QUANTIFYING THE ABOVE GROUND BIOMASS OF KRISHNA MANGROVES THROUGH REMOTE SENSING

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ABSTRACT

Mangroves are salt tolerant woody plants that form highly productive intertidal ecosystems in tropical and subtropical regions. Mangroves play a disproportionately large role in carbon sequestration relative to other tropical forest ecosystems. The carbon emissions resulting from mangrove loss especially biomass are uncertain. The point to be noted that mangroves biomass towards carbon stock is needed because when the changes occurs, much of carbon stock in the ecosystem will release to the atmosphere which may result in global warming, pollution etc. In this context, remote sensing is a tool of choice to provide spatio-temporal information on mangrove ecosystem biomass and carbon studies through digital image processing and modeling. Remote sensing techniques have demonstrated a high potential to detect, identify, map and monitor mangrove conditions and changes. The Krishna mangroves in Andhra Pradesh are located in the coastal plains of Krishna delta. This study provides reviews and highlighting remotely sensed data applied for measuring Above Ground Biomass (AGB) in Krishna mangrove forest from remote sensing perspective. This study assessed tree above ground biomass using a Support vector machine regression model equation. The Above Ground Biomass estimated from the model was 198.47 Mg/ha and an Allometric equation for Avicennia marina mangrove species was used to cross validate the estimated AGB from remote sensing technique and the average AGB from the field measurement was 217.53 Mg/ha. Thus the study reveals that the remote sensing is an effective tool to estimate above ground biomass with a good accuracy.

1. INTRODUCTION

Mangroves play a disproportionately large role in carbon sequestration relative to other tropical forest ecosystems. 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. Accurate assessments of mangrove biomass at the site-scale are lacking, especially in mainland Southeast Asia. Now a days mangroves are deforested by various human activities like cutting down of wood, land conversion to aquaculture, and coastal urban development etc. The importance of immediate protection measures and conservation activities to prevent the further loss of mangroves are essential. Forest ecosystems are an important part of the global carbon cycle because they store a large part of the total terrestrial organic carbon and exchange CO2 with atmosphere. As the tree biomass experience growth, the carbon held by the plant also increases carbon stock. Mangroves forests have long been known as a harsh environments and extremely productive ecosystems in cycling carbon. Coastal mangrove forests store more carbon than almost any other forest on Earth(Daniel et al. 2011).

Mangroves are shrubs and trees of medium height that grow between 25–30°S up to 25–30°N (depending on investigator and definitions) and are able to survive in brackish water, sea water, and salty evaporation pools with up to twice the salinity of ocean water. Sometimes, the term "mangrove" is used for all species of trees and shrubs tolerating these salty conditions; other times, it is used only for the mangrove family (Rhizophoraceae) or trees of the genus *Rhizophora*. Of about 110 known mangrove species, about 54 species in 20 genera from 16 families constitute the group of ―true mangroves occurring only in mangrove habitats. According to Tomlinson, the term ―mangrove‖ describes the intertidal ecosystem or the highly adopted plant families that live in this coastal environment. Most of the mangrove genera and families are not closely related to each other, but what they do have in common is their highly developed morphological, biological, physiological, and ecological adaptability to extreme environmental conditions. The most important characteristics to achieve this kind of adaptability are pneumatophoric roots (*Avicennia*, *Sonneratia* species), stilt roots (*Rhizophora*, *Brugueria*, *and Ceriops* species), salt-excreting leaves, and viviparous water-dispersed propagules. Mangroves build communities parallel to the shoreline. The species composition and structure depend on their physiological tolerances and competitive interactions. Distance from the sea or the estuary bank, frequency and duration of tidal inundation, salinity, and composition of soil are crucial environmental factors. Mangroves exhibit a high degree of ecological stability with regard to their persistence and resilience. However, they are highly sensitive to changes, especially within hydrological environments (e.g., water-quality changes), which go beyond their ecological range of tolerance; thus, the ecosystems act as change indicators on a broader scale.

2. Methods to estimate above ground biomass

Estimation of the accumulated biomass in the forest ecosystem is important for assessing the productivity and sustainability of the forest. It also gives us 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 us 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. Two methods of field measurement are available. The first one is the destructive method of tree biomass estimation. Among all the available biomass estimation method, 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. 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. 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, it is time and resource consuming, strenuous, destructive and expensive, and it is not feasible for a large scale analysis. This method is also not applicable for degraded forests containing threatened species. Usually, this method is used for developing biomass equation to be applied for assessing biomass on a larger-scale.

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. (Montes et al.)developed a non- destructive method for the above-ground biomass estimation of thuriferous juniper (*Juniperus thurifera* L.) woodlands in the High Central Atlas, South of Morocco. In this, 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. Another way of estimating the above-ground forest biomass by non-destructive method is by climbing the tree to measure the various parts 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 allometric equations. Since these methods do not involve felling of tree species, it is not easy to validate the reliability of this method. These methods can also involve a lot of labour and time and climbing can be troublesome.

3. Remote Sensing techniques and above ground biomass

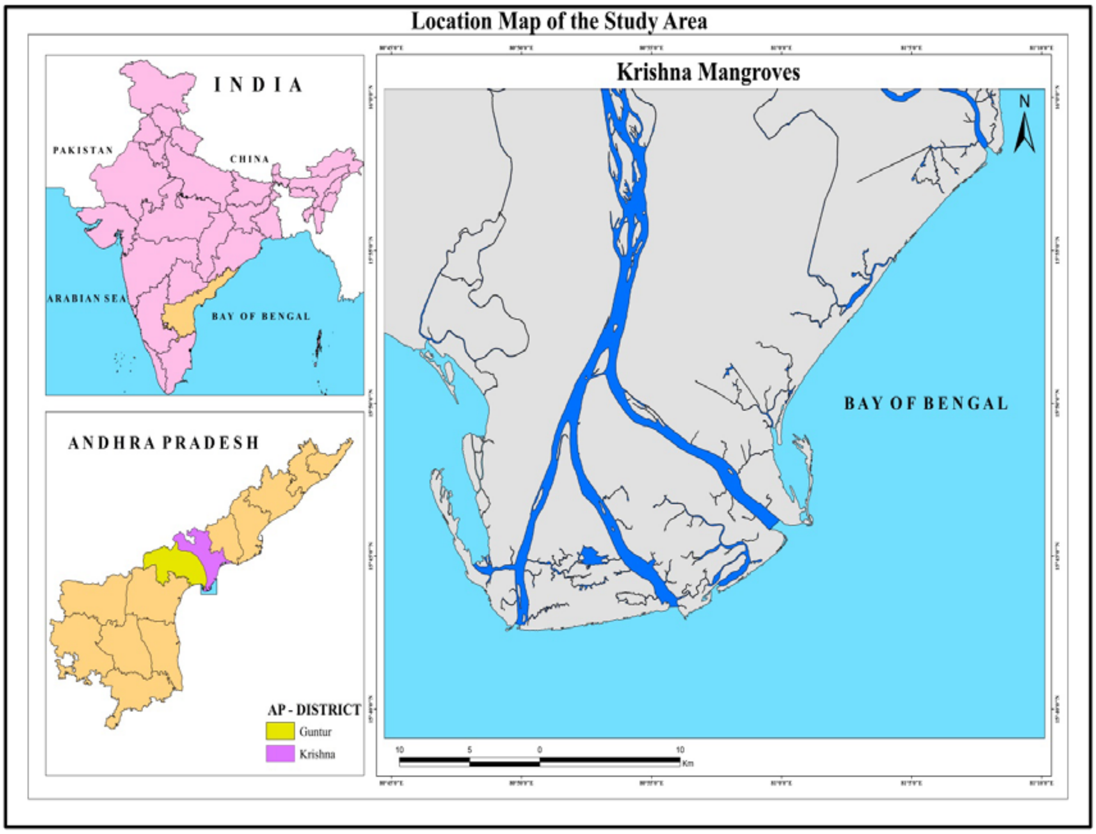
Remote sensing is the tool of choice to provide spatio-temporal information on mangrove ecosystem distribution, species differentiation, health status, and ongoing changes of mangrove populations. Such studies can be based on various sensors, ranging from aerial photography to high- and medium-resolution optical imagery and from hyper spectral data to active microwave (SAR) data. Remote-sensing techniques have demonstrated a high potential to detect, identify, map, and monitor mangrove conditions and changes during the last two decades. Also, climate change-related remote-sensing studies in coastal zones have increased drastically in recent years.

Use of satellite remote sensing to measure and map mangroves Biomass for carbon accounting has become widespread as it can provide accurate, efficient and repeatable assessments. Remote sensing captures spectral and spatial characteristics of mangroves area and therefore be an efficient method to estimate vegetation cover, as well as density and structure. Benefits of these methods are that they can explicit information at various scales.

4. STUDY AREA

Krishna mangroves

The Krishna mangroves in Andhra Pradesh are located in the coastal plains of Krishna delta. According to the Forest Department, the total are under mangroves is 5 000 ha. The Krishna mangroves lie between 15^0 42' N and 15^0 55' N in latitude and 80 42 -81 01 E in longitude spread across Krishna and Guntur districts. The Krishna wildlife sanctuary has been established in a part of the mangrove wetland – the total are of this sanctuary is 19,481 ha (194.81 sq.km); it includes Sorlagondi Reserve Forest (RF), Nachugunta RF, Yelichetladibba RF, Kottapalem RF, Molagunta RF, Adavuladivi RF and Lankivanidibba RF. They occupy the islands of the delta and the adjacent mainland's of both districts. A part of the mangroves is located far from the main mangrove area; it's near Machilipatnam on its eastern side and Nakshatranagar on its western side.



Map1 : Location Map of the Study area

5. Methods to estimate above ground biomass

Estimation of above ground biomass using Support Vector Machine Regression Model Equation

The Support Vector Machine Regression Model Equation is used to estimate the above ground biomass of the study area. The Equation is taken from the reference paper "Mangrove biomass estimation in Southwest Thailand using Machine Learning" of Nicholas R.A. Jachowski. The equation is as follows:

AGB=0.16*Elevation+ 0.27*(Blue Band/Green Band) – 0.11*Green Band + 0.41*
NIR Band – 0.03 [Eq. No.2]

Where,

AGB – Above Ground Biomass per pixel
Elevation – Elevation Data of the study area

In this case the bands of Landsat 8 OLI/TIRS and ASTER DEM where used to estimate above ground biomass in the above equation. The data was in unsigned 16 bit it is rescaled to unsigned 8 bit and then used in the equation. The equation was run in ERDAS imagine 9.1 model maker.

Validation of estimated above ground biomass through field measurements

The most widely used method for estimating biomass of forest is through allometric equations. The allometric equations are developed and applied to forest inventory data to assess the biomass and carbon stocks of forests. Many researchers have developed generalized biomass prediction equations for different types of forest and tree species. The allometric equations for biomass estimation are developed by establishing a relationship between the various physical parameters of the trees such as the diameter at breast height, height of the tree trunk, total height of the tree, crown diameter, tree species, etc. Equations developed for single species and for mixture of species give the estimate of biomass for specific sites and for large-scale global and regional comparisons.
In this study for validating estimated above ground biomass, an allometric equation is used which is taken from a website called GlobAllomeTree (www.globallometree.org). Allometric equation will differ according to plant species and the region. In this study area the Avicennia marina are the species mostly covered. So the allometric equation corresponding to this species in this region has selected from the website to validate the remotely sensed above ground biomass. The allometric equation is given below:

$$AGB = 1.3799 * Z^{0.687} * Y^{0.955} \qquad [Eq.No.3]$$

Where,

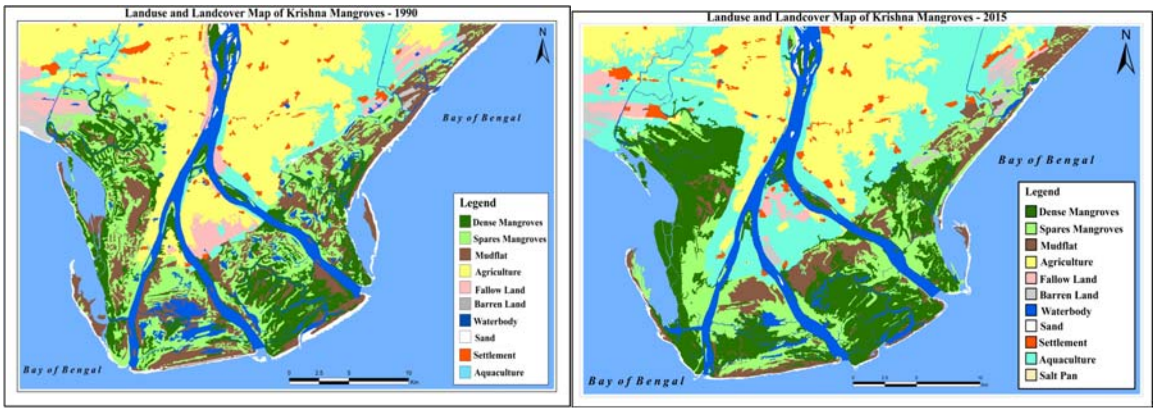
AGB – Above Ground Biomass
Z – Height of the Tree (in meters)
Y – Diameter at Breast Height (in centimeters)

The Diameter at Breast Height (DBH) must be measured above 1.3 m from the ground. The Unit of allometric equation is Mega gram per hectare area (Mg/ha). This equation is only appropriate for calculating biomass to a hectare area. The height of tree and diameter at breast height values are the mean values collected from the sample trees which is randomly selected in a hectare area.
The Estimated Above Ground Biomass using Support Vector Machine Regression Model is compared with the Above Ground Biomass obtained from Allometric equation for the validation.

6 RESULT AND EVALUATIONS

6.1 Land use Land cover Classification Map of Krishna mangroves on1990 and 2015

The landuse and land cover map has been prepared for the Krishna mangroves using landsat 5 TM satellite image for the year 1990 and Landsat 8 OLI/TIRS for the year 2015. The satellite image has been processed using unsupervised classification technique in ERDAS software.



Map 2 : Land use Land cover Map of Krishna Mangroves – 1990 and 2015

Sl No.	Land use and Land cover Class	Area (ha) 1990
1	Agriculture	39185.3898
2	Spares Mangroves	12465.0416
3	Dense Mangroves	9461.7113
4	Mudflat	9316.3068
5	Waterbody	8043.9510
6	Aquaculture	6740.2755
7	Fallow Land	3565.5998
8	Sand	2326.9643
9	Settlement	1686.5293
10	Barren Land	744.1205

Sl No.	Land use and Land cover Class	Area (ha)
1	Agriculture	31767.6227
2	Spares Mangroves	9344.863
3	Dense Mangroves	14427.6520
4	Mudflat	4908.4075
5	Waterbody	7268.9819
6	Aquaculture	18383.5171
7	Fallow Land	1351.3415
8	Sand	1395.0381
9	Settlement	2253.1727
10	Barren Land	1289.0410
11	Salt pan	56.125806

Land use and Land cover class and area of 1990 and 2015

According to the landuse and Landcover of 1990 , Agricultural lands have the highest area coverage of 39185.3898 ha in the study area. After that spares mangroves have the second largest area coverage of 12465.0416 ha in the study area. Dense Mangroves in the study area covers 9461.7113ha and Mudflat covers an area of 9316.3068 ha. Water body covers 8043.9510 ha, Aquaculture covers 6740.2755 ha, Fallow land covers 3565.5998 ha, Sand covers 2326.9643 ha, Settlement coverage is 1686.5293 ha, and Barren land covers 744.1205 ha in the study area. The total area coverage for the study area is 93535.8904ha.

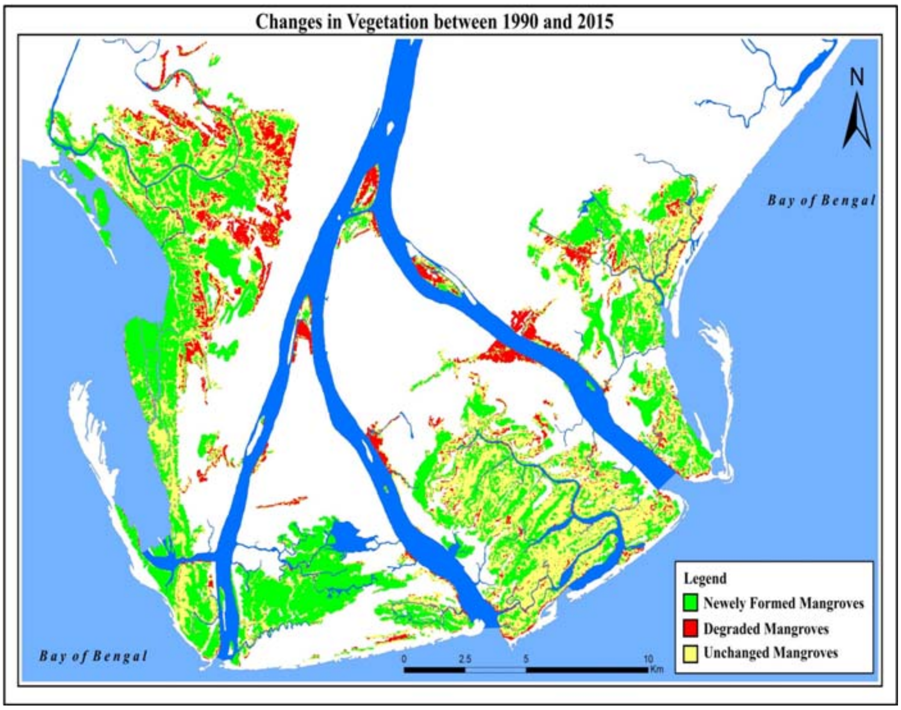
According to the landuse and Landcover of 2015, Agricultural lands have the highest area coverage of 31767.6227 ha and dense mangroves have the second largest area coverage of 14427.6520 ha in the study area. Spares Mangroves in the study area covers 9461.7113ha and Mudflat covers an area of 9316.3068 ha. Waterbody covers 8043.9510 ha, Aquaculture covers 6740.2755 ha, Fallow land covers 3565.5998 ha, Sand covers 2326.9643 ha, Settlement coverage is 1686.5293 ha, and Barren land covers 744.1205 ha in the study area. The total area coverage for the study area is 93535.8904ha.

The Land use Land cover Map of 1990 and 2015 are compared to find the land use land cover changes. By calculating the area it is easily examined that the dense mangroves area are increased by 4965.9407 ha within 15 years. Spares mangroves area is decreased to 3120.2116 ha and mudflat area also decreased to 4407.8993 ha in 2015 when compared to 1990. These decreased spares mangroves and mudflats are converted to dense mangroves in 2015.

6.2 Change detection using NDVI between 1990 and 2015

The change detection has been studied using NDVI maps between 1990 and 2015 of the study area. The vegetation change is clearly identified by the NDVI maps because NDVI is the vegetation index which highlights the vegetation of the area. In the change detection map green colour indicates the newly formed

Mangroves, red colour indicates the degraded mangroves and yellow colour represents the unchanged mangroves of the study area.

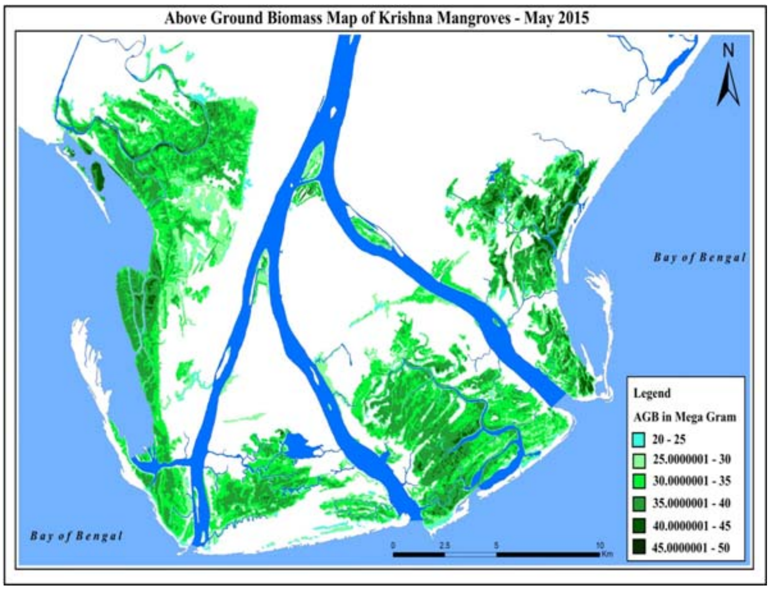


Map 3 - Change detection Map of Krishna Mangroves between 1990 and 2015

6.3 Evaluation of above ground biomass calculated from field measurements and using remote sensiing data

The Above Ground Biomass for Krishna (AGB) Mangroves is calculated per pixel according to the input image data. Blue, Green, Near Infrared Band and Elevation data is used to determine the AGB. The result shows 20 – 35 values of AGB for spares and degraded mangroves. The AGB value ranges from 35 – 50 for highly dense mangroves. The total area of mangroves including dense and spares mangroves is 23772.51 ha. The average AGB for the total mangroves area is calculated and found to be as 198.47 Mg/ha.

The field measurements were collected for the mangroves area in the month of June 2015 to validate the estimated Above Ground Biomass from the remote sensing data. Allometric equation is used to calculate the AGB from field inventories. The filed measurement value includes the mean height of the tree and diameter at the breast height of the tree for a hectare area. The Tree height ranges from 2 – 8.7 m and the diameter at breast height ranges from 27 – 48 cm. The total AGB of Krishna mangroves including spares and dense is found to be 217.47 Mg/ha.



According to the reference paper of Nicholas R.A. Jachowski the accuracy of the support vector machine regression model equation is 93 %, when the AGB estimated from the field measurements and using remote sensing are compared. The average AGB for Krishna Mangroves using remote sensing for the year 2015 is 198.47 Mg/ha and using field measurement is 217.53 Mg/ha. The Average difference of the AGB is 19.06 Mega grams (ton) per hectare area.

7 CONCLUSION

The main purpose of the study was to Map and Measure the Above Ground Biomass of Krishna mangroves through remote sensing. First of all visual interpretation is used to classify the study area. The resultant map revealed that the visual interpretation technique is an effective method to classify images of 30 m resolution. The Land use Land cover classification is done for 1990 and 2015. The two resultant maps are compared and found that there is a drastic change in Land use Land coverof the study area.

Normalized Difference Vegetation Index (NDVI) is calculated for the study area and found the vegetative cover for the years 1990 and 2015.The change detection process is done by these two NDVI mapsand found that there is a large change in vegetation cover. That eventually means the growth of mangroves is high in 2015 than 1990. The study proves that the NDVI is a best tool to find out the vegetation change in mangroves area.

The Above Ground Biomass (AGB) was calculated for Krishna Mangroves by using remote sensing and validated it with field measurements. The equation used to calculate the AGB through remote sensing was a Support Vector Machine Regression Model Equation. The resultant map shows the AGB value per pixel and it ranges from 20 – 50 Mega grams (Mg).The study area has mangroves coverage of 23772.51 ha. The average AGB calculated for the Krishna mangroves through remote sensing was 198.47 Mg/ha. The Mangrove Forest has high biomass related to other tropical forest.

The estimated Above Ground Biomass was validated with field measurements. An Allometric Equation was used for measure the AGB through field measurements. The Mean height of the tree and diameter at breast height were used in the equation to calculate AGB. The equation used was exclusively for the Avicennia marina mangrove species and also the equation was to calculate the AGB for a hectare area. The average AGB calculated for the Krishna mangroves through field measurements was 217.53 Mg/ha. Thusthe field measurements give a more accurate estimate of the Above Ground Biomass in mangrove forest.

The result provided by remote sensing technique will never be 100 % accurate. In this case also field measurements are taken to validate the result produced by remote sensing method. The Validation clearly proves that Support Vector Regression Model Equation has an accuracy of 93%.

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