest: Biomass carbon (Above ground and roots) and sediment carbon. To calculate above ground and root biomass allometric equations are used which are development by Komiyama et al. (2006) These allometric equations which use diameter and wood density as predictive variables have a coefficient of determination (R2) of 0.979 and 0.954, respectively, and are comparably reliable with allometric equations derived for natural stands (Chave et al., 2005,Kauffman & Cole, 2011).

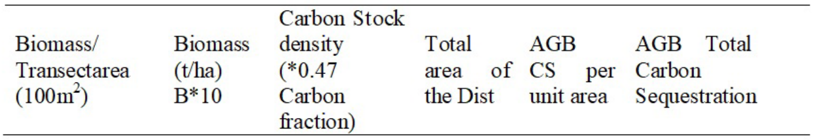
The DBH and height of individual tree are measured in each transect plot using diameter tape, linear tape for height. Each tree is recorded individually with species identification. Diameter measurement is basic measurement standard for tree. The diameter tape is put around the stem and care should be taken that it should exactly measure. To determine biomass of the tree published allometric equations are used. A number of allometric equations for mangrove biomass estimation are published (Chave et al. 2005, Smith and Whelan 2006, Komiyama et al. 2008, Kauffman and Cole 2010) and general equations are also available. Ideally, species specific equations were developed in the region and are used for calculation. Species specific equations are expected to yield better accuracy than any other equations. Chave et al, 2005 derived general equation is used to study the above ground biomass. All these equations are based on total wood mass and do not include leaves or stilt roots. The above and below ground biomass calculation are depicted below.

(i) Biomass Estimation Calculation Equations

Total Biomass = AGB+BGB+SOC

AGB (Above Ground Biomass)

Above Ground Biomass A (kg) = 0.0509*P*D2*H



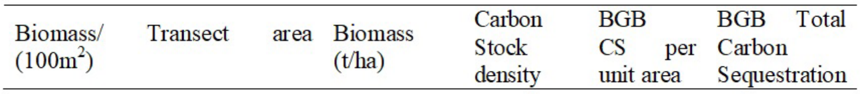
Biomass/ Transectarea ($100m^2$)	Biomass (t/ha) B*10	Carbon Stock density (*0.47 Carbon fraction)	Total area of the Dist	AGB CS per unit area	AGB Total Carbon Sequestration

Table 1 Above Ground Biomass carbon Sequestration calculation steps

BGB (Below Ground Biomass)

Below ground biomass B (kg) =0.199*P0.899* (D) 2.22

Table 2 Below Ground Biomass carbon Sequestration calculation steps



Biomass/ ($100m^2$)	Transect area	Biomass (t/ha)	Carbon Stock density	BGB CS per unit area	BGB Total Carbon Sequestration

Where A is the above-ground biomass (kg); B is the root biomass (kg); ρ is the wood density of the species; and D is the diameter at breast height. The values of total biomass (above-ground and root) per plot was summed for all plots and averaged to get the mean stand biomass which was then converted to tons per hectare. The calculated above ground and below ground carbon multiplied by the carbon concentration. The carbon fraction was determined by various previous studies.

(ii) Estimation of Soil Organic Carbon

Soil Sampling

Soil samples were collected from different location with the help of core sampler method at the depth of 0-10, 11- 20 and 21-30 cm. All the collected soil samples in the corer were placed into sample bags, which were labelled properly and transferred to the laboratory for further analysis.

Laboratory analysis

The collected samples were dried in an oven (105 ◦C) for minimum 48 hours until constant weight were attained. The bulk density was calculated by ration of dry weight of corer divided by sample volume. For determination of soil carbon (organic and inorganic), the material is sieved through 2 mm sieve. The sieved samples were used to evaluate Organic carbon by Walkey and Black, 1934 analytical method. The Soil organic carbon was calculated as the organic matter divided by Van Bemmelen factor 1.724, it is assumed that the soil organic matter is about 58% organic carbon. The bulk density were determined by following formulas

Bulk Density

BD (g/Cm3) = Dry weight of Soil (gm.)/Volume of soil (cm3) _________ (1)

Sediment mass per ha at specific depth (t/ha) =

BD at specific depth (g/Cm3) *10,000 (m2) *Depth (m) ______________ (2)

Sediment Carbon (t C/ha) =

Soil mass at specific depth (t/ha)*Organic carbon at specific depth_____ (3)

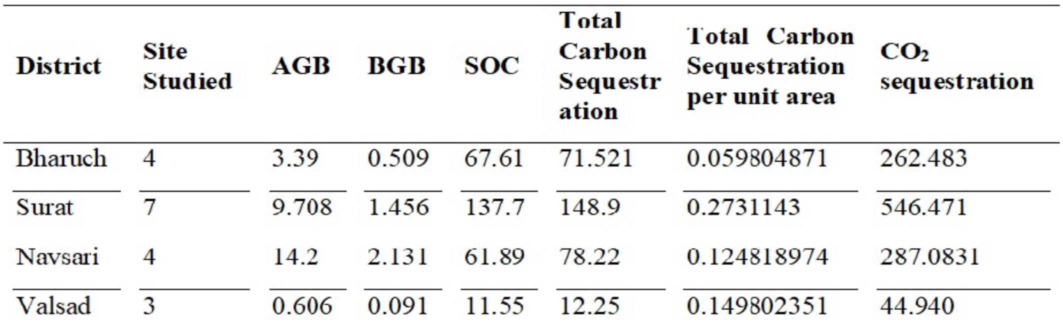
100

The carbon stock was determined by adding the biomass carbon and sediment carbon. The ration of molecular weight of carbon dioxide to carbon was used in conversion of total carbon to their equivalent. The carbon equivalent value is most common and reported in greenhouse gas inventory and emission (Kauffman & Donato, 2012).

Result and Discussion

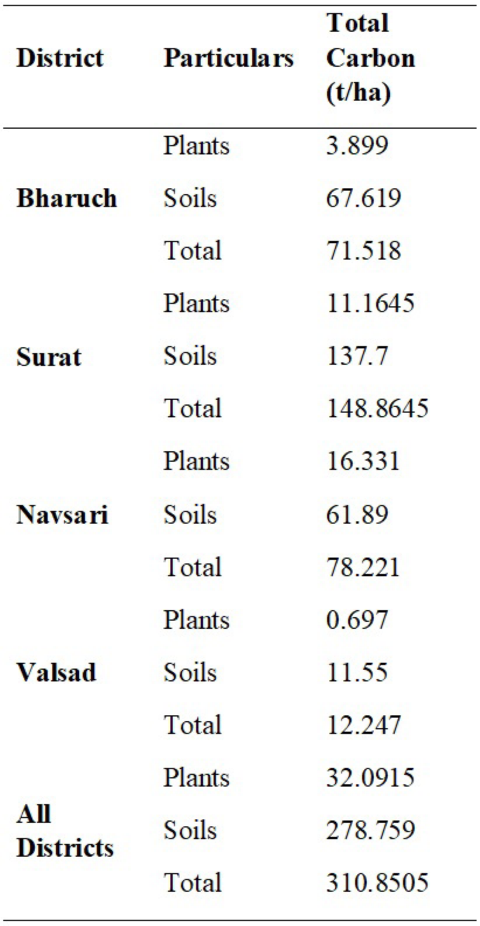
For the purpose of present study, mangrove forest of south Gujarat has been studied. A mangrove forest has been evaluated and marked on the basis of previous study with the help of Satellite images. The transect was laid down in the demarked areas. Total four districts were studied to fulfil the currents objective that was Bharuch, Surat, Navsari and Valsad. The obtained results are listed below.

Table 3: District wise Carbon data



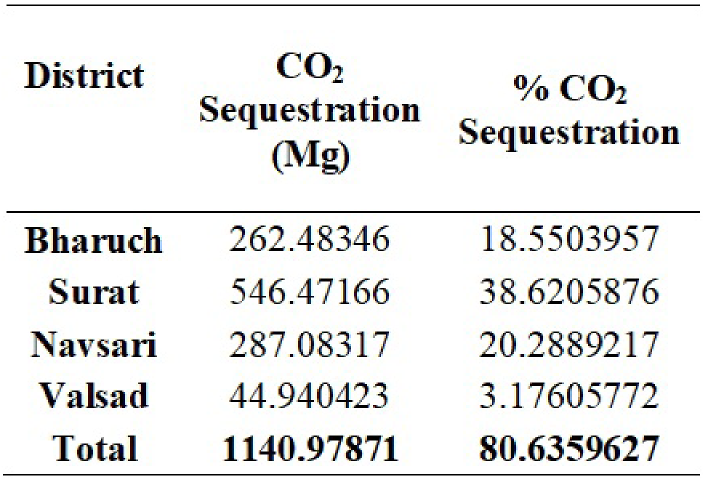
District	Site Studied	AGB	BGB	SOC	Total Carbon Sequestration	Total Carbon Sequestration per unit area	CO_2 sequestration
Bharuch	4	3.39	0.509	67.61	71.521	0.059804871	262.483
Surat	7	9.708	1.456	137.7	148.9	0.2731143	546.471
Navsari	4	14.2	2.131	61.89	78.22	0.124818974	287.0831
Valsad	3	0.606	0.091	11.55	12.25	0.149802351	44.940

Table 4: District wise Plant, Soil and Total Carbon.



District	Particulars	Total Carbon (t/ha)
Bharuch	Plants	3.899
	Soils	67.619
	Total	71.518
Surat	Plants	11.1645
	Soils	137.7
	Total	148.8645
Navsari	Plants	16.331
	Soils	61.89
	Total	78.221
Valsad	Plants	0.697
	Soils	11.55
	Total	12.247
All Districts	Plants	32.0915
	Soils	278.759
	Total	310.8505

Table 5 Carbon Sequestration and % Carbon Sequestration



District	CO_2 Sequestration (Mg)	% CO_2 Sequestration
Bharuch	262.48346	18.5503957
Surat	546.47166	38.6205876
Navsari	287.08317	20.2889217
Valsad	44.940423	3.17605772
Total	**1140.97871**	**80.6359627**

The carbon sequestered by different types of mangrove forests is comprised of sum of carbon sequestration by plants and soils. The maximum carbon has been reported in Surat District (148.8645 Mg/ha) while least is in Valsad District (12.247 Mg/ha). The high carbon content in mangrove cover is because of mangrove plantation project in 30 ha area with community based plantation models. The Gujarat Ecological Commission has taken initiative with Ministry of environmental and forest, New Delhi for plantation at various areas; the commission has planted mangroves at Surat. The Initiatives by Gujarat Ecological Commission has increased mangrove cover along the coast (Anonymous, 2015). The district wise plant and soil carbon is noted in the Table 4 & 5. The Carbon Dioxide sequestration and % Carbon dioxide sequestration also listed in the Table 4 & 5. Figure 5 (E) depicted that that soil has sequestered high amount of carbon than the Above Ground and Below Ground Carbon.

There are various studies accepted on CO2 flux measurements like eddy covariance technique, remote sensing and the forest inventory-based methodology (Grace, 2004; Lindner et al., 2004). Various techniques like Remote Sensing with process based models are used to quantify the net primary production of forest (Myneni et al., 2001; Nemani et al., 2003). The Forest inventory-based approaches to calculate approximately carbon stocks and flows use the NFI (National Forest Inventory) or other sampling networks that cover a wide range of conditions across a country or region (Liski et al., 2002, Kurz and Apps, 1999).

Mangrove forests usually show “zonation” patterns. Ellison et al., (2000) questioned the concept of “zonation”. In Southeast Asia, Sonneratia or Avicennia stands are often found on the sea anterior while Rhizophora or Bruguiera species are distributed more inland (Watson, 1929). In a primary mangrove forest on Halmahera Island in eastern Indonesia, Komiyama et al., (1988) estimated the above-ground biomass to be 169.1, 356.8, and 436.4 t ha−1 for Sonneratia, Rhizophora, and Bruguiera stands, respectively. Fromard et al., (1998) estimated the above-ground biomass to be 180.0 and 315.5 t ha−1, respectively for Avicennia and Rhizophora stands in French Guiana. Based on these figures, the above-ground biomass is relatively low in stands near the sea and increases inland. The reason for this result may be that Sonneratia and Avicennia stands are usually found on newly deposited sediments as the pioneer stage in mangrove areas. Apart from the possible succession explanation, environmental factors such as soil properties and nutrient status may also affect the growth rate in mangrove biomass.

Murray et al reported t carbon densities in mangrove forest ranges between 65 and 153 t C/ha and for estuarine site 290 t C/ha while 490 t C/ha for oceanic site (Murray et al., 2011). Nellemann et al stated carbon burial rate in mangrove sediment range between 0.2 and 6.54 t C/ha (Nellemann et al., 2009). Murray et al make available an average value for carbon sequestration in mangrove ecosystems of 1.7 t C/ha and year (Murray et al., 2011).

In a primary mangrove area on Halmahera Island in eastern Indonesia, a large below-ground biomass of Rhizophora apiculata was evaluated 196.1 t ha−1. In this site, the below-ground biomass was 180.7 and 38.5 t ha−1 in a Bruguiera, Gymnorrhiza and a Sonneratia alba stand, respectively. These values included the, buttresses, fine-roots pneumatophores, and prop roots (Komiyama et al., 1988). Cairns et al., 1997 evaluated biomass study of root and concluded that root biomass is normally below 150 t ha−1. The root biomass in mangrove forest is high, which could be an adaptation for living on soft sediments. Mangroves are capable to mechanically support their above-ground weight because of this unique root system. Additionally, soil moisture may also cause increased allocation of biomass to the roots (Kramer and Kozlowski, 1979), with improved cambial activity persuaded by ethylene production under submerged conditions (Yamamoto et al., 1995).

Alongi et al., 2000 has been studied the soil respiration magnitude in terms of CO2 flux in Rhizophora and Avicennia forests in Australia and concluded, 0.18–5.56 t C ha−1 yr−1 and in southern Thailand, 0.73–2.31 t C ha−1 yr−1. Kristensen study concluded that CO2 release from the sediment was higher in submerge condition than under exposed condition (Kristensen et al., 1995). Moreover, He has been estimated 2.28 t C ha−1 yr−1 In a Rhizophora stand, soil respiration. Mall et al., 1991 has reported high soil respiration rates 11.61–20.41 t C ha−1 yr−1 in mangrove forests on the Andaman Islands. All these studies suggest that CO2 released from the mangrove sediment is low, less than 3.0 t C ha−1 yr−1. Yoda, 1971 said that in tropical rain forests, the magnitude of soil respiration normally ranges from 15.0 to 37.5 t C ha−1 yr−1.

Conclusion

During the research work highest number of Mangroves and its associate species were reported from Valsas (12 mangrove species and 44 Mangrove associates) while least in Bharuch district (4 mangrove species and 10 Mangrove associates), 8 mangroves and 21 mangrove associates from Surat and 7 mangroves and 19 mangrove associates form Navsari districts. A. marina was dominant species among all districts. We found that The Carbon Stock assessment study revealed that the soil has sequestered more carbon (278.75 Mg/ha) than biomass (32.09 Mg/ha). The carbon concentration in ten years old mangroves with less above ground is decrease as compare to 40-50 years old mangrove forests (Alongi, 2001). The current study found that the carbon stock strongly correlated with core depth. Deforestation and forest degradation likely contribute to large quantity of emission and loss in carbon sink functionality of mangrove ecosystem. Both natural disaster and anthropogenic pressure resulted into significant decline of mangrove forest.

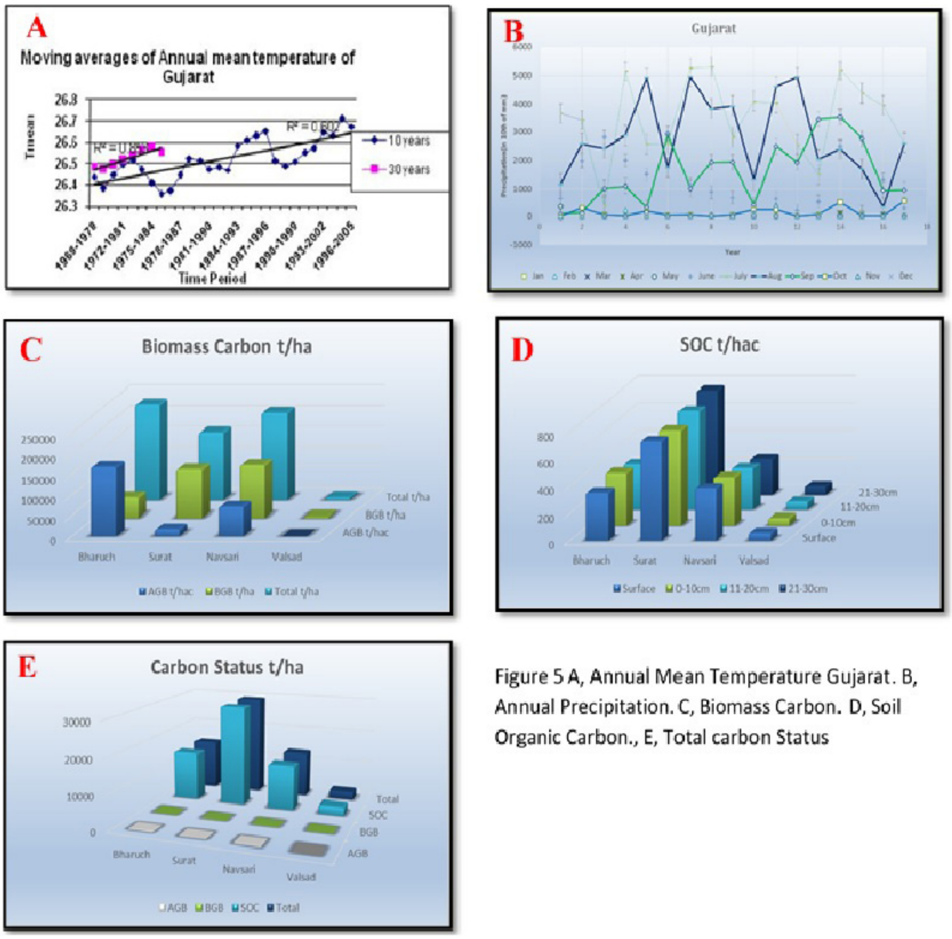


Figure 5 A, Annual Mean Temperature Gujarat. B, Annual Precipitation. C, Biomass Carbon. D, Soil Organic Carbon., E, Total carbon Status

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