ABOVE GROUND PHYTOMASS AND CARBON ESTIMATION IN TREES OUTSIDE FOREST USING REMOTE SENSING AND ANCILLARY DATA

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PRESENTATION FLOW

1. **Background and Problem Definition**
2. **Objectives**

3. **Methodology Development**
   - Study area and Data Used
   - Tree outside forest (TOF) Mapping
   - TOF sampling Design
   - Plot Wise Volume and Phytomass estimation: Ground Based Observation
   - Establishment correlation between Phytomass and NDVI
   - Carbon pool and Carbon sequestration estimation

4. **Results and Discussion**
   - Ranges of trees in different category of trees outside forest (TOF)
   - Relationship between NDVI and Estimated Phytomass
   - Calculated Phytomass of TOF
   - Calculated Carbon Content in TOF

5. **Conclusion and Recommendation**

Acknowledgment
Reference
Question and Suggestion

Background and Problem Definition

The scientist community believes that atmospheric carbon-dioxide (CO_2), which is major green house gas, has **been increasing steadily since pre-industrial times**. The IPCC estimates that the level of **CO_2 in today's atmosphere is 31% higher than it was at the start of Industrial Revolution about 250 years ago**.

Where **Forests and Tree outside forest play an important role in global carbon cycling**, since they are **large pools of carbon as well as potential carbon sinks and sources** to the atmosphere. Number of researcher has done a lot of research and management on forest, **but less focus on the Trees outside Forest (TOF)** where as TOF's makes a **contribution to the environment and to the social and economic well-being of humankind at local to regional scale** which has become important in current times since human activity leads to dramatic changes in land cover characteristics at local level to regional level.

So, accurate estimation of forest and trees outside forest Phytomass is required for **greenhouse gas inventories and terrestrial carbon accounting at local regional scale**. The needs for reporting carbon stocks and stock changes for the Kyoto Protocol have placed additional demands for accurate surveying methods that are verifiable, specific in time and space, and that cover large areas at acceptable cost (IPCC). In this regard Remote Sensing especially High spatial resolution satellite imagery has opened **effective way to estimate tree outside forest Phytomass and Carbon content**.

TOF in India contributes immensely in the carbon sequestration, after natural forest, but less focus in TOF. **Large gaps of knowledge in available data** on Phytomass and carbon for regional and national estimates in TOF.

Definition

Trees Outside Forest (TOF)

Trees outside forests "***in reference to trees and tree systems occupying lands other than those defined as "forests and other wooded lands***" (FAO). Trees outside the forest are located on "other lands" mostly on farmlands and built-up areas, both in rural and urban areas. A large number of TOF consist of planted or domesticated trees. TOF include trees in agro-forestry systems, orchards and small woodlots. They may grow in meadows, pastoral areas and on farms, or along rivers, canals and roadsides, or in towns, gardens and parks. Some of the land use systems include alley cropping and shifting cultivation, permanent tree cover crops (e.g. coffee, cocoa), windbreaks, hedgerows, home gardens and fruit-tree plantations.

Phytomass

Phytomass or *Plant Biomass defined* ***as the quantitative estimate of the total mass of plants in a stand, population, or within a given area, at a given time. The amount of wet weight or dry weight of growing, chlorophyll-containing plant material per unit ground area***. It is usually expressed in grams per square meter, tons per acre, or metric tons per hectare. Where as Biomass define as the dry weight of living matter, including stored food, present in a species population and expressed in terms of a given area or volume of the habitat. **Biomass consists of living organisms, or parts of living organisms, as well as waste products and incompletely decomposed remains of living organism**s. The term is quite **encompassing and includes plants (referred to as Phytomass), microbes, and animal material, or zoomass.**

Objectives

The present study demonstrate **the potential of stand wise tree outside forest inventory data and finer spatial resolution of IRS LISS-IV satellite data for estimating stand volume, aboveground Phytomass and the carbon content in TOF in a semi-arid region of the southern part of Haryana, India** by applying the regression and geo-statistical method.

The sub-objective of the study is to

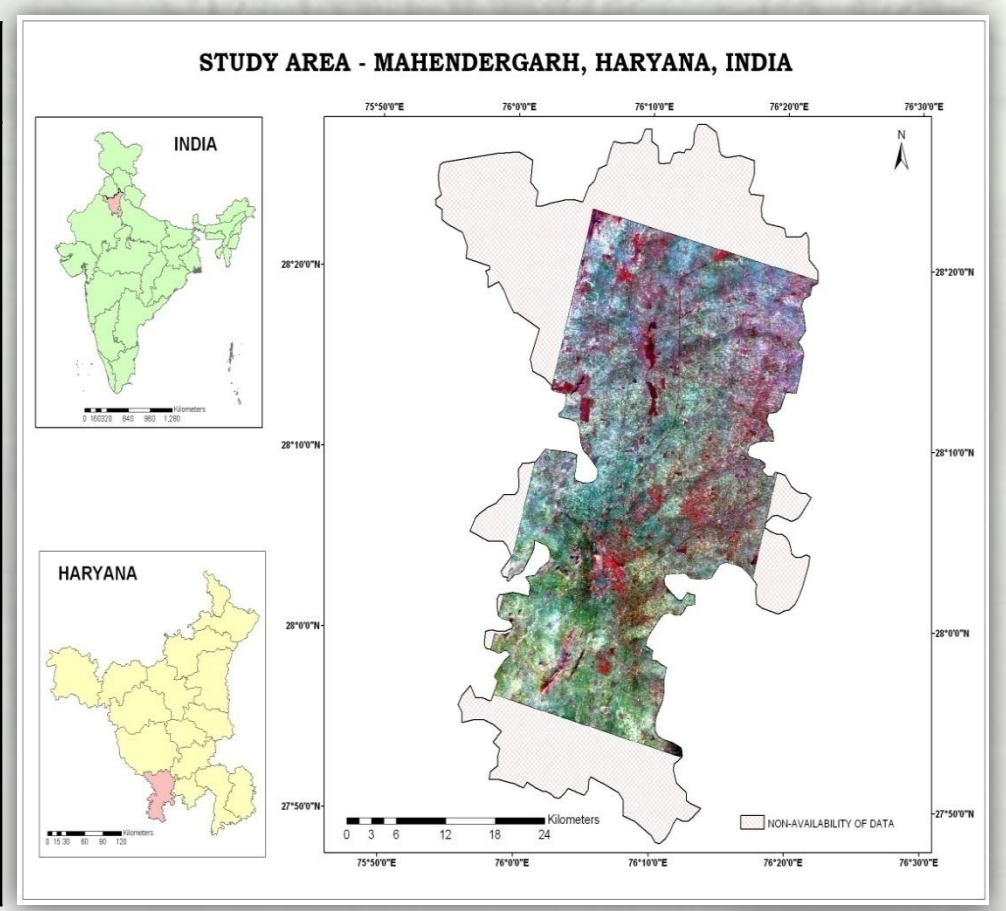
1. **Accurate mapping of TOF classes** mainly in Block, Linear and Scattered classes using high spatial resolution data of IRS-P6 LISS-IV sensor.
2. **Calculate the total Phytomass and Carbon content in TOF** in study area of semi arid region using geospatial tool.
3. Establishing **the correlation between ground sampling based Phytomass and satellite data (NDVI).**

Study Area

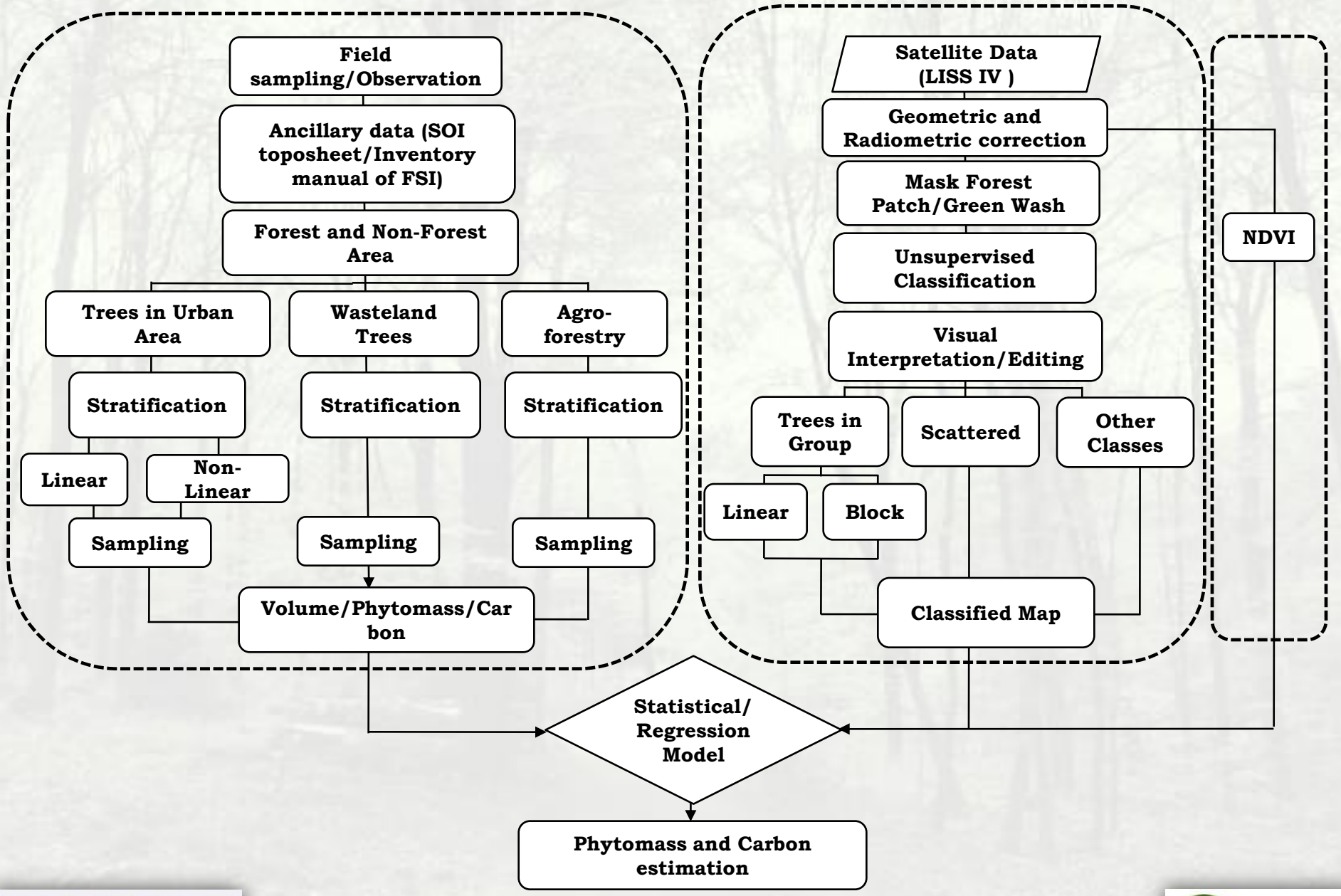
Estimates of above ground Phytomass and carbon contained in TOF was examined for the subpart of **Mahendergarh district** since the full image was not available. It is located in the southern part of **Haryana in India.** The district lies between north **latitude 27^0 47' N to 28^0 26' N and east longitude 75^0 56' E to 76^0 51' E**. The total extent of the study area is 1228.12 km^2.

Data and Software used

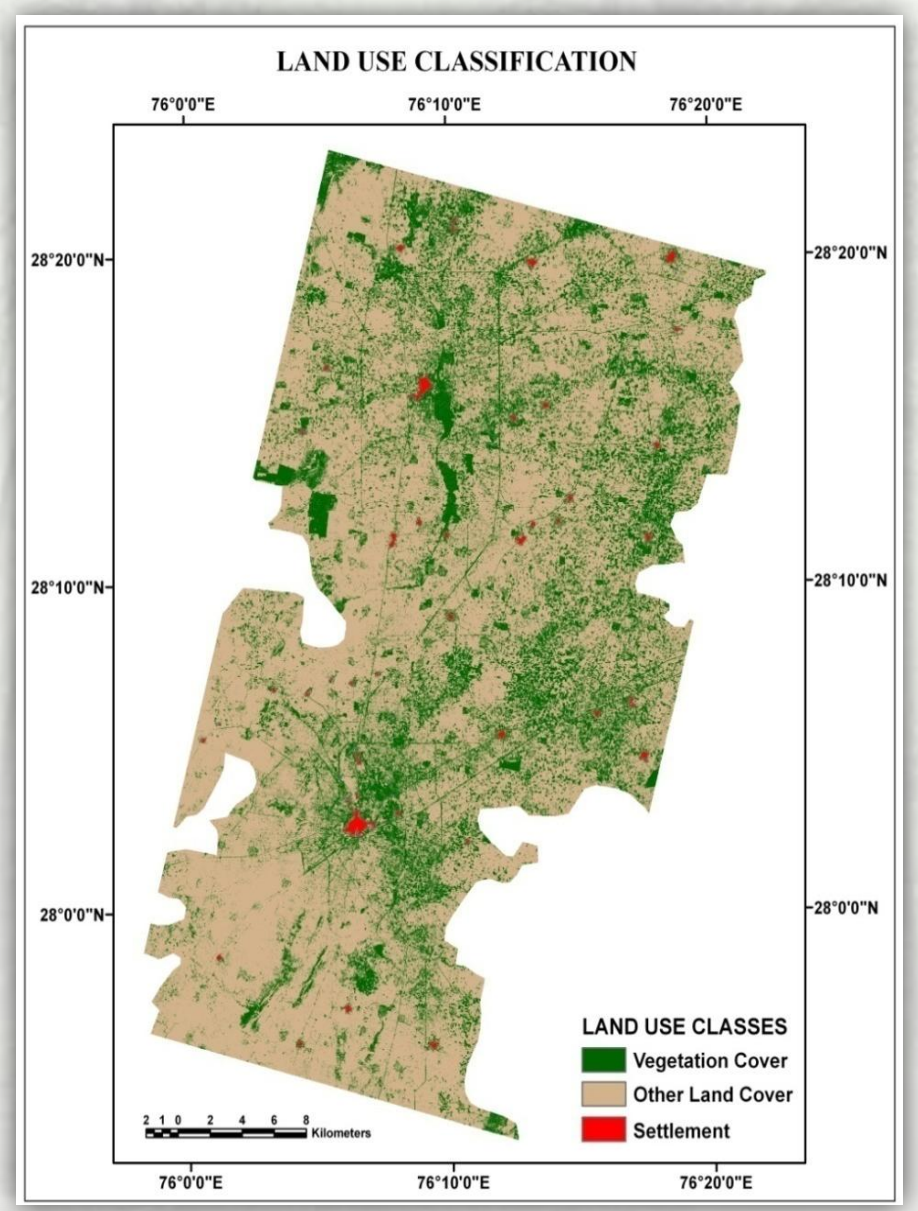
Data Used (Linear Imaging Self-Scanning Sensor (LISS-IV))		**Software/Instr-ument used**
Platform	Indian Remote sensing Satellite-P6 (RESOURCESAT-1)	•ERDAS-9.0 •ArcGIS-9.3 •Arc Info •SPSS 14 •MS-Access •Garmin Map source 6.11 •Hypsometer •Compass •Measuring Tape •Nylon rope
Category	High resolution multispectral sensor	
Spatial Resolution	5.8 meter	
Spectral Band (3 spectral Bands)	0.52 to 0.59 microns (Green)	
	0.62 to 0.68 microns (Red)	
	0.76 to 0.86 microns (Infra-Red)	
Swath	23.9 km (Multi-Spectral mode) 70 km (Mono mode)	

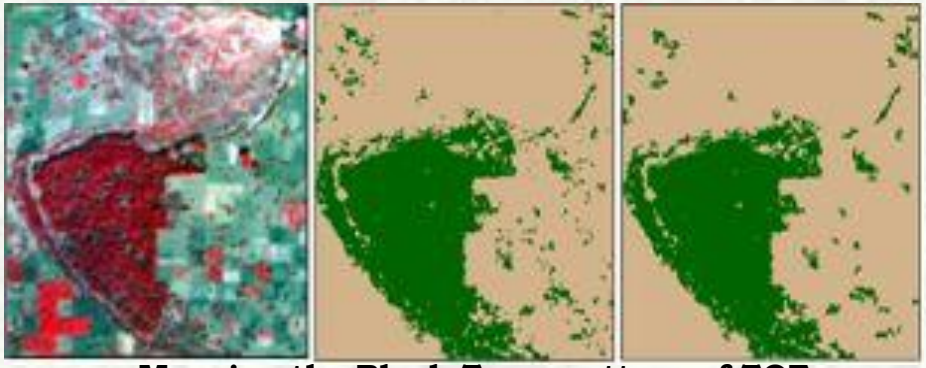


Schematic Chart of Methodology to Calculating Phytomass and Carbon in TOF

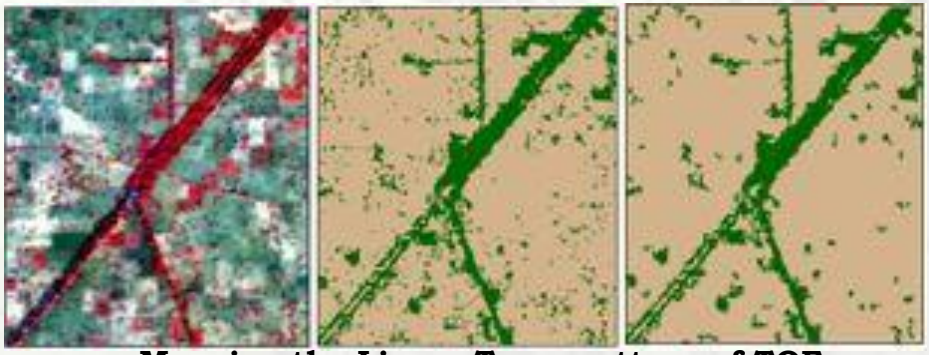


Mapping of Tree Outside Forest (TOF) Classes

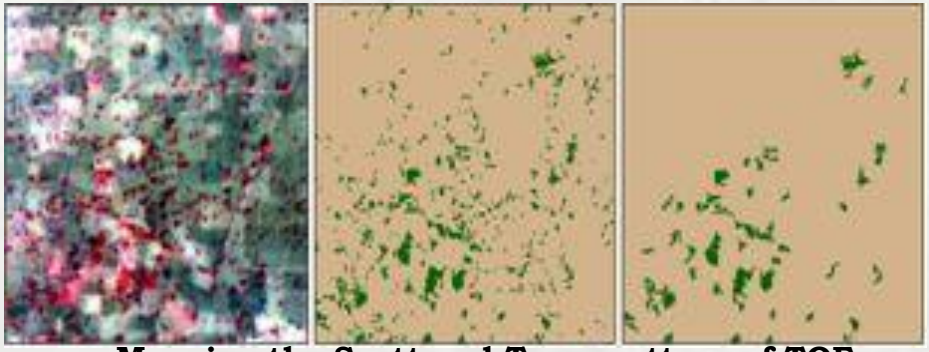




Mapping the Block Trees pattern of TOF

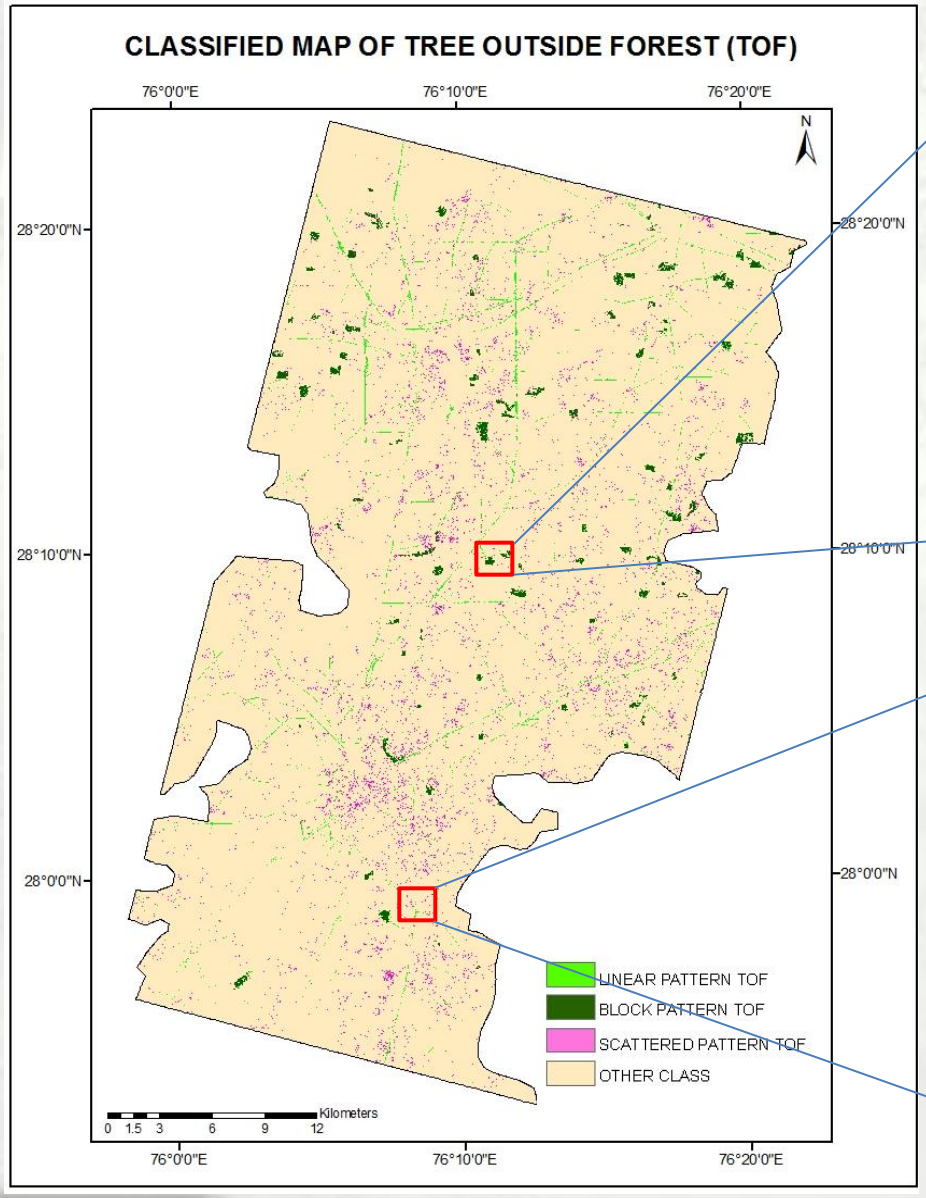


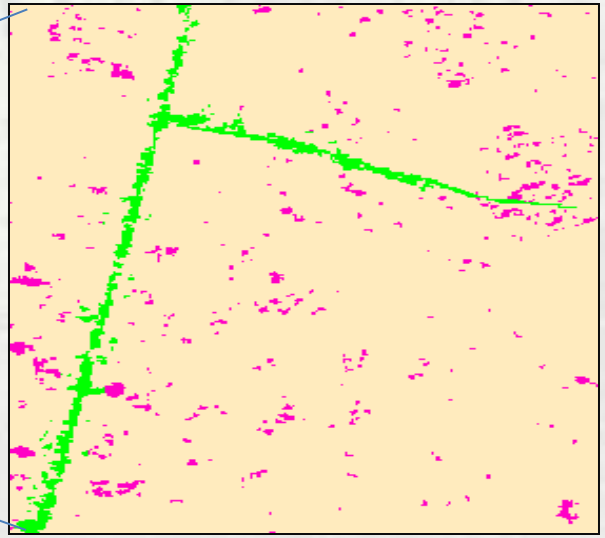
Mapping the Linear Trees pattern of TOF



Mapping the Scattered Trees pattern of TOF

Classified Map of Tree Outside Forest (TOF) Classes





Extensive Sampling Design for Tree Outside Forest (TOF)

Total **105 plots were surveyed** in the study Area.

Satellite data has made **important contribution to stratify the TOF** in more or less homogeneous areas.

Non-destructive approach has been used for Phytomass estimation

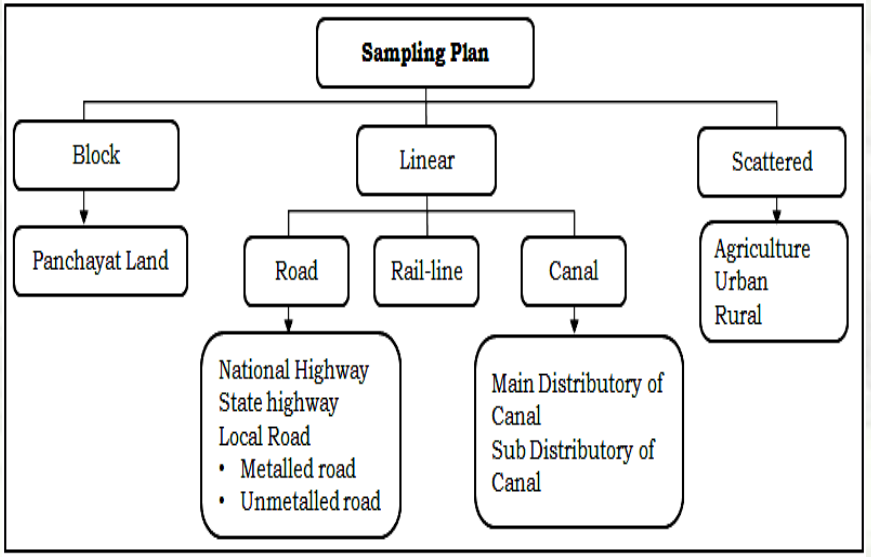
Dimension of Sampling Plot

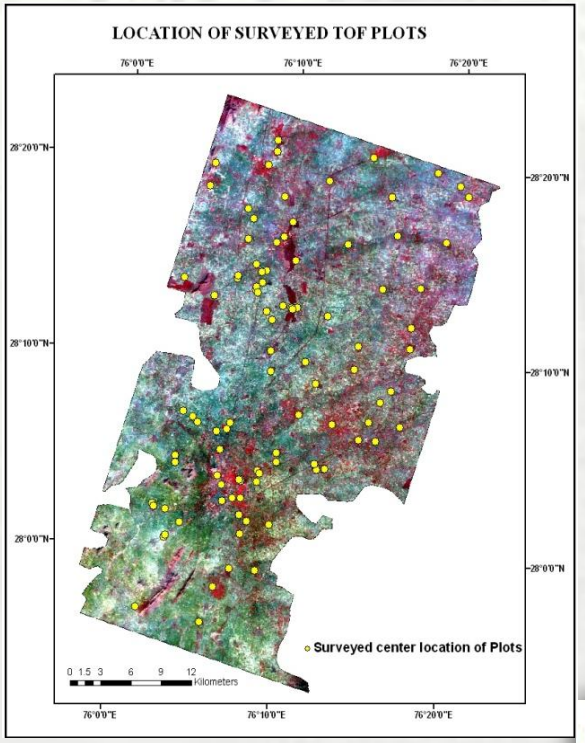
- **32 x 32 m for Block Pattern**
- **50 x 50 m** for Scattered Tree
- **50 x Total Width with Plantation** for Linear trees along the road, canal and railway line.

Detailed data and information has been taken regarding the TOF within the sample plots

- Enumeration of trees,
- Name of individual Tree species
- Average stand height
- Girth at Breast Height (GBH)
- Height of the Tree

Besides this information the general information like soil type, slope, water source for the site etc. was recorded on the predefined field forms.





Dimension and Layout of Sampling Plot for TOF survey

Dimension of Sampling Plot

Block

32 x 32 m for Block Pattern

1024 m^2 = 0.1 hectare

1. Minimum surveyed area for block category of TOF
2. Ease to make correlation between calculated Phytomass and NDVI on image.

Scattered

50 x 50 m and **100 x 100m** for Scattered Tree

1. Minimum surveyed area for Scattered tree category of TOF. For less dense scattered 100 x 100 area has been designed.
2. So that minimum number of trees can be surveyed in a plot.

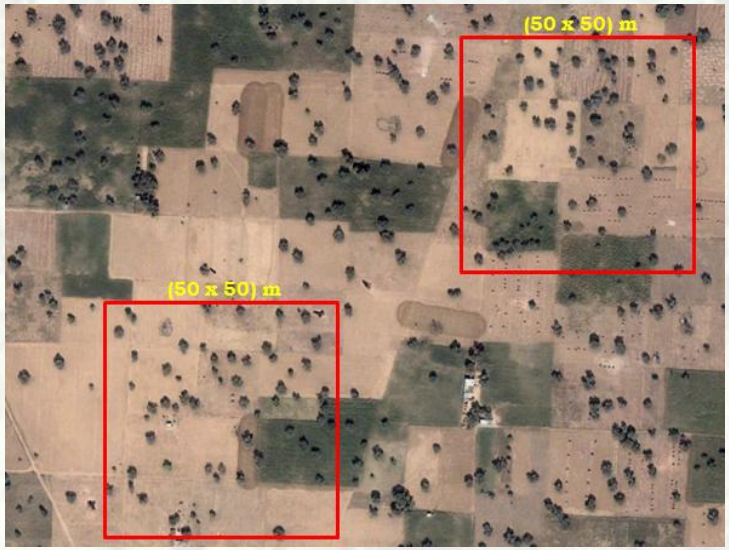
Linear

1. **50 x Total Width with Plantation m** for Linear trees along the road, canal and railway line.
2. Minimum surveyed length for linear category of TOF is 50 m. Where as width was decided on total width of plantation/trees across the linear feature.

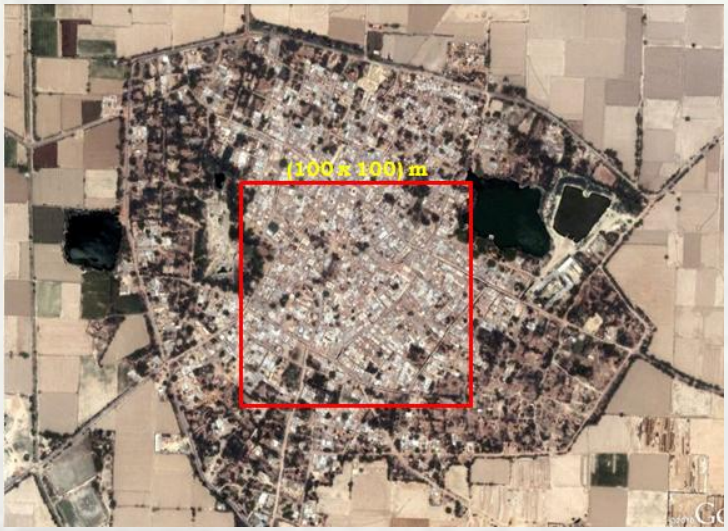
Layout of Sampling plot for Scattered TOF

Less Dense Scattered trees

Dense Scattered trees



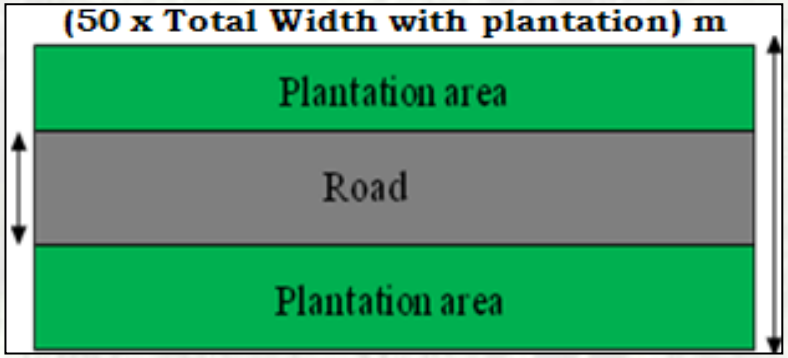
Urban Area Scattered trees



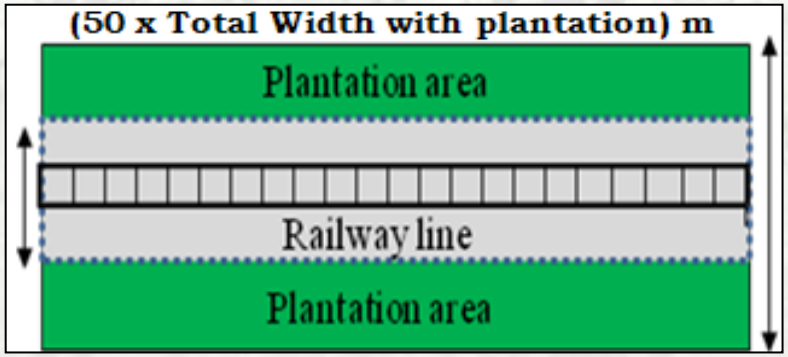
Rural Area Scattered trees

Layout of Sampling plot for Linear TOF

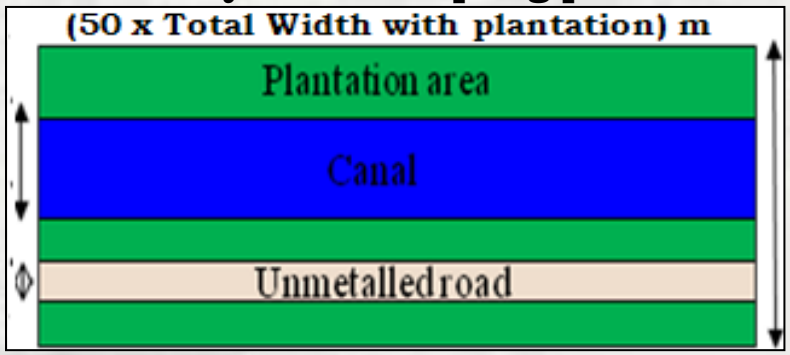
Layout of sampling plots for TOF along and across the Road



Layout of sampling plots for TOF along and across the Canal



Layout of sampling plots for TOF along and across the Railway Line



Volume Calculation for Tree Outside Forest (TOF)

Database Generation

Entered the Field Data for 105 plots in the MS-Access with respect to all the parameters for Phytomass.

Calculate DBH

Uniform Metric Units Convert GBH (Girth at Breast Height) (in cm) to GBH (in mt)

Calculate DBH (Diameter at Breast Height) = $\frac{GBH}{\prod}$ (Where $\prod$ =3.14)

Calculate the Volume of Trees

Plot-wise Phytomass for different species found in the study area was estimated using available **species specific volume equations** developed by **Forest Survey of India** (Forest Survey of India, 1996).

If the species volume equation was not found in FSI-FRI, India, 1996 Manual/literature, then **general volume equation** of same climatic zone were applied. If volume is negative, then **Quarter Girth** formula has been applied.

Acacia Species: $\sqrt{V}$=-0.00142+2.61911 * D-0.54703 * $\sqrt{D}$

Emblica Officinalis: V= 0.01244 + 0.34322 * D^2 * H

General Equation: V= 0.00471 + 1.79326 * D^2 **(S.E. Rajasthan)**

Quarter Girth formula: V= (G/4)2 *H

Where, V=Volume, D=Diameter at breast height (DBH), H=Height of the tree, G=Girth at breast height (GBH)

Phytomass Calculation for Tree Outside Forest (TOF)

Calculation of Phytomass

Based on volume the Phytomass was estimated using equation below:

Phytomass = Volume * Specific Gravity (S.G)

Species-specific, specific gravity, was obtained directly from FSI-FRI manual 1996. For other species for which species-specific, specific gravity was not available an area average specific gravity was used.

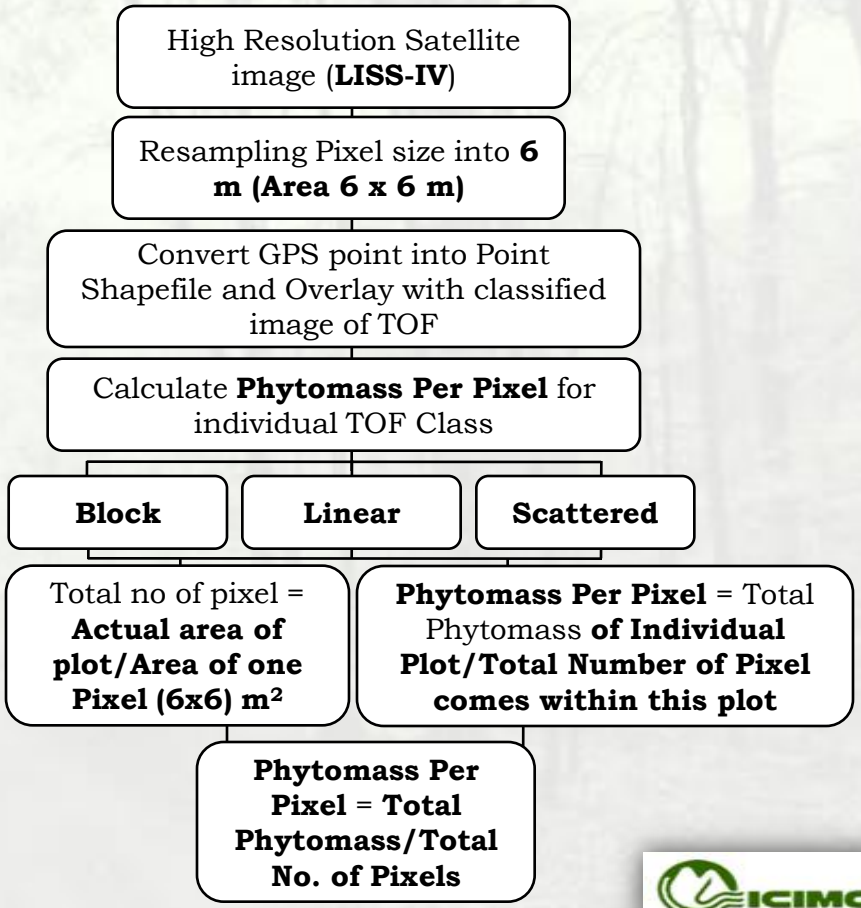
Phytomass Calculation for Surveyed Plots

Plot-wise Phytomass was estimated by aggregation of Phytomass of all the trees coming inside the plot.

TOF Categories Wise Phytomass was estimated by averaging the plot-wise Phytomass values belonging to that particular TOF Category.

Acacia nilotica	0.67
Acacia tortilis	0.66
Ailunthus	0.356
Albizia lebbek	0.534
Azadirachta indica	0.693
Cassia siamea	0.697
Delbergia sissoo	0.678
Eucalyptus hybrid	0.563
Morus alba	0.603
Prosopis cineraria	0.85
Average **S.G.**	**0.63**

Phytomass Calculation from Satellite image



Carbon Content Estimation for Tree Outside Forest (TOF)

Calculation of Carbon

Phytomass (Plant Biomass) has direct relationship with amount of carbon present in that Plant Biomass.

Westlake (1963) has observed that there is 47% carbon present in dry Plant Biomass, while Intergovernmental Panel on Climate Change (IPCC) reported that the carbon present in Plant Biomass is 45% of it (IPCC, 1995).

Based on the results of different studies related to estimation of carbon in wood, it was observed that carbon varies between 45% to 50% for different ecosystems and thus considering 47.5% carbon in the woody biomass is quite reasonable for regional level carbon pool estimations (Raghubansi et al., 1990).

Carbon Content in TOF = Multiplying the total Phytomass by a conversion factor 0.475 (47.5 % of Phytomass)

ID	PLOT_ID	State	Distt	TOF_Type	Location	Lat	Long	Alt(m)	Total-Width (m)	WidthRd/canal	WidthPatri along Canal
1	1	HR	MG	Linear Rd	On Narnol Road	28 14 24.2	76 08 28.5	272	20	8	
56	3	HR	MG	ScatteredRu	Jatwas village	28 14 27.6	76 07 57.1	272			
75	4	HR	MG	BlockRu	Jhanjriawas	28 14 42.6	76 07 50.3	275			
Plot Size	Final_Pl_Size	S_no.	Local_name	Botanical Name	cbh(cm)	CBH(m)	Dia(M)	SQRTD	D*D	D*D*D	Height(m)
50x20	50x12	1	Neem	Azadirachta indica	238	2.38	0.757	0.87	0.57	0.43	14.5
50x50	50x50	1	Neem	Azadirachta indica	142	1.42	0.451818	0.672174235	0.204139688	0.092234027	13.5
32x32	32x32	1	Kabuli kikar	Prosopis juliflora	43	0.43	0.136818	0.369889427	0.018719217	0.002561129	2
Vol-Eq	Q_G_F	V-SQRT	Volume	Sp_Gr	Phytomass	Tot_Bio/Plot	Tot_C/Plot	Biom/pix	C/Pix	Biom/ha	Car/ha
V=0.00471+1.79326D*D	V=(G/4*G/4)*L		1.033	**0.69**	0.716	3.723	1.768	0.22428	0.10653	61.80167	29.35579346
V=0.00471+1.79326D*D	V=(G/4*G/4)*L		0.370785537	0.693	0.256954377	1.355774	0.643993	0.019535646	0.009279432	5.423095359	2.575970295
V=0.00471+1.79326D*D	V=(G/4*G/4)*L		0.038278422	0.85	0.032536659	1.210474	0.574975	0.042622312	0.020245598	11.81422299	5.61175592

Establishment of Correlation between Phytomass and NDVI

Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that **uses the visible and near-infrared bands of the electromagnetic spectrum,** and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not .

NDVI = (NIR- Red)/(NIR+ Red)..... (Rouse, et. al, 1974)

In this study NDVI has been calculated for following purpose first one is to differentiated vegetated and non-vegetated area and then established correlation between Phytomass and NDVI. The NDVI values were represented as a **ratio ranging in value from -1 to 1** but in practice extreme negative values represent water, values around zero represent bare soil and values above then 0 represent vegetation and over 6 represent dense green vegetation.

Correlation between Phytomass and NDVI

In this study correlation has been established between Phytomass and NDVI, for this purpose GPS readings taken during the fieldwork at each sample plot were down loaded into Data base module. Convert this point data into point shape file. This shape file was overlaid on the NDVI image.

Average NDVI value of each plot was **obtained by taking a 3×3 matrix arou**nd the GPS point for blocks **and 9×1 matrix for linear features**. A regression analysis was performed on per pixel Phytomass and average NDVI value.

The coefficients obtained from the regression equation **showing highest R^2 value (regression coefficient) were applied on the NDVI image to extrapolate Phytomass per pixel**. The Phytomass, which is obtained from NDVI image, is predicted Phytomass.

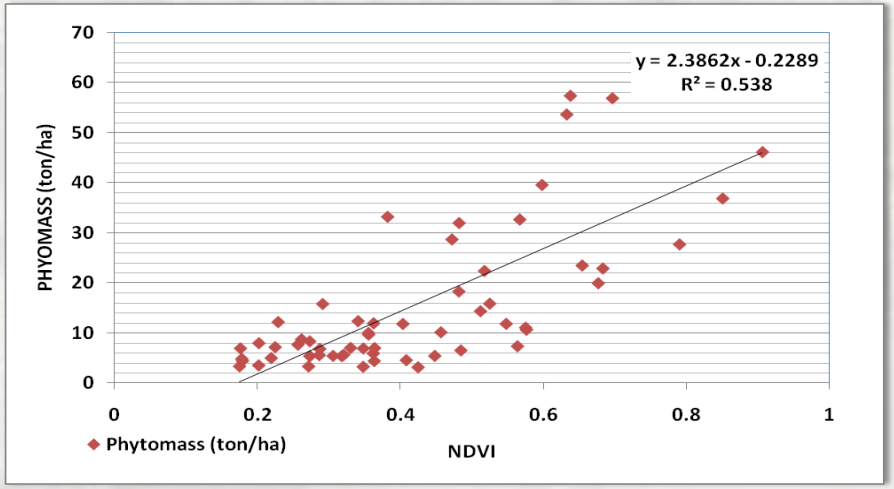
Establishment of Correlation between Phytomass and NDVI

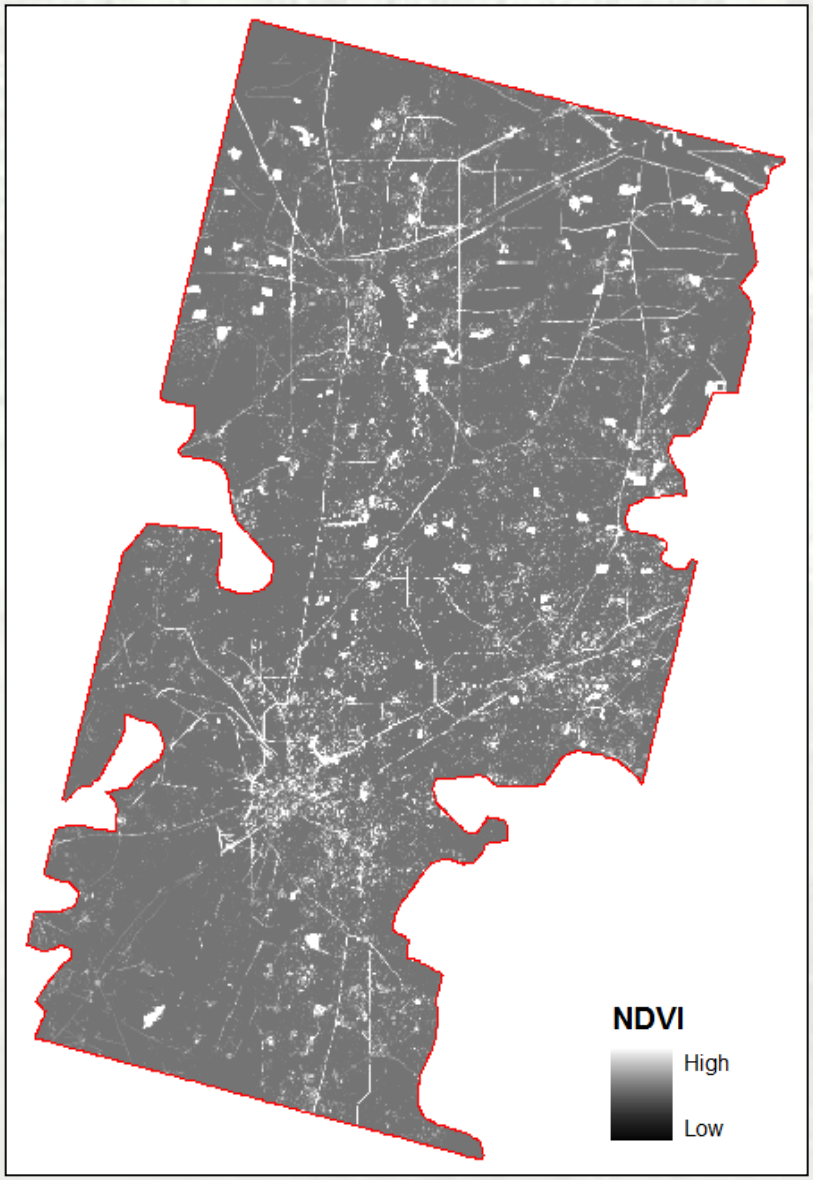
To estimate the Phytomass of the whole study area a co-relation between estimated phytomass per pixel and Normalized difference vegetation index (NDVI) values has been established.

The co-relation value r^2 0.343 i.e. obtained for 105 plots shows less co-relation. Later less co-relation showing plots were removed and co-relation was established between 74 plots which show a good co-relation and Phytomass has been calculated.

Y= 2.3862x +0.2289

Where, **m = 2.3862, c = 0.2289, x = input NDVI image**





Results and Discussion for the Calculation on Surveyed data

Range of trees in different categories of Trees outside Forest

During the field survey, it has been found that there is variation in number of trees and trees species in different types of trees outside forest.

More number of trees was present in the urban periphery and less number of trees in the centre of urban area.

It has been found that there is great contribution of Prosopis cineraria (Khejari) in Phytomass content which are scattered in agro-forestry system with number of trees varying from 64 and 164 trees/ha.

S. No.	TOF type		Number of trees/ha
1	Linear		
	a)	Road	**171-1556**
	b)	Rail	478-557
	c)	Canal	**852-1440**
2	Block		447-1200
3	Scattered		
	a)	Urban	170-416
	b)	Rural	132-336
	c)	Agro-forestry	**64-164**

Dominant Tree Species in Different categories of TOF

Linear		Block		Scattered	
Local Name	**Botanical Name**	**Local Name**	**Botanical Name**	**Local Name**	**Botanical Name**
Deshi kikar	Acacia nilotica	Kair	Capparis deciduas	Khejari	Prosopis cineraria
Khari	Acacia senegal	Deshi kikar	Acacia nilotica	Neem	Azadirachta indica
Totlus (Israeli kikar	Acacia tortilis	Khari	Acacia senegal		
Safeda	Eucalyptus hybrid				

Results and Discussion for the Calculation on Surveyed data

Calculated Phytomass of Trees outside Forest

The average Phytomass of different TOF has been found **2.203 (22.03 tons/ha) tons/per plot size (pps) in hectare.** It has been found that there is a variation in the Phytomass content of linear, block and scattered trees. The linear trees contains Phytomass content of 4.071t/pps ha, block contains 1.824 t/pps ha and scattered trees contains 0.715 t/pps ha.

S. No.	TOF Type	Phytomass (t/per plot size in hectare)
1	Linear	4.071
2	Block	1.824
3	Scattered	0.715
	Average	2.203

1. The per hectare Phytomass content along **linear trees has been found more** due to continue high trees density and old mature trees along the roads.
2. Phytomass content has been found **low in block as compared to linear pattern of trees** because of **vegetation type and external factors**, **site conditions, mainly either in reclaimed areas of river beds or in degraded hills**. Mainly the block plantation was found outside of the rural and urban area which was highly affected by many factors like **grazing, fire and lopping** etc. Even the area under block pattern of trees has been used for many **purposes mainly solid waste** (dung, agriculture wastes) disposal.
3. The content of Phytomass per hectare in scattered trees has been found less due to **low density of trees** in urban, rural and agro-forestry systems. The content of Phytomass per hectare has been found a bit **identical due to the presence of similar species** in vegetation and tree density.

S. No	TOF Type		Phytomass (t/pps ha)	Phytomass range (t/pps ha)
1	Linear			
	a)	Road	4.159	0.83-9.13
	b)	Rail	1.115	0.80-1.43
	c)	Canal	4.521	1.27-9.20
2	Block		1.824	0.680-6.49
3	Scattered			
	a)	Urban	0.953	0.13-2.54
	b)	Rural	0.679	0.32-1.35
	c)	Agro-forestry	0.633	0.33-1.24

Results and Discussion for the Calculation on Surveyed data

4. The Phytomass range is **nearly identical along the road and canal** because of almost **same type of trees species**.

5. The Phytomass tonnes/ha along **canal has been found a little high due** to **high moisture contents in the soil along the canal which favours the rate of growth of trees**.

6. The Phytomass tonnes/ha along the railway line has been found **less as compared to the other linear patterns of TOF**, because the trees density along the railway line is low, which is due to being changed from meter gauze to broad gauze.

S. No.	TOF Type	Carbon (t/per plot size in ha)
1	Linear	1.934
2	Block	0.866
3	Scattered	0.34
	Average	1.046

S. No.	TOF Type		Carbon (t/pps ha)
1	Linear		
	a)	Road	1.975
	b)	Canal	2.147
	c)	Rail	0.53
2	Block		0.866
3	Scattered		
	a)	Urban	0.453
	b)	Rural	0.322
	c)	Agro-forestry	0.3

Calculated Carbon Content in Trees Outside Forest

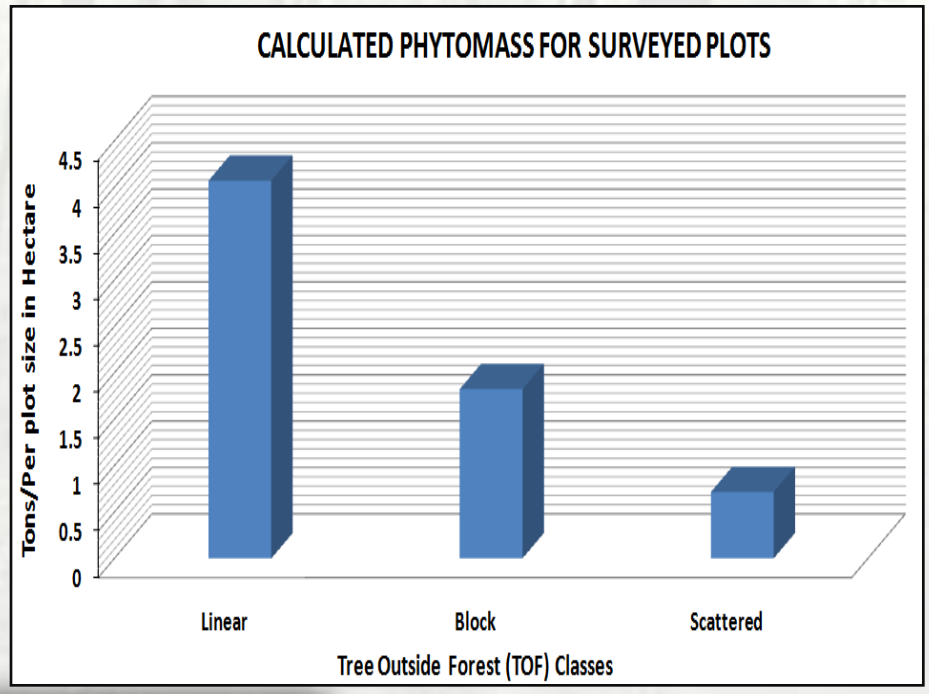
The content of Carbon in Phytomass has been reported from 45 to 50% of the total Plant biomass. Accordingly a mean value of 47.5 % of the Phytomass has been considered for carbon estimation

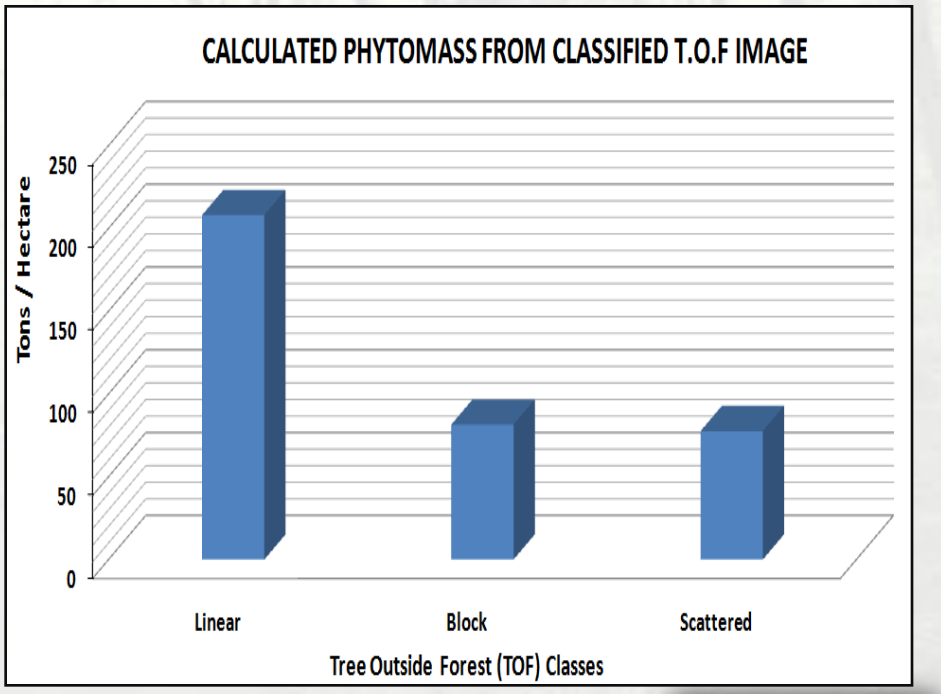
On an average the forest contains the 10.46 tons of carbon per hectare. The estimates of carbon have been found 19.34, 8.66 and 3.40 t/ha for different patterns of TOF i.e. linear, block and scattered respectively (table 5 and 6).

Results and Discussion for the Calculation on Satellite image data

After calculating the per pixel phytomass from filed surveyed data, the total phytomass has been calculated for Tree outside forest in study area by multiplying the per pixel phytomass with total area of individual classes of tree outside forest (TOF).

TOF Classes	Area (hectare)	Area % to total geographical area	Phytomass per pixel	Total Phytomass (Tons/Hectare)	Total Carbon (Tons/Hectare)
LINEAR	1386.66	1.13	0.15	**207.99**	**98.79**
BLOCK	1253.72	1.02	0.065	**81.49**	**38.71**
SCATTERED	2501.94	2.04	0.031	**77.56**	**36.84**





Conclusion

❑This study highlighted that estimation of Phytomass and carbon in TOF can be successfully achieved through the combined approach of new technology i.e. **Remote sensing and Geo-Statistical technique with the supplement of field survey by sampling method in the ground.**

❑Phytomass and Carbon content estimation studies like the present study is important to know the trends and the potential **of carbon sequestration in different categories of TOF** especially in semi-arid area where forest cover is very less. Considering the increasing importance of carbon sequestration studies world over, such type of studies will provide a **robust baseline database**, which can be used for different research and management purposes by the forest departments. This study can also further help in **tracking out the major carbon sequestration potential zones** of semi-arid region.

❑It is important that results of the present study **can be extrapolated to the entire semi-arid region of southern Haryana**, as these follow the similar climatic zones and structure and composition of different TOF types.

❑This study has been made an attempt to generate a **regression equation in semi-arid region which can be further applied to Mahendergarh district** and adjacent area for any different time set data to estimate the Phytomass and carbon present at that given time.

❑This study will be **very helpful in making systematic sampling plan in TOF** which is quite different to the sampling plan of forest region.

References

Z. Fazakas, M. Nilsson, H. Olsson., (1999) 'Regional forest biomass and wood volume estimation using satellite data and ancillary data' Agricultural and Forest Meteorology, 98-99 (1999), 417-425.

Joshi, P.K., P.S. Roy, Shefali Agrawal, Sarnam Singh, Deepshikha Yadav and P.C.Joshi, (2004) 'Aerospace Technology for Land cover Characterisation and Mapping in Central India – Application of Wide Field Sensor (IRS 1C – WiFS).' Asian Journal of Geoinformatics, 4(4), 1-8.

Turner, D. P., Guzy, M., Lefsky, M. A., Ritts, W. D., van Tuyl, S., & Law, B. E. (2004) 'Monitoring forest carbon sequestration with remote sensing and carbon cycle modeling.' Environmental Management, 33, 457–466.
Hingane LS (1991) 'Some aspects of Carbon dioxide exchange between atmosphere and Indian plant biota.' Climate Change, 18, 425-35.

P. Muukkonen J. Heiskanen(2007) 'Biomass estimation over a large area based on stand wise forest inventory data and ASTER and MODIS satellite data: A possibility to verify carbon inventories.' Remote Sensing of Environment, 107, 617–624.

Krankina, O. N., Harmon, M. E., Cohen, W. B., Oetter, D. R., Zyrina, O., & Duane, M. V. (2004) 'Carbon stores, sinks, and sources in forests of Northwestern Russia: Can we reconcile forest inventories with remote sensing results?.' Climatic Change, 67, 257–272.

State of forest report, Dehradun, 2005. Forest Survey of India, Ministry of Environment and Forests, Dehradun, India

Champion, H. G., & Seth, S. K. (1968) 'A revised survey of forest types of India.' New Delhi, India, Govt. Publication.

Rawat J.K., Dasgupta, S., Kumar Rajesh, Anoop, Chauhan, K.V.S. (2003) 'Training manual on inventory of Trees Outside of Forest.' FAO under the EC-AO Partenership Programme

Chhabra, S. S., 2004 'Modeling the effects of Scale on Mapping Trees Outside Forests.' M. Sc. thesis, IIRS-ITC, Dehradun-Netherland.

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Appendix I

Results and Discussion for the Calculation on Satellite image data

Phytomass per pixel in different pattern of TOF

TOF	Phytomass per pixel
LINEAR (Avg.)	0.15
LINEAR_RAIL	0.04
LINEAR_ROAD	0.17
LINEAR_CANAL	0.13

TOF	Phytomass per pixel
BLOCK (Avg.)	0.065
BLOCK	0.079
BLOCK_RAIL	0.024
BLOCK_RIVER	0.058
BLOCK_RURAL	0.054
BLOCK_URBAN	0.070

TOF	Phytomass per pixel
SCATTERED (Avg.)	0.031
SCATTER_HOME	0.037
SCATTER_AGRI	0.023
SCATTER_RURA	0.030
SCATTER_URBA	0.037
SCATTER_TOWN	0.027

TOF	Area (hectare)	Area % to total geographical area	Phytomass per pixel	Total Phytomass (Tons/hectare)	Total Carbon (Tons/Hectare)
LINEAR	1386.66	1.13	0.15	**207.99**	**98.79**
BLOCK	1253.72	1.02	0.065	**81.49**	**38.71**
SCATTERED	2501.94	2.04	0.031	**77.56**	**36.84**