STUDY AND EVALUATION OF CARBON SEQUESTRATION USING REMOTE SENSING AND GIS: A REVIEW ON VARIOUS TECHNIQUES

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ABSTRACT
Climate change or global warming are refers to the increasing average surface temperature on Earth, which affects life and natural resources in the recent decades. Increasing the atmospheric temperature resulting from absorption of certain gases due to solar energy leads to the Green house effect. Gases, such as Carbon dioxide (CO₂), Water vapors, Nitrous Oxide (N₂O), Ozone (O₃) and Methane (CH₄) which capture solar energy and radiated by the earth’s Surface. CO₂ is one of chief green house gas. Rising the carbon dioxide levels continuously, warming atmosphere resulting from rising sea levels, agriculture disruptions, and stronger storms. To reduce the amount of Carbon dioxide in atmosphere Carbon Sequestration is needed. Carbon Sequestration is the process of capture and long-term storage of atmospheric carbon dioxide (CO₂). Storing the carbon dioxide in plants and soil (Terrestrial Sequestration), Underground (Geological Sequestration) and Deep in Ocean (Ocean Sequestration). Terrestrial or biologic sequestration is process of atmospheric carbon dioxide is stored as carbon in the stems and roots of plants and also in soil. Estimating the amount of forest biomass is very crucial for monitoring and estimating the amount of carbon that is lost or emitted during deforestation, and it will also give an idea of the forest potential to sequester and store carbon in the forest ecosystem. Estimations of forest carbon stocks are based upon the estimation of forest biomass. Whereas Geological and Ocean Sequestration are the storing the carbon dioxide in large tunnels. Remote Sensing (RS) and Geographic Information System (GIS) had great potential in current estimation, future prediction and management of Terrestrial carbon sequestration. In climate change mitigation, this approach can provide an efficient and cost-effective means of estimating above and below ground biomass, delineating spatial variability, predicting potential carbon stocks and revenues and outlining appropriate management strategies for localized and regional scale. In future, the deployment of an integrating RS-GIS approach for precision carbon
management will become more visible. This paper aims to review and summaries the various methods and studies that were carried out to estimate the above-ground biomass of the forest.

**Keywords:** Carbon Sequestration, Remote Sensing, GIS and Terrestrial carbon sequestration.


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1. **INTRODUCTION**

Carbon is found in all living organisms and is the major building block for life on Earth. Carbon exists in many forms, predominately as plant biomass, soil organic matter, and as the gas carbon dioxide (CO₂) in the atmosphere and dissolved in seawater. Carbon emission through different sources and carbon is a casual factor for global warming, which is the most dreaded problem across the world. Over the past century, human activities like burning of fossil fuels, deforestation and urbanization have resulted in high concentration of CO₂ and other greenhouse gases in the atmosphere (USGS, 2002). Carbon dioxide is removed from the atmosphere (or "Sequestered") when it is absorbed by plants as part of the biological carbon cycle. Gases that trap heat in the atmosphere are called greenhouse gases. It is significant that carbon dioxide stays in the atmosphere because CO₂ is the most important gas for controlling Earth's temperature. Carbon dioxide (CO₂), Water vapors, Nitrous Oxide (N₂O), and Methane (CH₄) are greenhouse gases that absorb a wide range of energy including infrared energy (heat) emitted by the Earth and re-emits. The re-emitted energy travels out in all directions, but some returns to Earth, where it heats the surface. Carbon dioxide remains a gas at a wider range of atmospheric temperature than water. Carbon dioxide molecules provide the initial greenhouse heating needed to maintain water vapor concentrations.

Carbon dioxide concentration drops, Earth cools, some water vapor falls out of the atmosphere. When Carbon dioxide concentration rise, air temperatures go up, and more water vapor evaporates into the atmosphere which then amplifies greenhouse heating. Atmospheric concentrations of carbon dioxide have been steadily rising, from approximately 315 ppm (parts per million) in 1959 to a current atmospheric average of approximately 385 ppm [1]. Current projections are for concentrations to continue to rise to as much as 500-1000 ppm by the year 2100 (IPCC 2007). Higher concentrations of CO₂ are likely to have on global climate; rising CO₂ concentrations are also likely to have profound direct effects on the growth and physiology of plants, independent of any effects on climate. These effects results from the central importance of CO₂ to plant metabolism. As photosynthetic organisms, plants take up atmospheric CO₂ chemically reducing the carbon. This represents not only an acquisition of stored chemical energy for the plants, but also provides the carbon skeletons for the organic molecules that make up a plant structure. Overall, the carbon, hydrogen and oxygen assimilated into organic molecules by photosynthesis make up ~96% of total dry mass of a typical plant. Photosynthesis is therefore at the heart of nutritional metabolism of plants, and increasing the availability of CO₂ for photosynthesis can have profound effects on plant growth and many aspects of plant physiology. Above Ground Biomass (AGB) is related to many important components, such as carbon cycles, soil nutrient allocation, fuel accumulation and habitat environments in terrestrial ecosystems. The AGB governs the potential carbon emission that could be released to the atmosphere due to deforestation and change of regional above ground biomass is associated with changes in climate and
Carbon Sequestration is the process of transfer and secure storage of atmospheric CO2 into other long lived carbon pools that would otherwise be emitted or remain in atmosphere [3]. Remotely sensed data is a technology to calculate the biomass and ultimately carbon sequestration value of plants in a larger area in quick turnaround time and is cost effective [4]. CO2 is one of the most common greenhouse gases resulting global warming which in turn brings about rise in sea level, draught, deforestation, etc. Forests, soils, oceans and atmosphere are agents for storage of carbon. They act as source or sink at different time and release more carbon than they absorb. Carbon sequestration is a phenomenon for the storage of CO2 or other forms of carbon to mitigate global warming. Through biological, chemical or physical processes, CO2 is captured from the atmosphere. A carbon sink may be defined as reservoir that collects and stores carbon containing chemical compound. Forests, soils, oceans, plants and algae are natural sinks. Carbon sinks remove CO2 from the atmosphere through absorption. The conventional methods like remotely sensed satellite data and GIS is a technology to calculate the amount of carbon sequestration in above ground biomass in a larger area.

2. WAYS THAT CARBON CAN BE STORED (SEQUESTERED)

- In plants and soil "Terrestrial Sequestration or Carbon sinks"
- Underground "Geological Sequestration"
- Deep in Ocean "Ocean Sequestration"

2.1. Terrestrial Sequestration

Terrestrial or biologic sequestration means using plants to capture CO2 from the atmosphere and then storing it as carbon in the stems and roots of the plants as well as in the soil. In photosynthesis, plants take in CO2 and give off the oxygen O2 to the atmosphere as a waste gas. The plants retain and use the carbon to live and grow. When the plant dies, part of the carbon from the plant is preserved (stored) in the soil (Fig-1). Terrestrial sequestration is a set of land management practices that maximizes the amount of carbon that remains stored in the soil and plant material for the long term. Wetland management, rangeland management, and reforestation are examples of terrestrial sequestration. It is important to remember that terrestrial sequestration does not store CO2 as a gas but stores the carbon portion of the CO2 (the C in the CO2). If the soil is disturbed and the soil carbon comes in contact with oxygen in the air, the exposed soil carbon can combine with O2 to form CO2 gas and re-enter the atmosphere, reducing the amount of carbon in storage. Sequestration of carbon dioxide into the soil improves soil fertility and water holding capacity.
2.2. Geologic Sequestration

Geologic sequestration is putting CO$_2$ into long term storage in geologic zones deep underground. Geologic sequestration is the method of storage that is generally considered for carbon capture and storage (CCS) projects. Storing of CO$_2$ underground in rock formations able to retain large amounts of CO$_2$ over a long time period (Fig - 2). Only a handful of specialized facilities like natural gas processing plants, coal gasification plants, and ethanol plants currently have processes that separate CO$_2$ and make it available for geologic sequestration. To develop economical methods of separating and capturing CO$_2$ at other large scale systems like power plants that produce relatively large quantities of anthropogenic CO$_2$. Although pure CO$_2$ has been stored as a gas in natural underground deposits for millions of years and oil field operators have safely pumped millions of tons of CO$_2$ underground into oil producing formations to increase production (CO$_2$ flooding).

2.3. Ocean Sequestration

Carbon Sequestration by direct injection into the deep ocean involves the capture, separation, transport and injection of CO$_2$ from land or tankers (Fig - 2).
3. NEED OF CARBON SEQUESTRATION

Carbon releases from different sources is a casual factor for global warming, which is the most dreaded problem across the world. Over the past century, human activities like burning of fossil fuels, deforestation and urbanization have resulted in high concentration of CO₂ and other greenhouse gases in the atmosphere [5]. CO₂ is one of the most common greenhouse gases resulting global warming which in turn brings about rise in sea level, draught, deforestation and etc., Areas where carbon is stored are otherwise known as carbon "sinks". Forested areas are large carbon sinks because enormous amounts of carbon dioxide are naturally stored in the soil, a result of photosynthesis. The long term storage of atmospheric carbon dioxide (CO₂) is known as Carbon Sequestration, to mitigate or defer global warming and avoid dangerous climate change. Forests, soils, oceans and atmosphere are agents for storage of carbon. They act as source or sink at different times and release more carbon than they absorb [6]. This increase has apparently triggered global temperature rise, causing a great deal of discomfort to the world population. Terrestrial carbon sinks include natural forests, plantation forests, wetlands and the soil biome. Accurate delineation of succession and mature forest biomass distribution becomes considerably significant in reducing the uncertainty of carbon emission and sequestration, understanding their roles in influencing soil fertility and land degradation or restoration, and understanding the roles in environmental processes and sustainability [7]. To mitigate greenhouse effects, it is essential to provide managers and policy makers with accurate information on the current state, dynamic, and spatial distribution of carbon sources and sinks [8]. Forest ecosystem as a huge carbon pool, has been also proposed as a mean to reduce net greenhouse gas emissions, by either reducing CO₂ sources or enhancing sinks [9]. Forest carbon sink and stock would be possible to substantially offset the industrial emissions of carbon dioxide by expanding the forest areas [10]. Carbon Sequestration is the process of transfer and secure storage of atmospheric CO₂ into other long storage carbon pools that would otherwise be emitted or remain in the atmosphere [11]. Terrestrial carbon sinks includes natural forest, plantation forest, wetlands and the soil biome.

4. METHODS FOR ESTIMATING TERRESTRIAL CARBON SEQUESTRATION

There are five carbon pools of terrestrial ecosystem involving biomass, namely the above-ground biomass, below-ground biomass, the dead mass of litter, woody debris and soil organic matter. [12]. The carbon dioxide predominant in plants during photosynthesis is transferred across the different carbon pools. The above-ground biomass of a tree constitutes the major portion of the carbon pool. It is the most important and visible carbon pool of the terrestrial forest ecosystem [13]. Any changes in the land use system like forest degradation and deforestation has a direct impact on this component of the carbon pool. The below-ground biomass which constitutes all the live roots plays an important role in the carbon cycle by transferring and storing carbon in the soil. The dead mass of litter and woody debris are not a major carbon pool as they contribute merely a small fraction to the carbon stocks of forests. Generally, the estimated biomass components are the aboveground live biomass which includes the trees and shrubs excluding the roots, dead above-ground biomass like litters and fallen branches or stem, and the below-ground biomass which comprise of the roots.

Estimating the biomass in the forest ecosystem is important for assessing the productivity and sustainability of the forest. It also gives an idea of the potential amount of carbon that can be emitted in the form of carbon dioxide when forests are being cleared or burned. Biomass
estimation of the forest ecosystem enables to estimate the amount of carbon dioxide that can be sequestered from the atmosphere by the forest. The accurate assessment of biomass estimates of a forest is important for many applications like timber extraction, tracking changes in the carbon stocks of forest and global carbon cycle. Forest biomass can be estimated through field measurement and remote sensing and GIS methods [14]. There are two methods for estimating the above ground Biomass (Table - 1).

The first one is the destructive method of tree biomass estimation. The destructive method, also known as the harvest method, is the most direct method for estimation of above-ground biomass and the carbon stocks stored in the forest ecosystems [15]. This method involves harvesting of all the trees in the known area and measuring the weight of the different components of the harvested tree like the tree trunk, leaves and branches and measuring the weight of these components after they are oven dried [16]. This method of biomass estimation is limited to a small area or small tree sample sizes. Although this method determines the biomass accurately for a particular area. This method is also not applicable for degraded forests containing threatened species.

The second method of tree biomass estimation is the non-destructive method. This method estimates the biomass of a tree without felling. The non-destructive method of biomass estimation is applicable for those ecosystems with rare or protected tree species where harvesting of such species is not very practical or feasible. The biomass of the individual tree was estimated by taking into account the tree shape (by taking two photographs of the tree at orthogonal angles), physical samples of different components of the trees like branches and leaves and dendrometric measurements, volume and bulk density of the different components. Although it is a non-destructive method, to validate the estimated biomass, the trees had to be harvested and weighted [17]. Another way of estimating the above-ground forest biomass by non-destructive method is by climbing the tree to measure the various parts [18], or by simply measuring the diameter at breast height, height of the tree, volume of the tree and wood density and calculate the biomass using algometric equations[19].

5. REMOTE SENSING AND GIS TECHNOLOGY FOR TERRESTRIAL CARBON SEQUESTRATION ESTIMATION

Quantification and estimation of spatially explicit services for Carbon Sequestration potential may differ based on climate, management applications, ecosystem, species and the local communities. A case by case scenario will be most effective in producing reliable data using the Remote Sensing and GIS integration. Currently, scientists are designing specific models to improve the precision of carbon stock estimates that changes through time [20]. Meanwhile, the voids in computing net primary productivity, depth distribution of biomass carbon, relationship between litter carbon pools and belowground (roots and microbes) sequestration [21].

Remote Sensing technology offers acquisition and analysis of geo referenced data from assorted platforms and can be operationally linked with spatial data layers and models within a GIS. The effortless ability of integrating RS data with other sources of information makes geospatial technology powerful contemporary instruments [22]. GIS collects and pre processes spatial data from various sources. It provides the utilities to manage attribute data, location and topology in spatial analyses. RS data can be used as input for analysis within a GIS. GIS can provide ancillary data for improved RS analysis for discrimination of ecosystem types, land cover and land use classes. The application of Remote Sensing and other spatial data within a GIS provides capabilities for modeling and scenario analysis.
Integrated Remote Sensing and GIS can act as a Decision Support System (DSS) tool in Carbon Sequestration management and monitoring.

The forest biomass estimation is the most accurate method, it is expensive, time consuming and destructive (which may not be very practical for those forest ecosystems with threatened or rare or protected plant species). Moreover, it is applicable for only a small sample of trees and small-scale analysis. Therefore, remote sensing technology is expected to provide a solution for the above mentioned challenges. Remote sensing is a process of acquiring data from a distance of an object, area or a phenomenon by analyzing the data through instruments without being in contact with the object or area which is/ are being examined. Remote sensing technology provides a synoptic view of the surface area of interest, thereby capturing the spatial variability in the attributes of interest. A major advantage of remote sensing technology is that it can obtain information about an area of interest that is difficult to access or inaccessible. Remote sensing has enabled us to monitor natural resources on a continental, even on a global scale. It is also the only realistic and cost-effective way of acquiring data over a large area. Remotely sensed data are useful for mapping and monitoring vegetation, land cover and land-use change (Table - 1). Forest’s carbon stocks can be evaluated using remote sensing technology. Several studies have been conducted to estimate the forest biomass using the data of remote sensing with the data collected from the field [23]. The utility of laser profiling data for the estimation of forest biomass and volume. In this study, they co-related the data of forest biomass and volume, obtained from field measurements taken from specific plots of the laser flight lines, with the corresponding estimates of forest canopy height obtained from the laser profiling [24].

### Table 1 Techniques for above-ground biomass estimation

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Category</th>
<th>Methods</th>
<th>Data used</th>
<th>Characteristics</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Field measurement-based methods</td>
<td>Destructive sampling</td>
<td>Sample trees</td>
<td>Individual trees</td>
<td>Klinge et al. (1975)</td>
</tr>
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<td></td>
<td>Conversion from volume to biomass</td>
<td>Volume from sample trees or stands</td>
<td>Individual trees or vegetation stands</td>
<td>Brown and Lugo (1984), Brown et al. (1989), Brown and Lugo (1992), Gillespie et al. (1992), Segura and Kanninen (2005)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Remote sensing-based methods</td>
<td>Methods based on fine spatial-resolution data</td>
<td>Aerial photo-graphs, IKONOS</td>
<td>Per-pixel level</td>
<td>Tiwari and Singh (1984), Thenkabail et al. (2004)</td>
</tr>
<tr>
<td></td>
<td>Methods based on coarse spatial-resolution data</td>
<td>IRS-1C WiFS, AVHRR</td>
<td>Per-pixel level</td>
<td>Barbosa et al. (1999), Wylie et al.(2002), Dong et al. (2003).</td>
<td></td>
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<td></td>
<td>Methods based on radar data</td>
<td>Radar, lidar</td>
<td>Per-pixel level</td>
<td>Harrell et al. (1997), Lefsky et al. (1999b), Santos et al. (2002, 2003)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>GIS-based methods</td>
<td>Methods based on ancillary data</td>
<td>Elevation, slope, soil, precipitation, etc.</td>
<td>Per-pixel level or per-field level</td>
<td>Brown et al. (1994), Iverson et al. (1994), Brown and Gaston (1995)</td>
</tr>
</tbody>
</table>
To examine the potential of Landsat TM images in estimating the aboveground biomass of tropical secondary forests [25]. To estimate the above-ground biomass in the Brazilian Amazon using Landsat TM data. The study showed that the use of Landsat TM image for estimating forest above-ground biomass is more successful for succession forest rather than mature forests [26]. A combination of SAR image texture and LANDSAT TM data were used for the estimation of tropical forest biomass. The result is suggested that inclusion of SAR texture with multispectral data can be successfully applied to a predictive relation at times and space other than which it was developed [27]. For the estimation of forest biomass, they used a combination of data sources like remotely sensed data, topographic information and climatic variables, to map the above-ground biomass. They found that the estimate of forest biomass at the regional scale with this method gives a pretty much accurate estimates of the aboveground biomass [28]. Remote sensing data has become an important tool for the estimation of forest biomass. Biomass estimation using remotely sensed data is an emerging technology and it is being increasingly used to inventory forest biomass. Satellite-based estimates of carbon stock are likely to become more accessible over the next few years [29] (Table -2).

**Table 2 Biomass estimation using Landsat TM data**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Datasets</th>
<th>Techniques</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Landsat 5</td>
<td>Liner and exponential regressions</td>
<td>Steininger (2000)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multiple regression analysis</td>
<td>Lu (2005)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Estimated crowndiameter using an exponent model, then calculated biomass using crown diameter</td>
<td>Phua and Saito (2003)</td>
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<td></td>
<td></td>
<td>K nearest-neighbour method</td>
<td>Fazakas et al. (1999)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multiple regression analysis</td>
<td>Roy and Ravan (1996)</td>
</tr>
<tr>
<td>2</td>
<td>Landsat 4 and 5</td>
<td>Multiple regression model, neural network</td>
<td>Foody et al. (2003)</td>
</tr>
<tr>
<td>3</td>
<td>Landsat 7</td>
<td>Multiple regression analysis</td>
<td>Zheng et al. (2004)</td>
</tr>
<tr>
<td>4</td>
<td>Landsat TM derived land cover data, forest inventory data, climate and soil data</td>
<td>A productivity model (PnET)</td>
<td>Mickler et al. (2002)</td>
</tr>
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</table>

To estimate the above-ground biomass in three biomes-temperate deciduous, temperate coniferous and boreal coniferous, using LiDAR remote sensing. LiDAR remote sensing is designed to allow the signal to penetrate the canopy. LiDAR systems send out pulses of laser light and measure the signal return time to directly measure the height and vertical structures of forests. They compared the LiDAR-measured canopy structure with the field measurements of above-ground biomass and found that a single equation can be used to relate the remotely sensed canopy structure to the above-ground biomass for all the three biomes with distinctly different forest communities [30]. Estimating carbon stocks using a high resolution, helicopter-borne 3-dimensional (3-D) scanning LiDAR system. The study was conducted in a Japanese cedar forest, and the LiDAR system measures the 3-D canopy structure of every tree in the forest. The study demonstrates that the algometric relationship between the tree height and carbon stocks will enable estimation of the total carbon stocks stored in the forest [31]. LiDAR data can be used to measure precisely the biophysical
parameters of individual trees such as the diameter at breast height (DBH) which is one of the commonly used variables for biomass estimation of forest [32]. LiDAR surveys along with field sampling and statistical modeling can be successfully used for accurately estimating high resolution and spatially explicit biomass and carbon dynamics in conifer forests [33]. To assess the accuracy of LiDAR-based biomass estimation where they used the airborne laser scanning (ALS) sampling approach. Their finding suggested the systematic ALS assisted survey was more efficient than the ground-based inventory. Image texture is an important property which gives information about an object or a selected region in an image [34]. The potential of optical imagery using ALOS AVNIR-2 texture indices for biomass estimation and obtained a significant improvement while using the ratio of texture parameters [35].

Dry lands cover more than 30% of the Earth’s surface and comprise a variety of ecosystems, such as shrub lands and grasslands, which are large reservoirs of carbon as well as potential carbon sinks and sources to the atmosphere. The terrestrial carbon cycle is a highly dynamic system that includes several storage pools and different components of the flux. Components of the terrestrial carbon flux are gross primary production (GPP), net primary production (NPP) and net ecosystem production (NEP). The amount of carbon that is fixed from the atmosphere, i.e., converted from CO$_2$ to carbohydrates during photosynthesis, is called GPP, which is carbon assimilation by photosynthesis ignoring photorespiration. Net ecosystem production, NEP, is the difference between gross primary production (GPP) and total ecosystem respiration (Re), which determines the amount of carbon lost or gained by the ecosystem without disturbances. The model is used to calculate GPP, NPP and NEE at a spatial resolution of 1 km$^2$ and a temporal resolution of ten days. The basis for this modeling is a time series of the described SPOT-Vegetation data set. The growing season GPP and NPP was significantly higher in the areas covered by the steppe grassland. This difference was primarily a reflection of differences in the productive potential of the vegetation in the two land cover types. As the steppe grassland occupies territories with significantly higher precipitation amount, the conditions for vegetation growth are much better. This study describes and tests a satellite data-based model for mapping total carbon sequestration over a semi-arid grassland-dominated region and the model employs the algorithm of Montecito and combines remote sensing data from SPOT-Vegetation satellite and ground inventory data on biomass [36].

To mitigate greenhouse effects, it is essential to provide managers and policy makers with accurate information on the current state, dynamics, and spatial distribution of carbon sources and sinks. Forest ecosystem, as a huge carbon pool, has been also proposed as a means to reduce net greenhouse gas emissions, by either reducing CO$_2$ sources or enhancing sinks. Forest carbon sink and stock would be possible to substantially offset the industrial emissions of carbon dioxide by expanding the forest areas. The VCSi (vegetation carbon sink) as carbon sequestration from the atmosphere. Accordingly, forest carbon stock mainly includes vegetation carbon stock, soil carbon stock, litter carbon stock and animal carbon stock. VCSi (vegetation carbon stock) is the carbon content that above-ground vegetation holds. SCS (soil carbon stock) refers to carbon content that soil organic matter (e.g. soil humus) holds. By integrating forest inventory data and soil inventory data into GIS, vegetation photosynthesis method combined with forest biomass method and stem volume method were employed to quantify the VCSi and VCSi, and soil type method was applied to calculate the SCS. VCSi mainly involves forest CO$_2$ fixation. In forest ecosystem, plants transform solar energy into biotic energy through photosynthesis, fixing CO2 and releasing O2, and mitigating greenhouse gases increase, and it plays an irreplaceable role in maintaining the CO2/O2 balance. Based on the forest inventory data, in this study we adopted the photosynthesis method associated with vegetation NPP. NPP, a key component of the terrestrial carbon
cycle, represents the net carbon accumulation by the stand and accounts most of the annual carbon fluxes between the atmosphere and biosphere [37]. The formula of photosynthesis is as follows:

$$CO_2(264g) + H_2O(108g) \rightarrow C6H12O6(180g) + O2(193g) \rightarrow Amylase (162g) \quad \text{Eq (1)}$$

As shown in the Eq. (1), plants absorb 6772cal solar energy and 264 g CO$_2$ for producing 193g O$_2$ and 162g dry material stored as fibre and starch in the plants [38]. And at a molecule level, the ratio of carbon, hydrogen and oxygen of vegetation fibre is 1.5:2:1 and most trees keep the same ratio. On the basic of relative atomic mass of carbon, hydrogen and oxygen, we estimate that the VCSt density equals to half of the forest biomass volume [39]. In this study, a ratio of 0.5 is used to convert biomass to VCSt density [40]. Using the method, we can estimate material amount of atmospheric CO$_2$ fixation, and calculate the VCSt amount of Tiantai County. The equations (2, 3, 4, 5 & 6) are shown below:

$$MVCSI = 1.63 \times \sum_i S_i \times NPP_i \quad \text{Eq (2)}$$

$$MVCSi = \sum_i S_i \times DCSDi \quad \text{Eq (3)}$$

$$DCSDi = Bi \times 0.5 \quad \text{Eq (4)}$$

Where $MVCSI$, $MVCSi$ are the amounts of VCSI (t.a$^{-1}$) and VCSt (t.a$^{-1}$), respectively? $S_i$ is the area of the $i$th vegetation type (hm$^2$). $NPP_i$ is net primary productivity value of the $i$th vegetation type (t.hm$^{-2}$.a$^{-1}$). $DCSDi$ and $Bi$ are the carbon stock density and biomass of the $i$th vegetation type (t.hm$^{-2}$), respectively.

The equation of soil carbon density estimate is as follows:

$$DCSDi = \rho \times PSOCI \times Bf \quad \text{Eq (5)}$$

Where $DCSDi$ is the soil carbon density of the $i$th soil genera (kg.m$^{-2}$). $\rho$ is the average bulk density of soil (kg.m$^{-3}$). $PSOCI$ is the percentage of organic matters of the $i$th soil genera (%). $Bf$ is the Bemmelen factor (0.58).

The relation of SCS estimate is as follows:

$$MSCS = \sum_i DCSDi \times A_i \quad \text{Eq (6)}$$

Where $MSCS$ is the amount of SCS $A_i$ is the area of the $i$th soil genera (m$^2$).

The selected carbon sink value and carbon stock values in the case area were mapped as data layers in GIS after gridding process. The use of GIS to quantify the allocation of carbon sink and stock values of forest ecosystem at county level, this can be an important research avenue to provide a GIS-based framework for valuation and mapping at provincial or national scale [41]. However, remote sensing data does not directly estimate the amount of biomass that is present in the forest. It only measures the parameters which are correlated to biomass like the tree height, crown size, forest density, forest type, forest volume, leaf area index, etc. Remote sensing data coupled with the field-based measurement of the forest is used to estimate the above-ground biomass. The field measurements are commonly used to develop predictive models or algometric equations for biomass and to validate the results obtained.
from the remotely sensed data. Once it is validated the remotely sensed data can be used to estimate the forest biomass for wider area where there is very little or no field measurement data available.

6. CONCLUSION
CO$_2$ is one of the most common greenhouse gases resulting global warming which in turn brings about rise in sea level, draught, deforestation, etc. Forests, soils, oceans and atmosphere are agents for storage of carbon. Carbon sequestration describes long-term storage of carbon dioxide or other forms of carbon to either mitigate or defer global warming and avoid dangerous climate change. It has been proposed as a way to slow the atmospheric and marine accumulation of greenhouse gases, which are released by burning fossil fuels. The Remote Sensing and GIS Techniques like Image Classification Techniques, Vegetation Index models and Estimation of above Ground Biomass methods are used for estimating the Carbon Sequestration. Land Use and Land cover Mapping was used for comparison and estimation of carbon sequestration either increased or decreased. Spectrally-based Normalized Difference Vegetation Index (NDVI) and other vegetation indices, derived from RS platforms, are common indicators used to monitor biophysical conditions and vegetation cover. These indices are solely designed to optimize the spectral signatures of vegetation and to minimize the influence of soil reflectance and atmospheric attenuation. GIS data layers and NDVI measurements were manipulated to estimate CO$_2$ sequestration in a particular area. The combined use of biomass models and NDVI data has simplified estimation of carbon stocks in Forest area. Agricultural land is available in great quantities as natural resource; however the potential of these lands as carbon sink during the cropping season has not been speculated or exploited to the optimum. It is high time that the world and India in a particular understands that there are alternative sinks of carbon, apart from the traditional concepts of forests being a sink. Forests are major source and sinks of carbon in nature. Estimation of the forest carbon stocks enable to assess the amount of carbon loss during deforestation or the amount of carbon that a forest can store when such forests are regenerated. The principal element for the estimation of forest’s carbon stocks is the estimation of forest biomass.

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