

## **ASSESSMENT OF CARBON STORAGE AND EROSION USING INVEST MODEL IN VISAKHAPATNAM DISTRICT, ANDHRA PRADESH**

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### **ABSTRACT**

*Human Activities, especially deforestation, agriculture and expanding the industries may impact on depletion of natural resources and contribute to global climate change. Deforestation and expanding the industries have caused a substantial increase in the concentration of carbon dioxide (CO<sub>2</sub>) level in the atmosphere. These activities affect on the environment depending on the Terrestrial ecosystem. Remote Sensing data are used for calculating the Terrestrial ecosystem to estimate the increasing and decreasing amount of carbon dioxide in the atmosphere. Storage of carbon on land depends on four carbon pools, they are above ground biomass, below ground biomass, soil, and dead organic matter. Using the land use and land cover maps, the InVEST (Integrated Valuation of Ecosystem Services and Tradeoff) model can estimate the net amount of carbon stored in a land parcel. The outputs of InVEST model can support NGOs, and decisions by governments. The InVEST model result indicates positive values for carbon storage increased where negative values show loss of carbon. -1392299789.91 mg of C loss of carbon during 2011-2014. -423909045.87 mg of C loss of carbon during 2014-2015. 1512332394.91 mg of C of carbon sequestered during 2015-2016.*

**Keywords:** Terrestrial Ecosystem, Remote Sensing, Land Use and Land Cover, InVEST (Integrated Valuation of Ecosystem Services and Tradeoff) Model.

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## Introduction

Absorption and releasing of greenhouse gases (GHG) by ecosystems can be majorly controlled by CO<sub>2</sub> in the earth climate. The others which can store carbon in the atmosphere are forests, shrubs and other above ground ecosystems (Lal 2007). Climate change due to the eco systems and storage of carbon in soil, wood, and other biomass keep CO<sub>2</sub> out of the atmosphere. InVEST (Integrated Valuation of Ecosystem Services and Tradeoff) model can be used for estimation of amount of carbon loss or storage. Field data of four carbon pools and raster datasets of land use and land cover maps are inputs for In VEST model. Integrating the field data of four carbon pools (above ground biomass, below ground biomass, soil, dead organic matter) and land use / land cover maps are used to estimate the carbon storage in current landscape. Above ground biomass includes material of

plants of all living above the soil like bark, trunks, branches, and leaves. Biomass of below ground involves the living root systems of living plants. Dead organic matter comprises standing dead wood and litter. The InVEST model estimates the net amount of carbon stored in a land parcel using land use and land cover maps.

## Study Area and Data

**Study Area:** Visakhapatnam district is located in Andhra Pradesh which is eastern shore of India. The Visakhapatnam district lies in region between 17°15' and 18°32' northern latitude and 83°54' and 85°30' eastern longitude. The area of the district is 11,342.84 (sq km). It is almost 4.1 per cent of the area of the entire State. The district is divided into three revenue divisions and 43 mandals. The population of the district is 42.88 lakhs as per the 2011 Census and this constitutes 5 per cent of the population of the State.



**Figure 1: Location of Study Area Visakhapatnam District in Andhra Pradesh**

**Data:** The aim of the study being the evaluation of changes in the last 4 years, Landsat 5, thematic mapper was preferred as it was available through most of the study period. Landsat 8, Operational Land Imager (OLI) data of 2014, 2015 and 2016 were also used in the study. All these data were

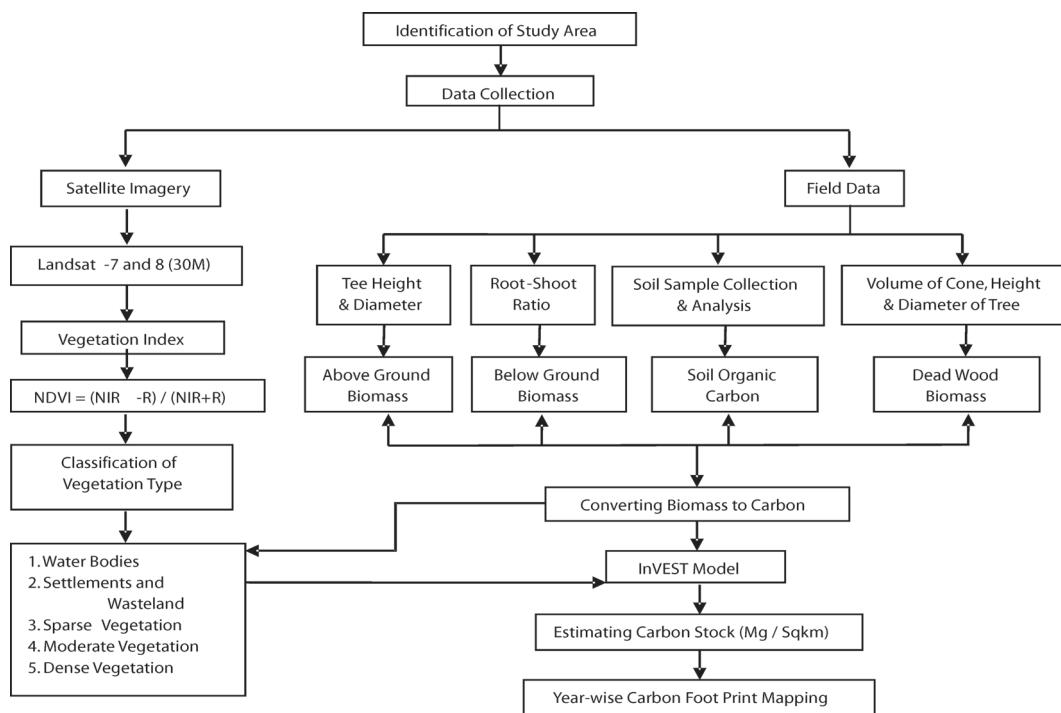
downloaded from USGS (United States Geological Survey). The dates of acquisition and resolution details are given in Table 1. Toposheets of Survey of India of scales 1:50000 and 1:250000 have been digitized in order to arrive at the base layers.

**Table 1: Details of Squired Satellite Data**

Image Acquisition Date	Sensor	Spatial Resolution
02-03-2011	LANDSAT_5 TM	30 m
26-03-2014	LANDSAT_8 OLI	30 m
07-12-2014	LANDSAT_8 OLI	30 m
13-03-2015	LANDSAT_8 OLI	30 m
26-03-2016	LANDSAT_8 OLI	30 m

**Methodology**

The schematic representation of the methodology adopted in the current research work is given in Figure 2.

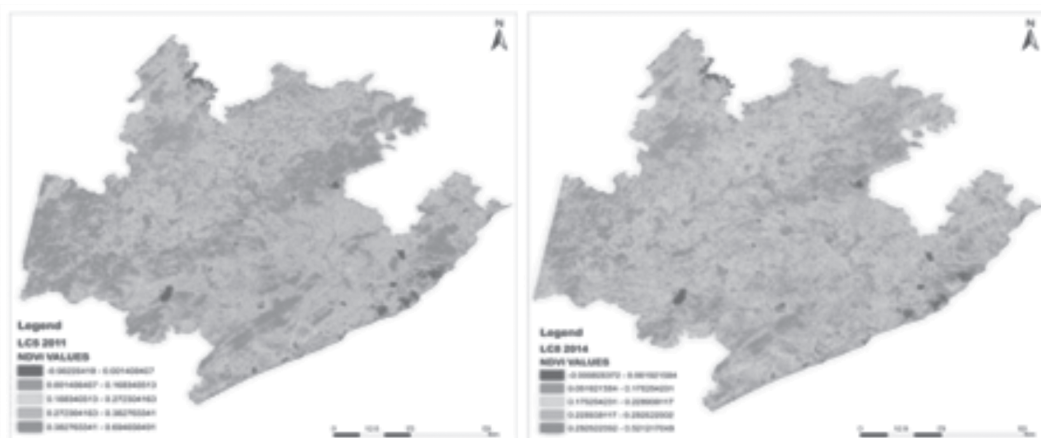


**Figure 2: The Flow Chart of Methodology Followed in Research**

**Generation of NDVI:** The Normalised Difference Vegetation Index (NDVI) gives the different values for the land cover type of 2011, 2014, 2015 and 2016. The NDVI values are generated. NDVI helps analyse temporal vegetation cover, with values ranging between -1 and +1. Very low values below -0.1 indicate soil or barren areas, zero corresponds to water cover, 0.1-0.3 corresponds to vegetation of low density while values between 0.6-0.8 correspond to dense vegetation.

Extraction of vegetation from remotely sensed satellite imagery is the process of extracting vegetation information which depends on the interpretation of satellite image colour, texture, patterns, tone, and association information (Asrar et al., 1984 and Galio et al., 1985). Classification of image and pre-processing techniques are used for mapping of vegetation.

Pre-processing of image can be done for each pixel of the scene to get better improvement in quality of image and for assignment of a membership matrix of the vegetation groups (Beeri et al., 2007). The Normalised Difference Vegetation Index (NDVI) was used to characterise land use/ land cover types in the region of study. The NDVI images for 2011, 2014, 2015 and 2016 are used for defining vegetation type and observing the vegetation characteristics of the research area. The NDVI values show the changes in vegetation in 2011, 2014, 2015 and 2016. In this, the NDVI images are analysed for 2011-2014 (Figure 3), 2014-2015 (Figure 4), 2015-2016 (Figure 5) to estimate vegetation type changes. The mean NDVI values tabulated are as follows for 2011-2014 (Table 2), 2014-2015 (Table 3), 2015-2016 (Table 4), respectively. Fig. 6 shows the changes in mean NDVI values of vegetation type for 2011, 2014, 2015 and 2016.



**Figure 3: Vegetation Density Maps of 2011-2014**

**Table 2: NDVI Mean Values of Land Use Classes in 2011-2014**

S. No.	Land Use Classes	Mean NDVI +/- STD Devn	
		2011	2014
1	Water bodies	-0.15+/-0.15	-0.03+/-0.06
2	Settlements and wasteland	0.12+/-0.04	0.15+/-0.02
3	Sparse vegetation	0.22+/-0.03	0.20+/-0.02
4	Moderate vegetation	0.33+/-0.03	0.25+/-0.02
5	Dense vegetation	0.44+/-0.04	0.31+/-0.03



**Figure 4: Vegetation Density Maps of 2014-2015**

**Table 3: NDVI Mean Values of Land Use Classes in 2014- 2015**

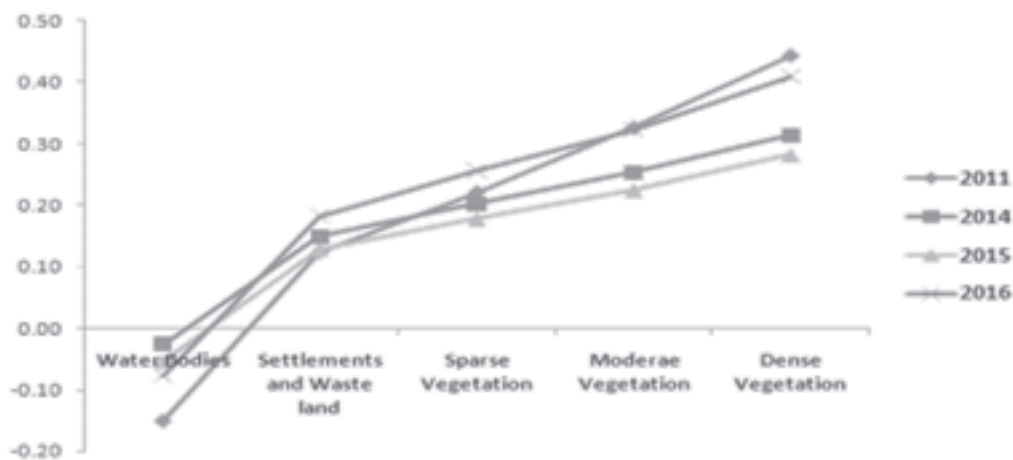
S.No.	Land Use Classes	Mean NDVI +/- STD Devn	
		2014	2015
1	Water bodies	-0.03+/-0.06	-0.05+/-0.08
2	Settlements and wasteland	0.15+/-0.02	0.13+/-0.02
3	Sparse vegetation	0.20+/-0.02	0.18+/-0.01
4	Moderate vegetation	0.25+/-0.02	0.22+/-0.02
5	Dense vegetation	0.31+/-0.03	0.28+/-0.03



**Figure 5: Vegetation Density Maps of 2015-2016**

**Table 4: NDVI Mean Values of Land Use Classes in 2015- 2016**

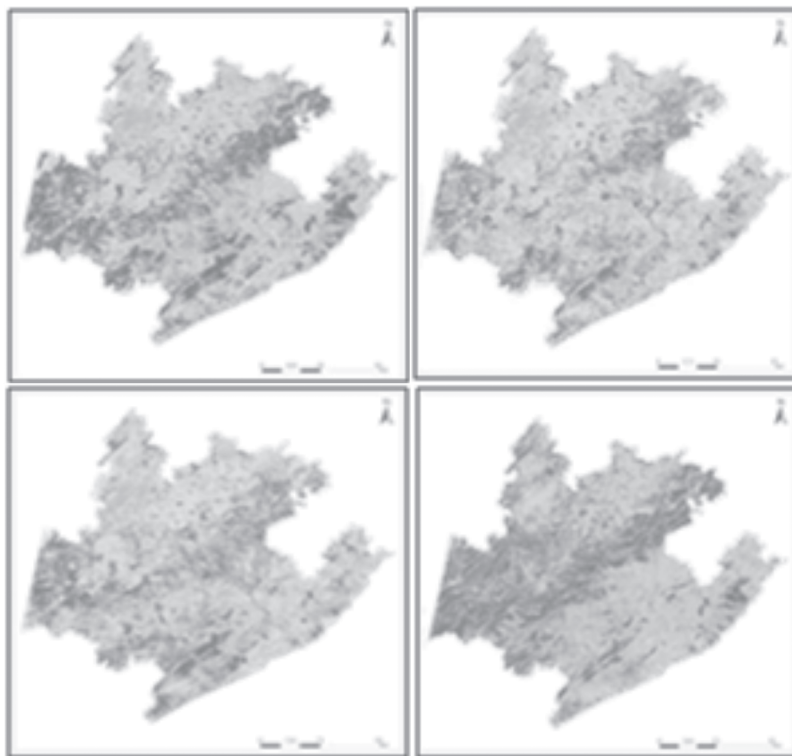
S.No.	Land Use Classes	Mean NDVI +/- STD Devn	
		2015	2016
1	Water bodies	-0.05+/-0.08	-0.08+/-0.1
2	Settlements and wasteland	0.13+/-0.02	0.18+/-0.04
3	Sparse vegetation	0.18+/-0.01	0.26+/-0.01
4	Moderate vegetation	0.22+/-0.02	0.32+/-0.02
5	Dense vegetation	0.28+/-0.03	0.41+/-0.03

**Figure 6: Changes in Mean NDVI Values of Vegetation Type for 2011, 2014, 2015 and 2016**

**Land Use Classification:** An ecosystem comprises soil, water in association with flora fauna (biotic component), which is an important natural resource (Rao et al, 1991). The response of many characteristics of the land surface can be recorded by a remote sensor, including the natural and artificial cover. The visual image interpretation derive information about land use and land cover activities (Colwell, 1997). Classification of land use can be defined in 3 levels, where level 1 will distinguish the overall land use types. Level 2 classification is sub-divide of level 1. Level 3 classifications usually contain specific information at micro level. Depending upon quality of the satellite images, spatial,

spectral and radiometric resolution can influence the level of data in classification of landuse/landcover. Land use and land cover classification is done by NDVI. Water bodies, settlements and wasteland, sparse vegetation, moderate vegetation and dense vegetation classes derived for 2011, 2014, 2015 and 2016 are presented in Figure 7. The area of each land use in sqkm was shown in Table 5.

- Below 0 – for water bodies
- 0.0014 – 0.16 – settlements
- 0.16 – 0.27 – sparse vegetation
- 0.27 – 0.38 – moderate vegetation
- 0.38 – 0.69 – dense vegetation



**Figure 7: Land Use Classification through NDVI of 2011, 2014, 2015 and 2016, Respectively**

**Table 5: Land Use Classes Area in Sq Km of 2011, 2014, 2015 and 2016**

S. No.	LULC_NAME	AREA (sq km)			
		2011	2014	2015	2016
1	Water bodies	161.17	116.11	97.4	121.7
2	Settlements and wasteland	1711.7	1708.5	1472.3	1396.2
3	Sparse vegetation	3233	3966.9	3542.4	1843.4
4	Moderate vegetation	3305.2	3958.8	3443.9	4788.2
5	Dense vegetation	2946.5	2083.4	1944	3065.2

**Field Data:** To estimate the amount of carbon above and below the surface, few parameters data like tree height, the diameter of the trees, cone diameter and soil samples were collected randomly. In each land use class, carbon quantity is calculated by using allometric equation (Chave

et al., 2005; Mokany et al., 2006).

**Carbon Pools:** Storage of carbon mainly depends on size of above ground biomass, below ground biomass, soil organic matter and dead organic matter. All living biomass above the soil

including branches, bark, stems, stumps, seeds, and foliage are involved in above ground biomass. Below ground biomass includes all living biomass of living roots thicker than 2 millimeters in diameter. All non-living woody biomass either standing, lying on the ground (but not including litter), or in the soil come under dead wood. Soil organic carbon includes all organic material in soil to a depth of 1 meter.

**Calculation of Above Ground Biomass:** To estimate the stocks of live tree carbon in the area of interest, the biomass of all sampled trees is first estimated and then the area of vegetation type estimate is calculated. The biomass estimate is converted to tonnes of carbon and the area is applied to estimate carbon stocks on a per sqkm basis. Each plot is sampled by biomass of all trees

then summed to estimate a total carbon stock. (Chave et al., 2005). Whereas wood density is assumed to be 0.6 g/cm<sup>3</sup> for all trees. The above ground biomass is calculated for each land use type of 2011, 2014, 2015 and 2016 is shown in Table 6.

$$\text{Biomass} = \text{Density of wood} \left( \frac{\text{g}}{\text{cm}^3} \right) \times \exp(-1.499 + (2.148 \times \text{LN}(\text{DBH})) + (0.207 \times (\text{LN}(\text{DBH}))^2) - (0.0281 \times (\text{LN}(\text{DBH}))^3)) \quad (\text{Equation - 1})$$

The biomass of each tree is calculated on a per sqkm multiplied by area of tree biomass. The biomass converted into carbon (Eq-2).

$$C_{\text{plot}} = \text{MD} \times \text{FC} \quad (\text{Equation - 2})$$

Where:  $C_{\text{plot}}$  = plot of carbon stock; MD = plot of dry biomass; FC = fraction of carbon.

**Table 6 : Carbon Storage Tonnes Per Sq Km in Above Ground Biomass of Land Use Classes**

		Year-wise Carbon Storage in AGB							
S. No.	LULC Classes	2011		2014		2015		2016	
		Area (sqkm)	AGB	Area (sqkm)	AGB	Area (sqkm)	AGB	Area (sqkm)	AGB
1	Water bodies	161.17	0	116.11	0	97.4	0	121.7	0
2	Settlements and wasteland	1711.7	24.22	1708.5	24.18	1472.3	20.84	1396.2	19.76
3	Sparse vegetation	3233	251.66	3966.9	224.73	3542.4	116.95	1843.4	230.56
4	Moderate vegetation	3305.2	692.72	3443.9	721.79	3958.8	630.55	4788.2	803.55
5	Dense vegetation	2946.5	5754.6	1944	3796.7	2083.4	3456	3065.2	3986.5

**Calculation of Below Ground Biomass:** To estimate below ground biomass based on above ground biomass or based on a series of root-to-shoot (R/S) ratios by major forest types (Mokany

et al, 2006). The Below Ground Biomass calculated for each land use type of 2011, 2014, 2015 and 2016 is shown in Table 7.

$$\text{BGB} = \text{AGB}(\text{tC} / \text{sqkm}) \times 0.235 \quad (\text{Equation - 3})$$



**Table 7 : Carbon Storage Tonnes Per Sq Km in Below Ground Biomass of Land Use Classes**

Year-wise Carbon Storage in BGB									
S.No.	LULC Classes	2011		2014		2015		2016	
		Area (sqkm)	AGB	Area (sqkm)	AGB	Area (sqkm)	AGB	Area (sqkm)	AGB
1	Water bodies	161.17	0	116.11	0	97.4	0	121.7	0
2	Settlements and wasteland	1711.7	5.69	1708.5	5.68	1472.3	4.9	1396.2	4.64
3	Sparse vegetation	3233	59.14	3966.9	52.81	3542.4	43.65	1843.4	55.32
4	Moderate vegetation	3305.2	194.98	3443.9	169.62	3958.8	140.65	4788.2	235.83
5	Dense vegetation	2946.5	1352.3	1944	1106.3	2083.4	956.19	3065.2	1406.8

**Calculation of Soil Organic Matter :** To calculate the soil organic matter these calculation methods are used to estimate the carbon content in soil in tonnes per hectare. The Sampling Soil Carbon methods are used for soil sampling as well as the laboratory requirements for collecting samples. Carbon concentration data obtained soil sample, collected and analysed carbon concentration data obtained from the laboratory,

the amount of carbon per unit area is given by:

$$C = [(DB_{soil}) \times DS \times C] \times 100 \quad (\text{Equation - 4})$$

Where: C = carbon;  $DB_{soil}$  = bulk density of soil (g/cm<sup>3</sup>); DS = depth of soil.

The soil organic matter calculated for each land use type of 2011, 2014, 2015 and 2016 is shown in Table 8.

**Table 8 : Carbon Storage Tonnes Per Sq Km in Soil Organic Matter of Land Use Classes**

Year wise Carbon Storage in Soil									
S.No.	LULC Classes	2011		2014		2015		2016	
		Area (sqkm)	AGB	Area (sqkm)	AGB	Area (sqkm)	AGB	Area (sqkm)	AGB
1	Water bodies	161.17	0	116.11	0	97.4	0	121.7	0
2	Settlements and wasteland	1711.7	90.74	1708.5	90.57	1472.3	78.05	1396.2	74.02
3	Sparse vegetation	3233	171.39	3966.9	210.3	3542.4	187.79	1843.4	190.58
4	Moderate vegetation	3305.2	175.21	3443.9	209.86	3958.8	191.56	4788.2	253.83
5	Dense vegetation	2946.5	156.2	1944	123.06	2083.4	100.44	3065.2	162.49

**Calculation of Dead Organic Matter:** Using the sound density of wood converts volume to dry biomass.

$$BD = VOL \times DW \times 0.001 \quad (\text{Equation - 5})$$

Where: BD = biomass of dry (kg); VOL = volume (cm<sup>3</sup>); DW = density of wood (g cm<sup>-3</sup>).

By using correct scaling factor, volume and density of each tree, dry biomass is calculated. In next phase, the above outcome is counted to carbon/estimation (Equation -6). The Dead organic matter is calculated for each Land use type of 2011, 2014, 2015 and 2016 is shown in

Table 9.

$$C_{(p)} = MD_{plot} \times FC \quad (\text{Equation - 6})$$

Where:  $C_{(p)}$  = plot of carbon stock (  $Csq\ km^{-1}$ );  $MD_{plot}$  = plot of dry biomass ( dry matter  $sqkm^{-1}$ )  $FC$  = fraction of carbon.

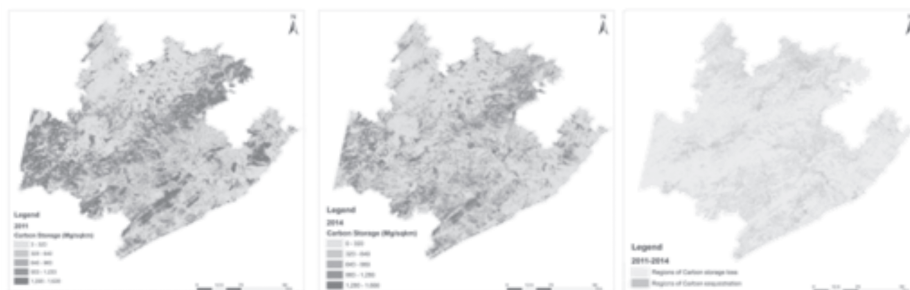
**Table 9 : Carbon Storage Tonnes Per Sq Km in Dead Organic Matter of Land Use Classes**

		Year-wise Carbon Storage in Dead-Wood							
S.No.	LULC Classes	2011		2014		2015		2016	
		Area (sqkm)	AGB	Area (sqkm)	AGB	Area (sqkm)	AGB	Area (sqkm)	AGB
1	Water bodies	161.17	0	116.11	0	97.4	0	121.7	0
2	Settlements and wasteland	1711.7	63.15	1708.5	63.03	1472.3	54.32	1396.2	51.51
3	Sparse vegetation	3233	954.25	3966.9	1170.9	3542.4	1045.6	1843.4	1044.1
4	Moderate vegetation	3305.2	4994.8	3443.9	5204.5	3958.8	5982.6	4788.2	7236.1
5	Dense vegetation	2946.5	10436	1944	6885.5	2083.4	7379.1	3065.2	7235.7

### 3.4 InVEST (Integrated Valuation of Ecosystem Services and Tradeoff) MODEL

The InVEST carbon model uses terrestrial ground biomass, below ground biomass, dead organic, and soil organic matter, which are useful for analysis of carbon storage or carbon loss on particular area (Tallis et al, 2010). The carbon density of each land-use classification and a land-use map are key input data to estimate carbon

storage in each pixel (Asako et al, 2008). InVEST model run for entire Visakhapatnam district to estimating the amount of carbon sequestration and loss in the year of 2011 - 2014 (Figure 8), 2014-2015 (Figure 9) and 2015- 2016 (Figure 10) and observed the results in Table 10, Table 11 and Table 12, respectively. The InVEST model result indicates positive values for carbon storage increased where negative values show loss of carbon.



**Figure 8: Amount of Carbon Storage (mg/sqkm) in 2011 and 2014, Respectively**

**Table 10: Carbon Storage in 2011 - 2014**

Carbon Storage in 2011 - 2014		
Description	Value	Units
Total cur (2011)	7683615981	mg of C
Total fut (2014)	6094050713	mg of C
Change in C for fut	-1392299790	mg of C



**Figure 9: Amount of Carbon Storage (mg/sqkm) in 2014 and 2015, Respectively**

**Table 11: Carbon Storage in 2014 - 2015**

Carbon Storage in 2014 - 2015		
Description	Value	Units
Total cur (2014)	5544900993	mg of C
Total fut (2015)	5135064915	mg of C
Change in C for fut	-423909045.9	mg of C



**Figure 10: Amount of Carbon Storage (Mg/Sqkm) in 2015 and 2016, Respectively**

**Table 12: Carbon Storage in 2015 - 2016**

Carbon Storage in 2015 - 2016		
Description	Value	Units
Total cur (2015)	6023415545	mg of C
Total fut (2016)	7592711728	mg of C
Change in C for fut	1512332395	mg of C

### Results and Discussion

#### **Generation of Vegetation Density Map Using Remotely Sensed Data :**

This study produced vegetation density comparison of 2011, 2014, 2015 and 2016. NDVI Mean values for sparse vegetation in 2011, 2014, 2015, and 2016 are 0.22, 0.20, 0.18, and 0.26, respectively. NDVI Mean values for moderate vegetation in 2011, 2014, 2015, and 2016 are 0.33, 0.25, 0.22, and 0.32, respectively. NDVI Mean values for dense vegetation in 2011, 2014, 2015, and 2016 are 0.44, 0.31, 0.28, and 0.41, respectively.

#### **Impact of Land Use and Land Cover on Terrestrial Carbon Stock:**

The land-use changes, cultivation, and plantation significantly affected total ecosystem carbon storage although management induced differences in carbon stocks were confined to differences in above and below ground biomass. Land use of study area is classified into water bodies, settlement and wasteland, sparse vegetation, moderate vegetation and dense vegetation in 2011, 2014, 2015 and 2016.

#### **Mapping of Carbon Stock Using Spatial Database:**

The carbon stored in carbon pools are used to calculate the amount carbon can be sequestered or loss on the particular area. For above ground biomass, 224.73, 721.79, 3796.74

t of carbon for 2014 and 116.95, 630.55, 3456.04 t of carbon for 2015 sparse, moderate and dense vegetation, respectively. For below ground biomass, 52.81, 169.62, 1106.32 t of carbon for 2014 and 43.65, 140.65, 956.19 t of carbon for 2015 sparse, moderate and dense vegetation, respectively. For soil organic matter, 210.30, 209.86, 123.06 t of carbon for 2014 and 187.79, 191.56, 100.44 t of carbon for 2015 sparse, moderate and dense vegetation, respectively. For dead organic matter, 1170.88, 5204.46, 6885.49 t of carbon for 2014 and 1045.57, 5982.57, 7379.06 t of carbon for 2015 sparse, moderate and dense vegetation, respectively.

#### **Estimation of Carbon Stock above Using Four Carbon Pools:**

The estimated amount of carbon loss or sequestered during 2011, 2014, 2015 and 2016 by using InVEST model. Field data of carbon pools and land use and land cover raster datasets are inputs for InVEST model to analyse the gross amount of carbon in each land parcel. The InVEST model output table show values in milligram per each grid cell. The InVEST model result indicates positive values for carbon storage increased where negative values show loss of carbon.

-1392299789.91 mg of C loss of carbon during 2011-2014.

-423909045.87 mg of C loss of carbon during 2014-2015.

1512332394.91 mg of C of carbon sequestered during 2015-2016.

### **Conclusion**

The output map shows the difference in storage of carbon in the current and the future landscape. The carbon storage and loss in this study area, the InVEST model will represent milligram in each pixel. The output Table shows

negative and positive values. The positive values represent carbon sequestration in particular area, whereas negative values represent carbon lost in that area. Depending upon high negative or positive values can indicate biggest changes in land use and land cover in that particular area. This study observed that there is loss of carbon in 2014-2015 compared to 2011-2014 in Visakhapatnam district. This model is useful for further analysis and also to estimate amount of carbon loss or sequestration.

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