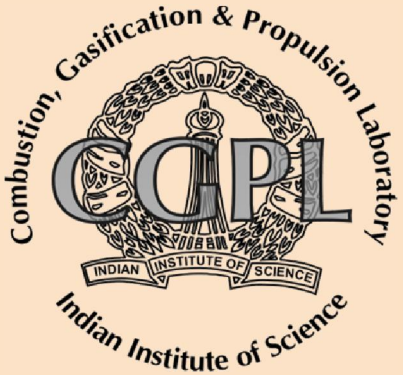
Mapping of Biomass Resources for Sustainable Power Generation



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The Biomass Assessment Programme

- To develop a digital biomass atlas for at National level to get an estimate on the Biomass Resources and its potential for Power Generation to be used by:
  - Energy Consultants, Investors & Entrepreneurs
  - Administrators & Financial Organizations
- Mapping of Biomass from Agro, Forest & Wasteland with an advanced feature of recognizing Biomass Surplus concentration centers using an image generated for each district with a predefined color gradient based on the Energy-useful Biomass Production index generated.
- To enable access of the atlas and data for users on internet for quick look.

The Key-Aspects of the Work

1. The Statistical biomass data analysis and compilation
2. Graphical vectorization for the base GIS layers
3. Integration of remote sensing data into GIS layers
4. Current Strategy to identify Crop is by 'Implied NDVI' of Land use area and Statistical Crop area extent
5. New Strategies for Crop Identification – use of NDVI and Rainfall parameters with AI (artificial intelligence) techniques
6. Create strategic query responses for a variety of users
7. Provide options for dynamic queries with both graphical or tabular outputs
8. Resolve taluk or block level data spatially

The Approach

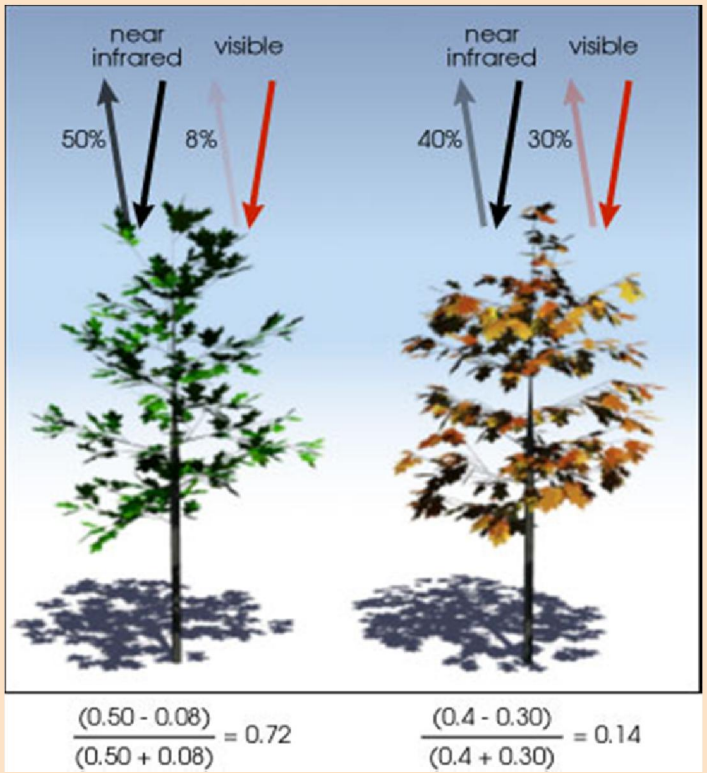
- **GIS:** Geographical Information System is the technology containing the methodologies to define and access the geographical space and to automate the spatial data analysis by making use of computational power of Computer.

- **Land use:** is a description of how people utilize the land (Urban and agricultural land uses are two of the most commonly recognised high-level classes of use). There may be multiple and alternate land uses such as Forest and Waste lands for Energy.

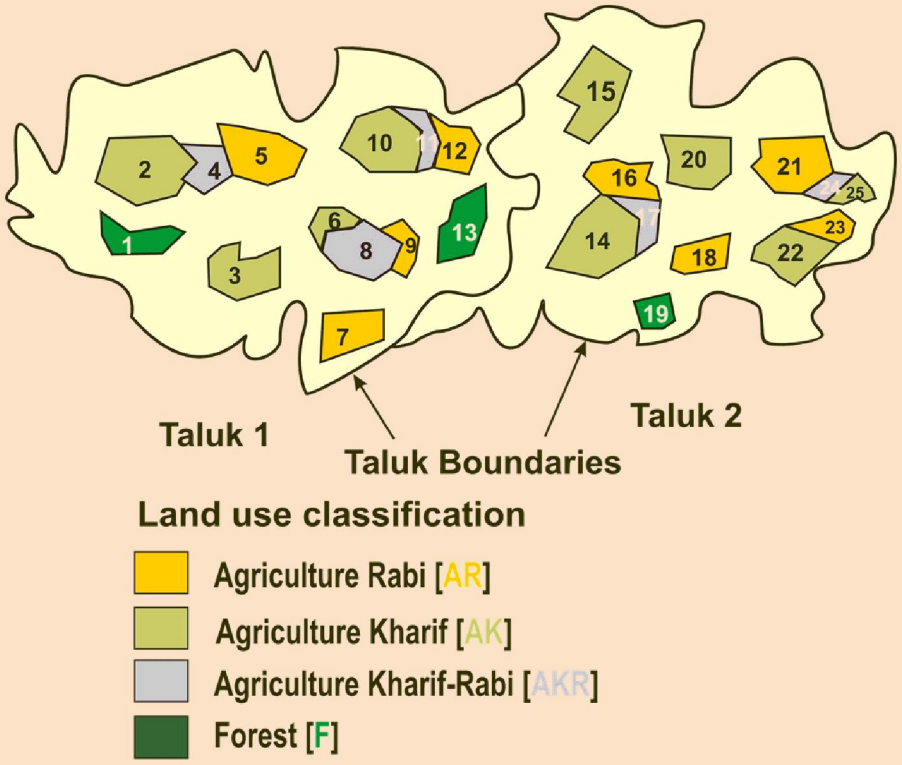
Adaptation of NDVI

- NDVI = Normalized difference Vegetation Index
- It is defined as **NDVI = (NIR — VIS) / (NIR + VIS) where NIR = Near infrared reflection and VIS = Visible reflection.**
- Spatial representation of Land use is done in GIS through irregular Polygons of different classes of NDVI.

NDVI illustrated

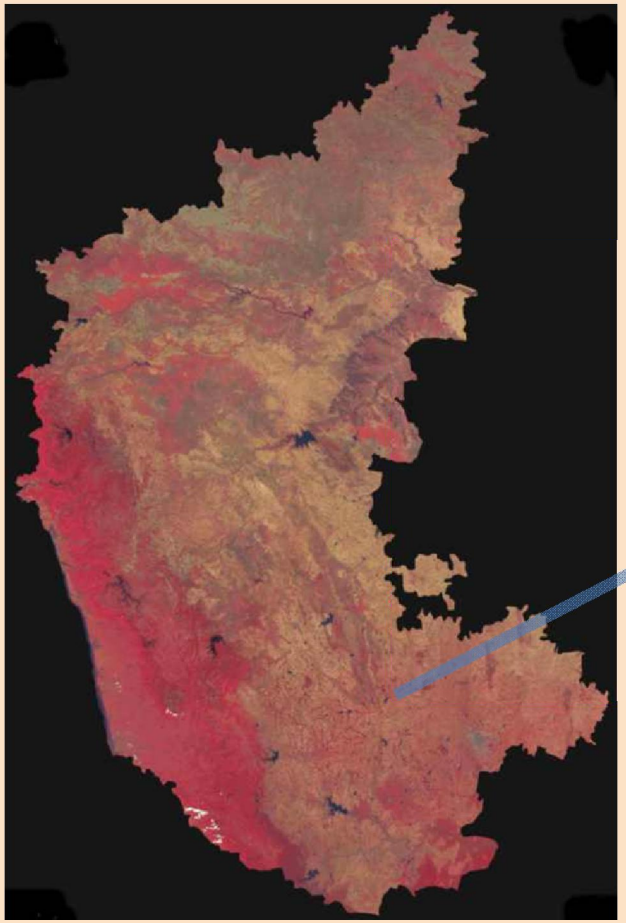


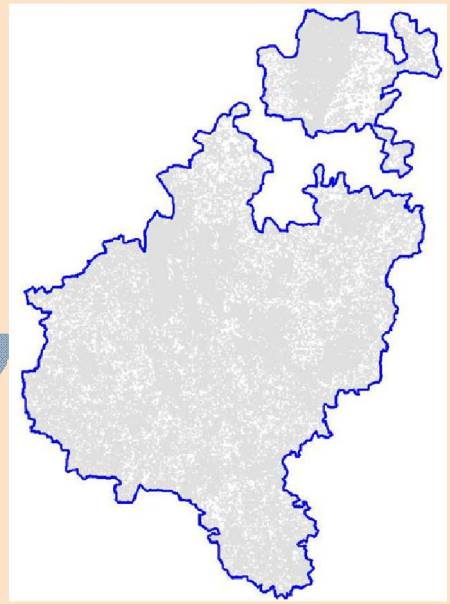
LU-Polygons- a graphic illustration



Land Use as seen by Satellite

- **Spatial representation of Land use is done by Satellite as an image seen by the IR and Visible light range camera. A sample for Karnataka is shown here:**



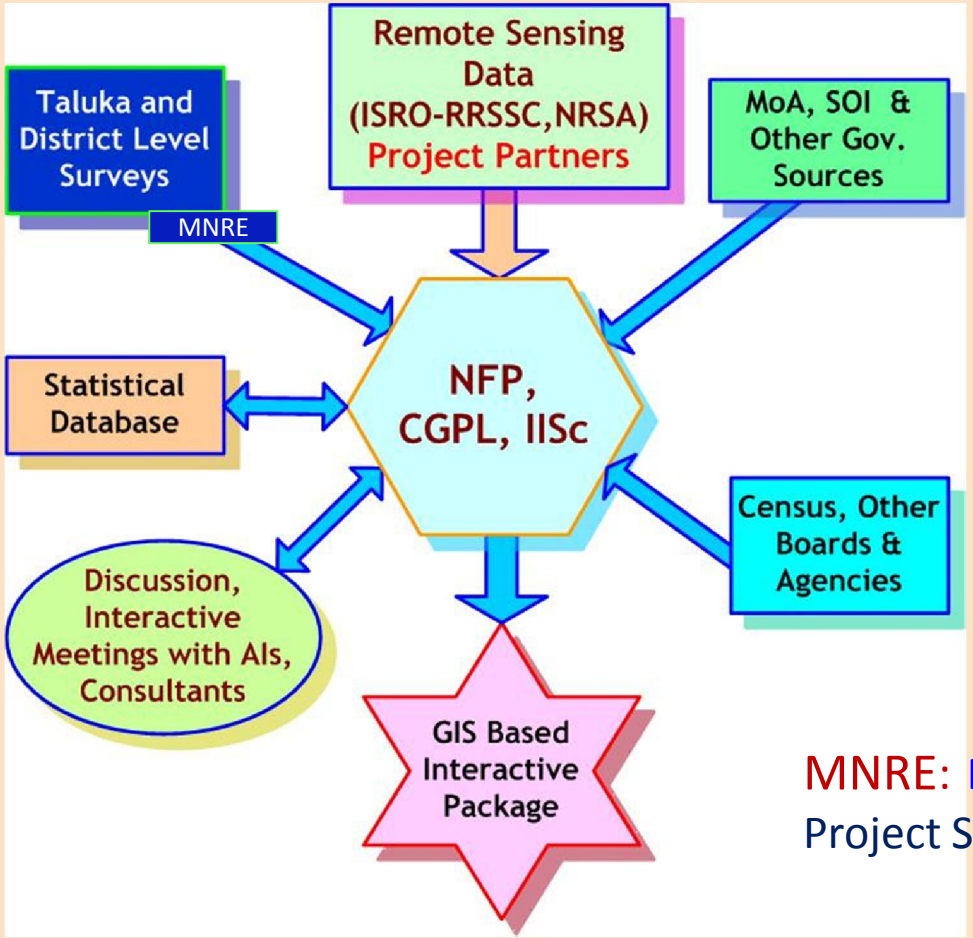


– The Image provides an index for Vegetation. This is used to group the respective similar Pixels and classified into Corresponding Land Use Polygons Called Vectors.

Types of Biomass

- **Biomass can be classified into three broad classes based on the type of land and the way it is generated as follows:**
  - Agro-Biomass
  - Forest Biomass
  - Wasteland Biomass
- **The Biomass maps for these classes are done on different layers of GIS for the 8 states.**
- **Agro-Biomass is the 'by-product' of the grown crops.**
- **Forest Biomass are the residues generated in the densely vegetated areas having different species of plants.**
- **Waste land is presently unused cultivable land defined to be worthy for afforestation.**

The Scheme of the Work



AI: Apex Institute who Analyze & Validate the Survey Reports for Biomass Availability.

SOI: Survey of India

MoA: Ministry of Agriculture.

NFP: National Focal Point do the data verification, Software development, Map generation and Web deployment of Biomass Resource Atlas.

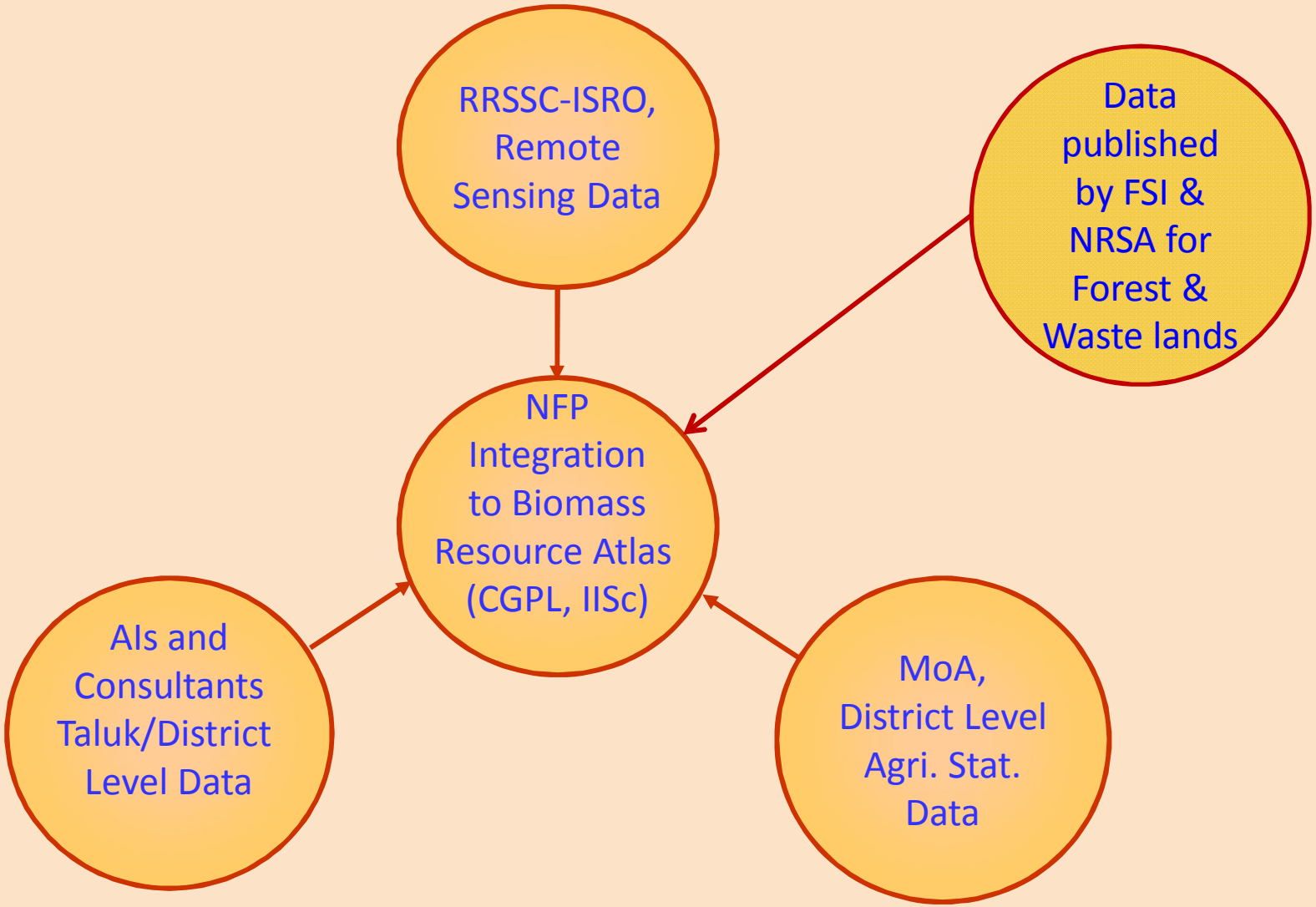
MNRE: Ministry for New and Renewable Energy – Project Sponsoring Ministry.

ISRO: Indian Space Research Organization.

NRSA: National Remote Sensing Agency.

RRSSC: Regional Remote Sensing Service Center.

The Main Data Sources



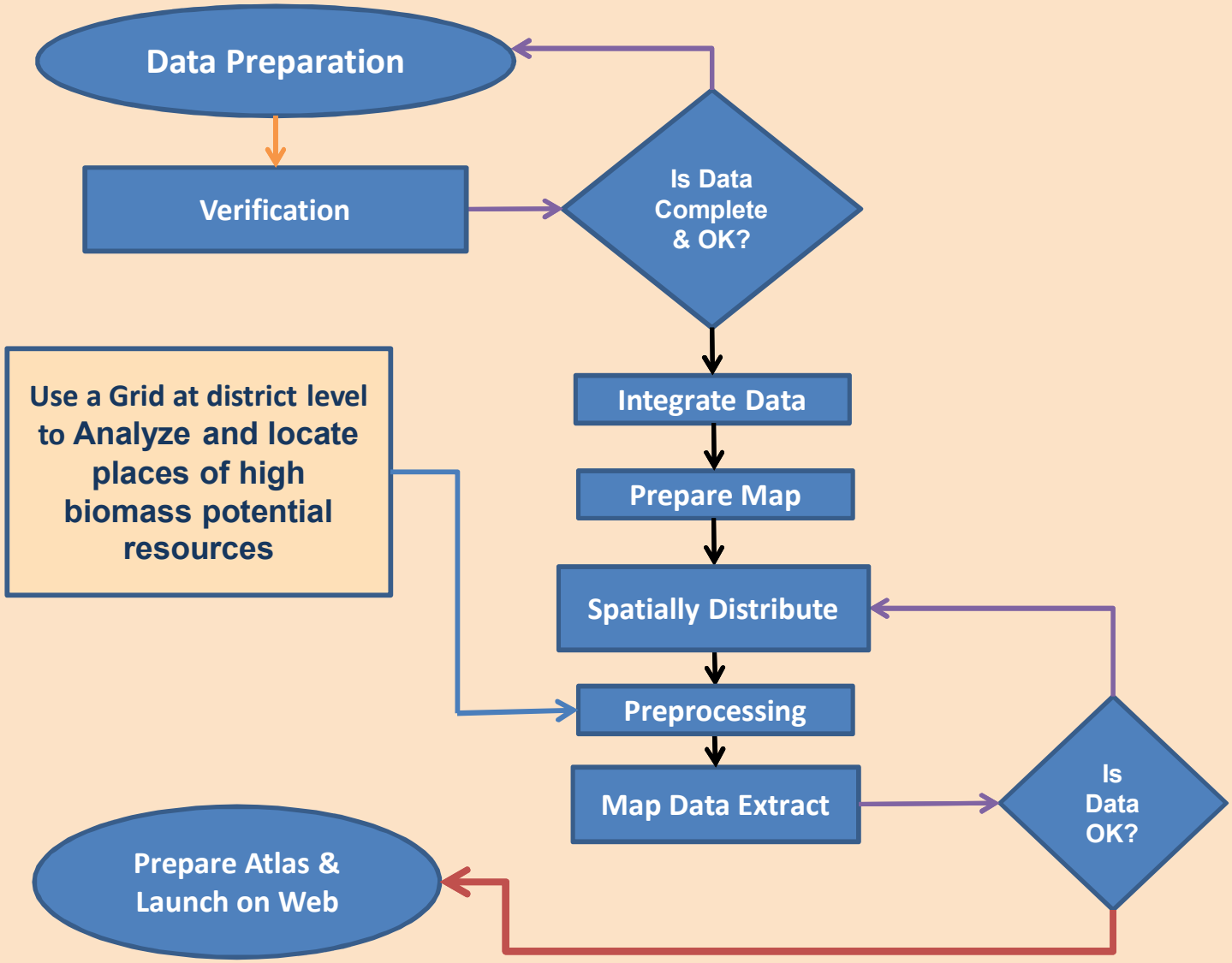
Reclassification of Agri-Land use (LU)

- Usage of the same LU Data for subsequent years (about 10), as long as the area under the agricultural activity in the selected zone remains roughly same – a feature generally true.
- Land use has been classified based on NDVI analysis of the earth surface temporally i.e. season-wise. Land use map for each state is available at Taluk level. It contains the agricultural land class polygons based on seasons- Kharif, Rabi, Kharif-Rabi.
- In the current method, polygons are classified into specific crops on the basis that same type of crop get into the same polygon due to 'Implied NDVI' for land use and Major crops go into larger polygons.
- AI is used to do the spatial distribution of Crops into Land use polygons using Major crops for larger polygons, Statistical Crop area and other apriori data such as season and type of land use. **What is AI?….**

AI [Artificial Intelligence] in the Crop Classification

- It makes use of If..... Then ..... Else.... Statements to decide the crop for the polygon depending on the crop area as given by Statistical data.
- Crops are distributed in the descending order of their crop area at the district level. The polygons are considered successively in the order of their area.
- As the major crop get distributed to Large polygons the chances of selecting large polygons further reduces.
- Land use agricultural polygons are generated based on similar Crop represented by a value of NDVI in the area and so it is implied.
- The larger polygons in an order are to major crops. Small polygons get classified into major crops depending on the terminal area required to meet the district level statistical crop area.

Process of Making Agro-Biomass Digital Atlas



Non-Spatial Statistical Data at District Level

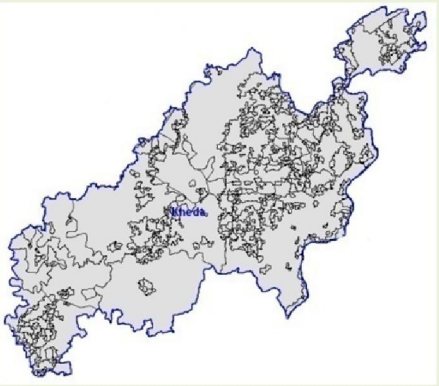
Agro-crop statistics is available at district level. Biomass generation from the crops are to be computed using Crop-Biomass parameter- CRR (Crop Residue Ratio=Residue Yield T/Ha / Crop Yield T/Ha). Following is the table showing Agro-Biomass statistics for the district of Kheda:

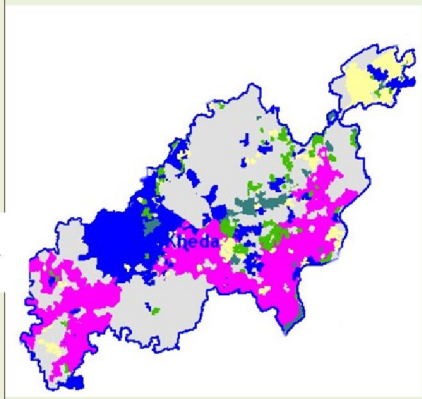
District level Agro-Residue-wise Data for Kheda of Gujarath;Annual						
Crop Name	Residue Name	Crop Area kHa	Crop Production kT/yr	Residue Generation kT/Yr	Excess Biomass kT/Yr	Power Projected Mwyre
Banana	Residue	3.3	204.2	612.6	61.3	8.0
Paddy	Straw	99.7	198.3	297.5	29.8	3.6
Paddy	Husk	99.7	198.3	39.7	31.7	3.5
Wheat	Pod	50.4	97.6	29.3	14.6	2.1
Bajra	Stalks	59.1	77.9	155.8	15.6	2.0
Wheat	Stalks	50.4	97.6	146.4	14.6	1.9
Maize	Stalks	24.5	68.3	136.7	13.7	1.8
Bajra	Cobs	59.1	77.9	25.7	12.9	1.7
Maize	Cobs	24.5	68.3	20.5	10.3	1.4
Tobacco	Stalks	40.5	74.5	74.5	7.4	1.0
Bajra	Husk	59.1	77.9	23.4	5.8	0.7
Arhar	Stalks	10.0	10.5	26.2	2.6	0.3
Til	Stalks	12.1	8.2	20.6	2.1	0.3
Arhar	Husk	10.0	10.5	3.1	1.6	0.2
Sugarcane	Tops & Leaves	0.4	29.4	1.5	0.4	0.1
Total		**300.0**	**768.9**	**1613.3**	**224.3**	**28.4**

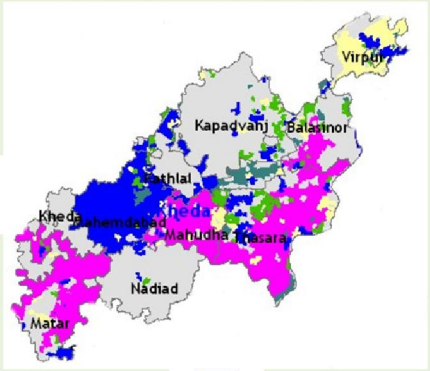
Classification of Agricultural Lands based on district level Crop Statistics

Crop	Area kHa
Paddy	99.7
Bajra	59.1
Maize	24.5
Til	12.1
Arhar	10.0
Total	205.4

District Crop Statistics







Taluk	Area (kha)	Power Potential (MWe)
Thasara	54.3	3.6
Matar	35.3	2.5
Virpur	17.8	2.1
Mahemdabad	37.4	1.7
Mahudha	22.7	1.7
Kathlal	16.5	0.9
Balasinor	9.5	0.7
Kapadvanj	5.1	0.2
Total	198.6	13.5

Taluk Biomass Power

How to Compute Biomass from Crop Spatial Area

- **Crop Yield** is the average Crop grown in T per Hectare based on measurements made on sample sets in a region.
- **Residue Generation kT=** $\mathbf{CropProduction * CRR}$

Where **Crop Production** is in kT= $\mathbf{Crop\ Spatial\ Area * CropYield}$

Crop Spatial Area is in kHa and

CRR (Crop Residue Ratio) = $\frac{\mathbf{ResidueYield}}{\mathbf{CropYield}}$ where Residue Yield is the average Residue generated per Hectare and Crop Yield is the average Crop grown per Hectare based on measurements made on the same sample sets in a region.

- **Residue Generation kT=** $\mathbf{ResidueYield * SpatialArea}$

Residue Generation is estimated for Biomass such as Coconut fronds, Cotton stalks, etc., by knowing the residue yield (T/Ha) and spatial area (kHa).

How to Compute Biomass from Crop Spatial Area (contd..)

- **Utilization** is kT of Biomass used for the purposes of Thatching, Fodder, and Domestic Fuel.
- **Biomass Surplus kT=** $\mathrm{ResidueGeneration} * (1 - \mathrm{UR})$

Where **UR=** $\dfrac{\mathrm{Utilization}}{\mathrm{ResidueGeneration}}$

- **Power Potential MWYre=** $\mathrm{FFP} * \mathrm{BiomassSurplus}$

Where FFP is in MWYre per kT

Factor for Power= $\dfrac{1}{\mathrm{kg\ perUnit\ Energy}} * 10^6 * \dfrac{1}{365 * 24 * 0.7 * 1000}$

- Where kg-per-Energy is found empirically which depends on moisture and ash content in the biomass.
- 0.7 is the 70% PLF (Plant Load Factor)

Extraction of Spatially Distributed Agro- Biomass Data for District Kheda in the state of Gujarath

District level Residue-wise Data for Kheda;Annual						
Crop	Residue	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Banana	Residue	3.3	204.7	614.0	61.4	8.0
Paddy	Straw	101.5	202.0	302.8	30.3	3.6
Paddy	Husk	101.5	202.0	40.4	32.3	3.6
Bajra	Stalks	59.4	78.5	152.6	15.3	2.0
Wheat	Pod	50.5	98.1	28.3	14.2	2.0
Wheat	Stalks	50.5	98.1	141.6	14.2	1.8
Maize	Stalks	24.7	68.9	134.2	13.4	1.7
Bajra	Cobs	59.4	78.5	25.2	12.6	1.6
Maize	Cobs	24.7	68.9	19.5	9.7	1.4
Tobacco	Stalks	40.6	74.7	73.6	7.4	0.96
Bajra	Husk	59.4	78.5	20.4	5.1	0.61
Arhar	Stalks	10.1	10.6	14.6	1.5	0.19
Til	Stalks	12.1	8.2	10.4	1.0	0.14
Arhar	Husk	10.1	10.6	1.8	0.88	0.11
Total		**302.3**	**745.6**	**1579.3**	**219.1**	**27.7**

Extraction of Spatially Distributed Agro-Data in the Taluk Thasara District Kheda of state Gujarath

Taluk level Residue-wise Data for Thasara;Annual						
Crop	Residue	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Wheat	Pod	39.4	76.4	22.9	11.4	1.6
Paddy	Straw	42.5	84.6	126.8	12.7	1.5
Paddy	Husk	42.5	84.6	16.9	13.5	1.5
Wheat	Stalks	39.4	76.4	114.4	11.4	1.5
Banana	Residue	0.49	30.6	91.7	9.2	1.2
Tobacco	Stalks	40.0	73.7	73.6	7.4	0.96
Maize	Stalks	2.2	6.0	12.0	1.2	0.16
Bajra	Stalks	4.5	5.9	11.8	1.2	0.15
Bajra	Cobs	4.5	5.9	2.0	0.98	0.13
Maize	Cobs	2.2	6.0	1.8	0.90	0.13
Til	Stalks	3.7	2.5	6.3	0.63	0.082
Bajra	Husk	4.5	5.9	1.8	0.44	0.053
Total		**132.8**	**279.7**	**482.1**	**71.0**	**8.9**

Agro-Biomass Surplus, state-wise

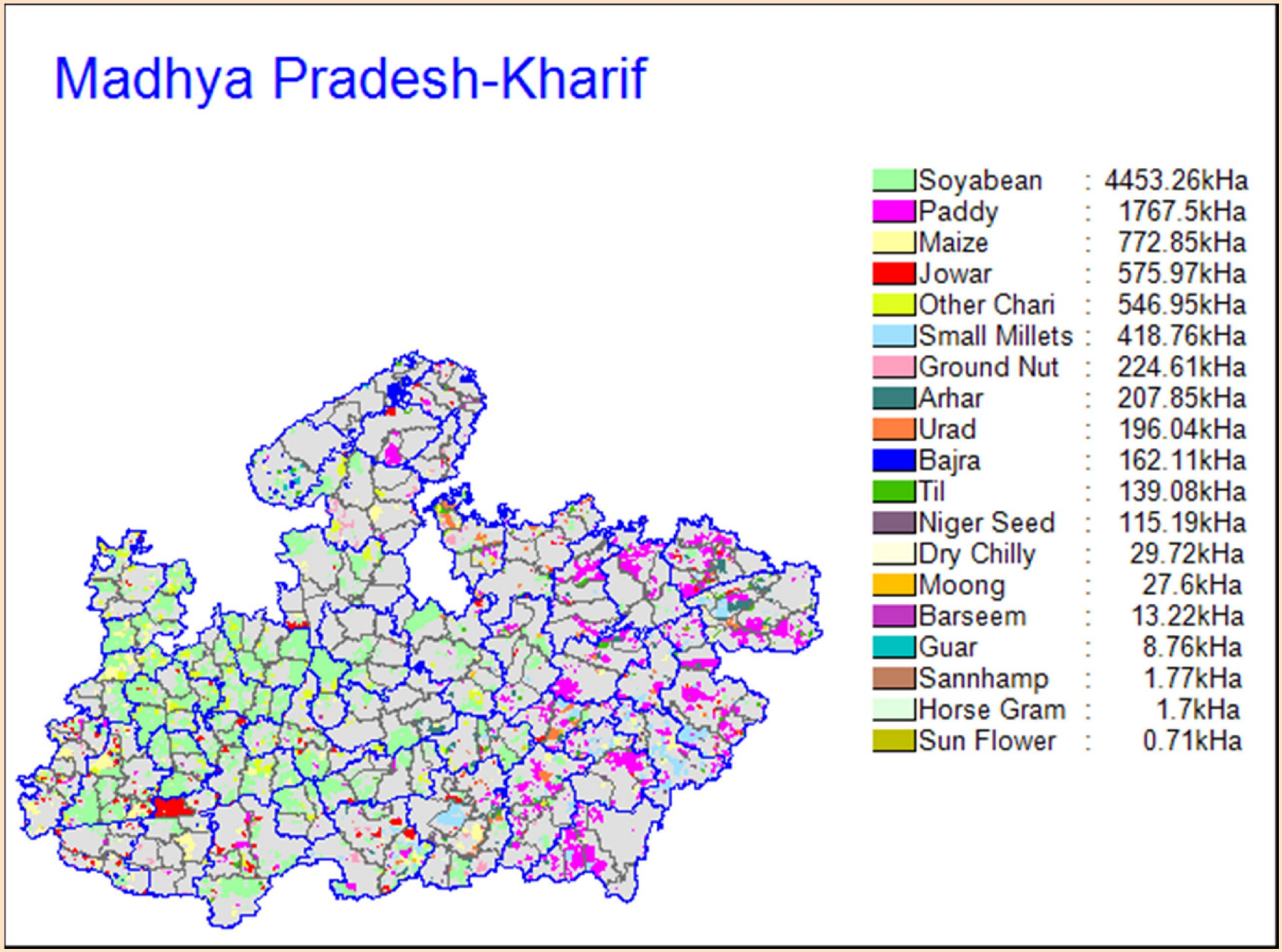
State-wise Biomass Data - Year : Based on Survey Data [2002-04] ; Annual					
State	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation kT/Yr	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Andhra pradesh	6021.5	28345.7	21569.8	3947.7	481.3
Assam	2586.6	5945.4	6625.1	1361.7	163.1
Bihar	5833.1	13817.8	20441.8	4286.2	530.3
Chattisgarh	3815.5	6142.8	10123.7	1907.8	220.9
Goa	156.3	554.7	928.5	180.5	22.7
Gujarat	6519.0	20635.5	25471.3	8352.7	1131.1
Haryana	4890.2	13520.0	26581.1	10105.9	1303.5
Himachal pradesh	710.3	1329.2	2668.2	988.3	128.0
Jammu & kashmir	368.7	648.7	1198.7	237.7	31.8
Jharkhand	1299.8	1509.0	2191.2	567.7	66.8
Karnataka	7356.0	38754.1	26949.3	7814.2	1041.3
Kerala	2058.4	9773.3	13072.6	7528.7	1017.9
Madhya pradesh	9937.0	14166.9	28348.7	9283.6	1240.2
Maharashtra	15542.3	51665.4	39348.6	12998.5	1751.1
Manipur	72.6	159.4	318.8	31.9	4.1
Meghalaya	0.8	14.0	42.0	8.4	1.1
Nagaland	27.1	87.6	149.2	27.2	3.1
Orissa	2436.6	3633.3	5350.4	1163.4	147.3
Punjab	6774.3	31698.9	50187.9	24637.5	3145.4
Rajasthan	10478.5	12762.9	25234.4	7419.9	975.0
Tamil nadu	2561.5	24688.4	17459.2	7400.8	967.2
Uttar pradesh	12672.5	46841.9	50622.1	11869.8	1496.6
Uttaranchal	66.4	135.8	159.9	51.6	6.6
West bengal	5575.6	21062.8	23332.7	2968.0	369.5
Total	**107760.7**	**347893.5**	**398375.4**	**125139.4**	**16245.7**

Agro-Biomass Surplus, Major Residues [Power potential > 500MWe-yr]

Nation Wide Residue-wise Data; Annual [>=500MWyre]						
Crop	Residue	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Paddy	Straw	40879.7	89566.6	115921.6	26904.9	3227.2
Cotton	Stalks	8038.8	5743.5	29986.7	16418.4	2298.6
Wheat	Stalks	21913.2	60946.4	90417.4	15861.4	2062.1
Wheat	Pod	21913.2	60946.4	18048.3	8084.6	1131.8
Paddy	Husk	40879.7	89566.6	15466.1	10264.2	1129.1
Cotton	Bollshell	8038.8	5743.5	6068.1	4347.0	608.6
Cotton	Husk	8038.8	5743.5	6068.1	4347.0	608.6
Maize	Stalks	6231.5	11550.8	21113.9	4182.2	543.7
Banana	Residue	106.6	3978.9	11885.9	4167.9	541.8
Coconut	Fronds	1813.4	5973.5	7219.9	3603.6	504.5
Total		**78983.2**	**177759.6**	**322195.9**	**98181.2**	**12655.9**

Following slides shows the Agro residue map and Demography maps for Madhya Pradesh.

Spatial view of Agricultural Residues in Madhya Pradesh



CGPL Site

Demography view of Madhya Pradesh

Agro-Biomass Surplus, Minor Residues [Power potential 100 to 500MWyre]

Nation Wide Residue-wise Data; Annual						
Crop	Residue	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Soyabean	Stalks	6046.3	5820.6	9863.1	3257.1	423.4
Mustard	Stalks	3935.0	3902.0	6591.2	2986.4	388.2
Tapioca	Stalks	205.8	5498.9	3398.2	2377.4	309.1
Maize	Cobs	6231.5	11550.8	4824.9	1835.4	257.0
Bajra	Stalks	8312.0	5976.8	11649.1	1864.7	242.4
Jowar	Stalks	9267.4	9986.0	14191.8	1738.2	226.0
Ground Nut	Stalks	6524.0	6503.8	11391.5	1708.9	222.2
Sugarcane	Tops & Leaves	2669.2	174238.1	8301.6	1517.6	212.5
Jowar	Cobs	9267.4	9986.0	3977.9	1507.1	211.0
Coconut	Husk & Pith	1813.4	5973.5	3113.4	1556.7	202.4
Black Pepper	Stalks	203.8	4673.2	2336.0	1401.6	182.2
Rubber	Primary Wood	498.5	0	1495.1	1196.1	167.4
Coffee	Pruning & Wastes	350.0	266.3	1383.7	1106.9	155.0
Coconut	Shell	1813.4	5973.5	1274.6	902.5	126.3
Ground Nut	Shell	6524.0	6503.8	1611.2	1027.8	123.3
Gram	Stalks	5928.4	4667.6	4641.8	921.0	119.7
Bajra	Cobs	8312.0	5976.8	1865.3	884.0	114.9
Total		**51985.2**	**239057.5**	**91910.4**	**27789.3**	**3683.0**

Agro-Biomass Surplus Minor Residues [Power potential 10 to 100MWyre]

Nation Wide Residue-wise Data; Annual						
Crop	Residue	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Arhar	Stalks	2777.5	2070.6	4418.5	768.3	99.9
Castor Seed	Stalks	526.0	413.4	1622.8	730.2	94.9
Jowar	Husk	9267.4	9986.0	1620.4	770.5	92.5
Rubber	Secondary Wood	498.5	0	995.2	597.1	83.6
Til	Stalks	1225.3	1024.6	1891.2	642.7	83.6
Tea	Sticks	573.6	1066.5	909.5	582.1	81.5
Safflower	Stalks	295.4	160.0	470.6	376.5	48.9
Bajra	Husk	8312.0	5976.8	1565.1	372.5	44.7
Arecanut	Fronds	262.8	265.4	769.3	269.3	37.7
Arhar	Husk	2777.5	2070.6	464.5	232.3	27.9
Moong	Stalks	1300.8	2408.4	2043.8	204.4	26.6
Casurina	Wood	21.2	0	208.9	177.6	24.9
Ragi	Straw	1453.9	2070.6	2329.4	197.6	23.7
Guar	Stalks	266.3	116.0	231.2	161.8	22.7
Potato	Leaves	119.6	1095.3	792.4	158.1	22.1
Urad	Stalks	1458.0	1876.6	1471.1	154.4	20.1
Meshta	Stalks	479.2	809.4	1483.7	148.4	19.3
Eucalyptus	Residue	16.3	3.1	160.7	136.6	19.1
Sun Flower	Stalks	1331.0	697.5	870.3	125.0	16.2
Moong	Husk	1300.8	2408.4	261.2	130.6	15.7
Urad	Husk	1458.0	1876.6	252.8	126.1	15.1
Pulses	Stalks	1874.8	1069.2	1142.5	114.3	14.9
Oilseeds	Stalks	341.9	458.8	882.4	95.6	11.5
Horse Gram	Stalks	418.0	764.5	789.4	79.0	10.3
Total		**32819.3**	**32332.6**	**27646.9**	**7350.7**	**957.2**

The Strategy Adopted for Forest & Waste land Biomass

- The spatial assessment of agro-biomass-power completed earlier is taken as the stage for further processing. Agro-biomass-power is estimated to be more than 16,000 MW of energy per year across the Country.
- The residues available from forest & wasteland are added on these data layers. CRR [Crop Residue Ratio] is not applicable in the case of forest and wasteland residues.
- Waste-Land is presently not well cultured with any biomass growing plants. Based on the species mix available in forest area a first level estimate is predicted.
- In this case, the biomass estimate is done using the yield of the residue.

Importance of Existing Utilization of Biomass from Forest & Waste land

- Given the inefficiency of administration and the 'soft' character of the political system, one could generalize that from a typical tree, **the stem goes to the rich and the towns, while the branches and twigs belong to the poor.**

- Human needs for biomass are, however, not restricted to the consumption and use of woody biomass.

- The maintenance of life support systems is a function performed mainly by the crown biomass of trees. It is this component of trees that can contribute positively towards the maintenance of the hydrological and nutrient cycles.

Importance of Existing Utilization (Contd…)

- Social forestry is also the most important source for the production of biomass for consumption as fuel, fodder, manure, fruits, etc.

- Social forestry as distinct from commercial forestry is supposed to be corrective aimed at the maximization of the production of all types of useful biomass which improve ecological stability.

- The appropriate unit of assessment of growth and yields of different tree species for social forestry programmes cannot be restricted to woody biomass production for commercial use. It must, instead, be specific to the end use of biomass.

Importance of Existing Utilization (contd...)

- Evidently, the crisis in biomass for mulching or animal feed cannot be resolved by planting trees that are fast growing and are absolutely unproductive as fodder.
- The assessment of yields in social forestry must include diverse types of biomass which provide inputs to agro ecosystems. When the objective of tree planting is the production of fodder or green fertilizer, it is relevant to measure **crown biomass** productivity.
- Keeping these factors in mind Wasteland has to be developed with Plantations suitable for energy.
- For the present, species available in Forest area are considered to be extended to Waste land area for the purpose of Biomass assessment for Energy.

Observations on Forest & Wasteland Biomass

- It is reported by FSI that the plantation density varies depending on the type of forest. FSI has published forest area based on the plantation density (next slide).
- The plants / trees species pattern grown in the forests are heterogeneous unlike agricultural crops. FSI has given % mix of these species in each state & nation wide (slide follows).
- Some of these species are leafy, some others generate more of twigs, some of them generate twigs-leaf-bark. Generation of bark also depends on the stem size.
- Though we do not get direct relations between these factors, there are some estimations available through internet sources and FSI regarding residue yields (slide follows).

Forest Plantation Density

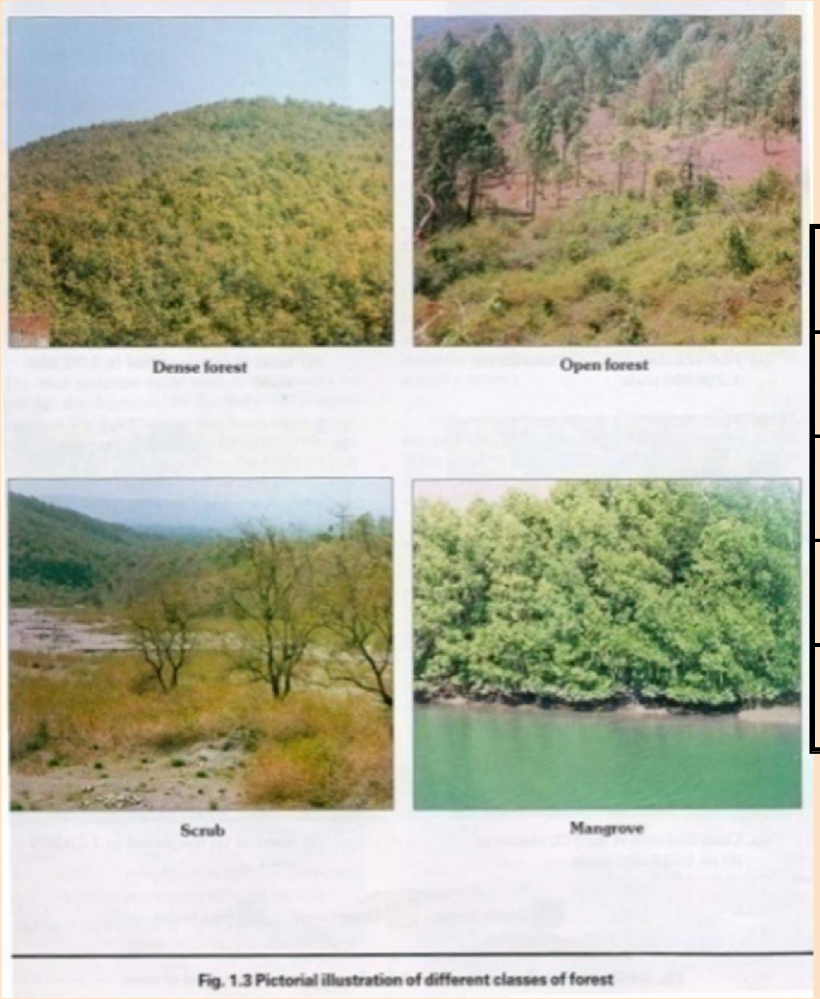


Fig. 1.3 Pictorial illustration of different classes of forest

Density Classification & Percentage Concentration [FSI]

Dense Forest	All lands with tree cover of canopy density of 40 percent and above.
Open Forest	All lands with tree cover of canopy density between 10 to 40 percent.
Mangrove	Salt tolerant forest ecosystem found mainly in tropical and sub-tropical inter-tidal regions.
Scrub	All lands with poor tree growth mainly of small or stunted trees having canopy density less than 10
Non-Forest	Any area not included in the above classes

National Species for Forest & Wasteland (FSI)

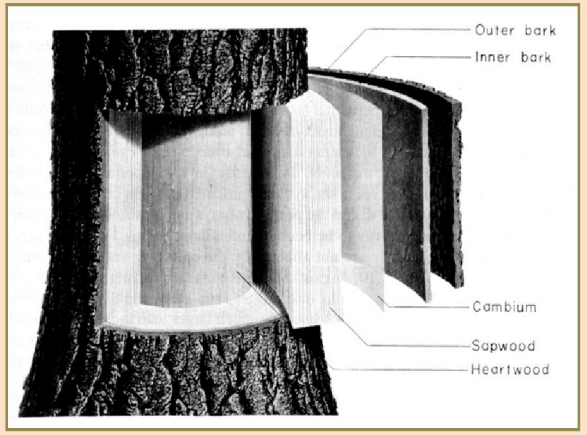
Species wise plantation upto 1997 by the state forest departments		
SPECIES	**Area in '000 ha.**	**Percentage**
Eucalyptus spp.	1,360.91	8.87
Tectona grandis	1,330.09	8.67
Acacia nilotica	801.61	5.23
Acacia auriculiformis	564.67	3.68
Bamboo	408.09	2.66
Pinus roxburghii	318.54	2.08
Dalbergia sissoo	266.58	1.74
Acacia catechu	259.54	1.69
Shorea robusta	250.28	1.63
Gmelina arborea	148.01	0.97
Anacardium occidentale	141.54	0.92
Casurina equisetifolia	133.99	0.87
Pinus kesiya	127.12	0.83
Cedrus deodara	124.93	0.81
Populus spp.	47.48	0.31
Bombax ceiba	37.97	0.25
Acacia mearnsii	37.56	0.24
Picea smithiana, Abies pindrow	16.74	0.11
Hevea brasiliensis	12.3	0.08
Santalam album	10.58	0.07
Others	8,938.10	58.28
Total	15,336.60	100

A sample of yields in terms of different residues

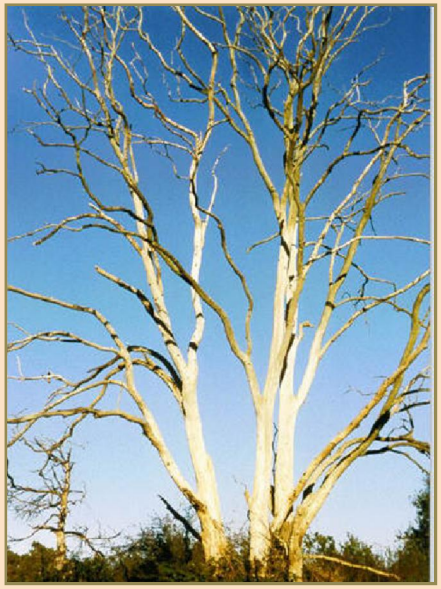
Coniferous & Deciduous	
Residue	**%**
Stem	65
Bark	3
Twigs	3
Branches	3
Leaves	3.5
Roots	17
Uncertain	5.5

Species	**Percentage in total Biomass (%)**		**Total Biomass**
	Stem wood and bark	**Branches and twigs**	**(Tons/ha)**
Eucalyptus	81	19	17.4
Subabul	77	23	23.0
Acacia Nilotica	47	53	31.6
Prosopis Juliflora	30	70	32.2

Twigs



Bark



Branches

Leaves – Crown Biomass

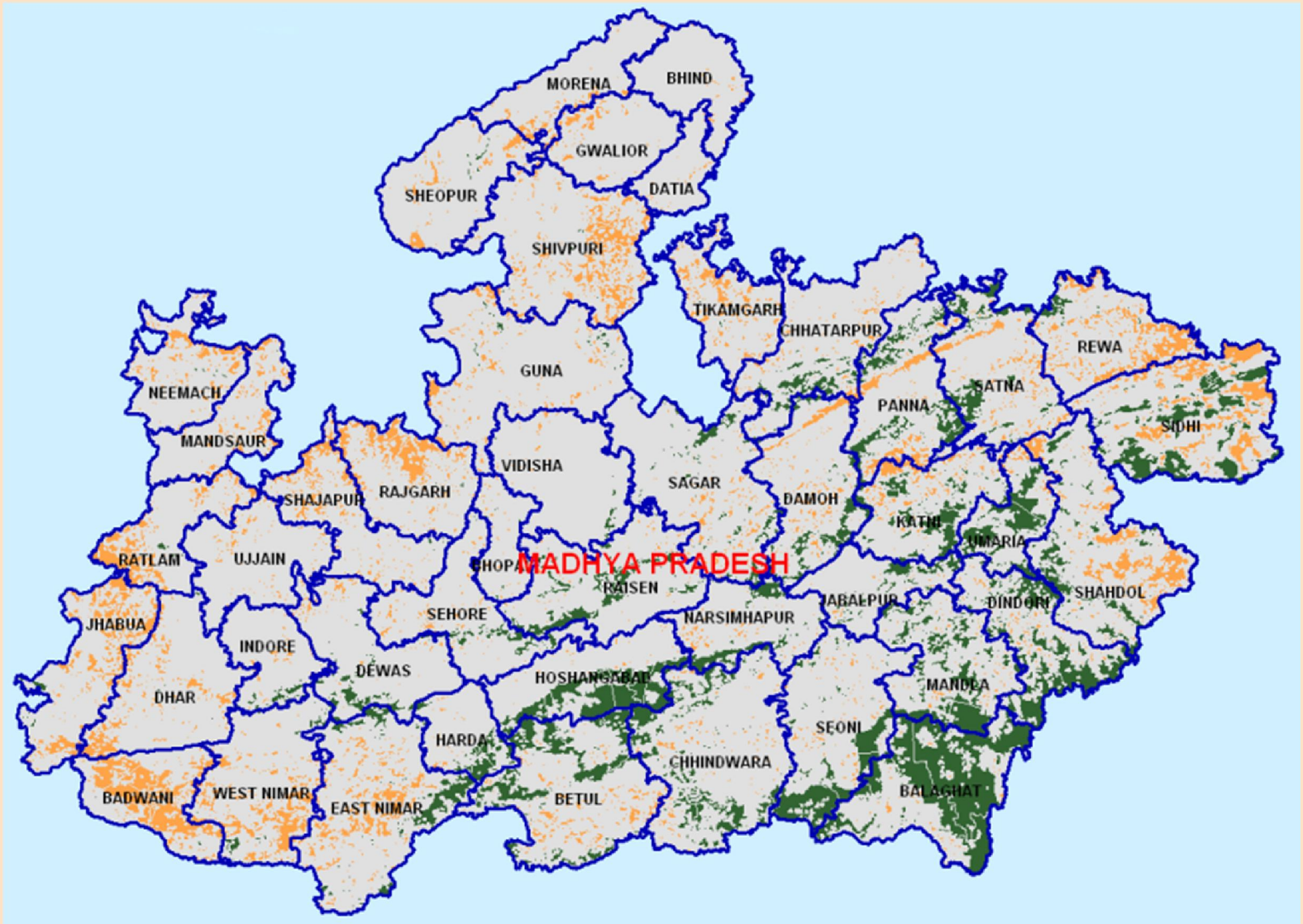
Method Adopted for the Assessment

- Initially the biomass in forest was assessed without considering the plantation density for a quick analysis to enable the process development.
- Later based on the observations the map was reclassified into sub-classes for low density & high density areas using available ground reference points.
- This involved additional image processing and spatial classifications. The assessment was reworked with this new classifications.
- It is found that there has been a considerable reduction in the errors in the estimation of biomass surplus with this approach.

Method Adopted for the Assessment (Contd…)

- The species spread is heterogeneous and their percentage mix being known for each state, they are distributed to the Forest and waste land area in the maps of the 8 states.
- The distributed data is extracted from map into a data base with the spatial area, plantation density and polygon references.
- The biomass assessment is made similar to Agro-Biomass assessment as shown in the following slide.

Madhya Pradesh Spatial Forest and Wasteland



Biomass Computation from Forest & Waste land Spatial Area

- **Residue Generation kT=** $\mathrm{ResidueYield} * \mathrm{SpatialArea} * \mathrm{Plantation\ Density}$

Residue Yield in T/Ha, Spatial Area in kHa, Plantation density a ratio

- **Biomass Surplus kT=** $\mathrm{ResidueGeneration} * (1 - \mathrm{UR})$

Where **UR=** $\dfrac{\mathrm{Utilization}}{\mathrm{ResidueGeneration}}$

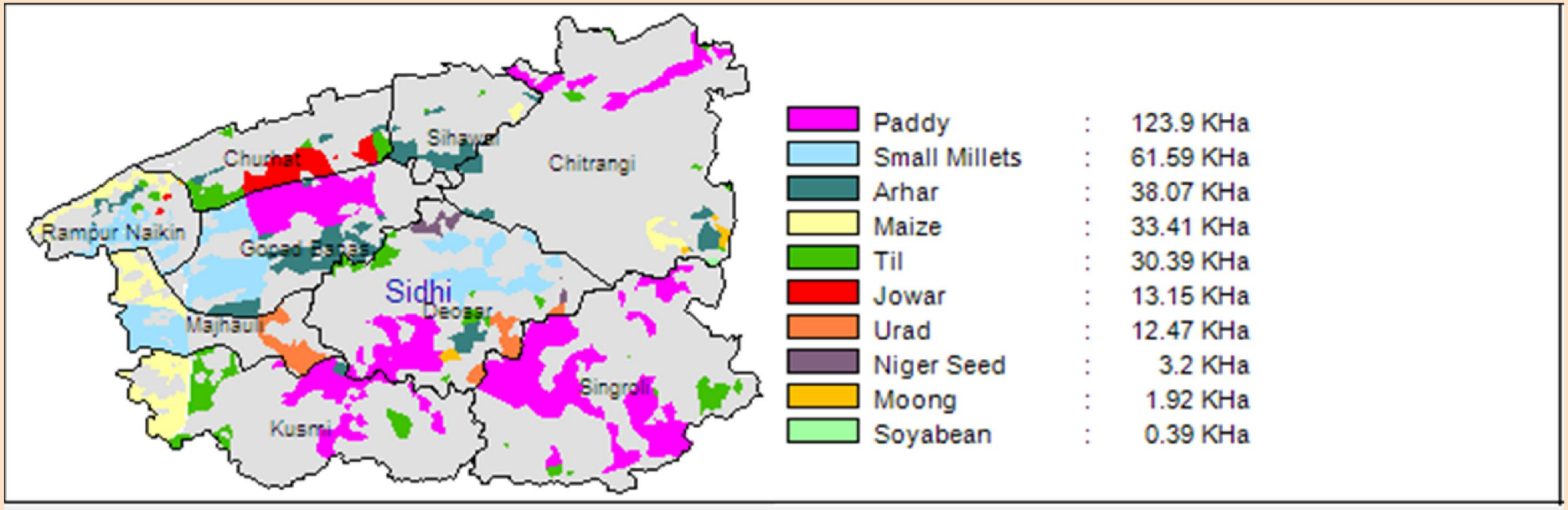
Residue generation in kT, Utilization in kT and UR a ratio

- The Power potential is computed similar to Agro-power knowing the factor for power (FFP) for each type of residue.
- This is then aggregated at Taluk level, District level and state levels.

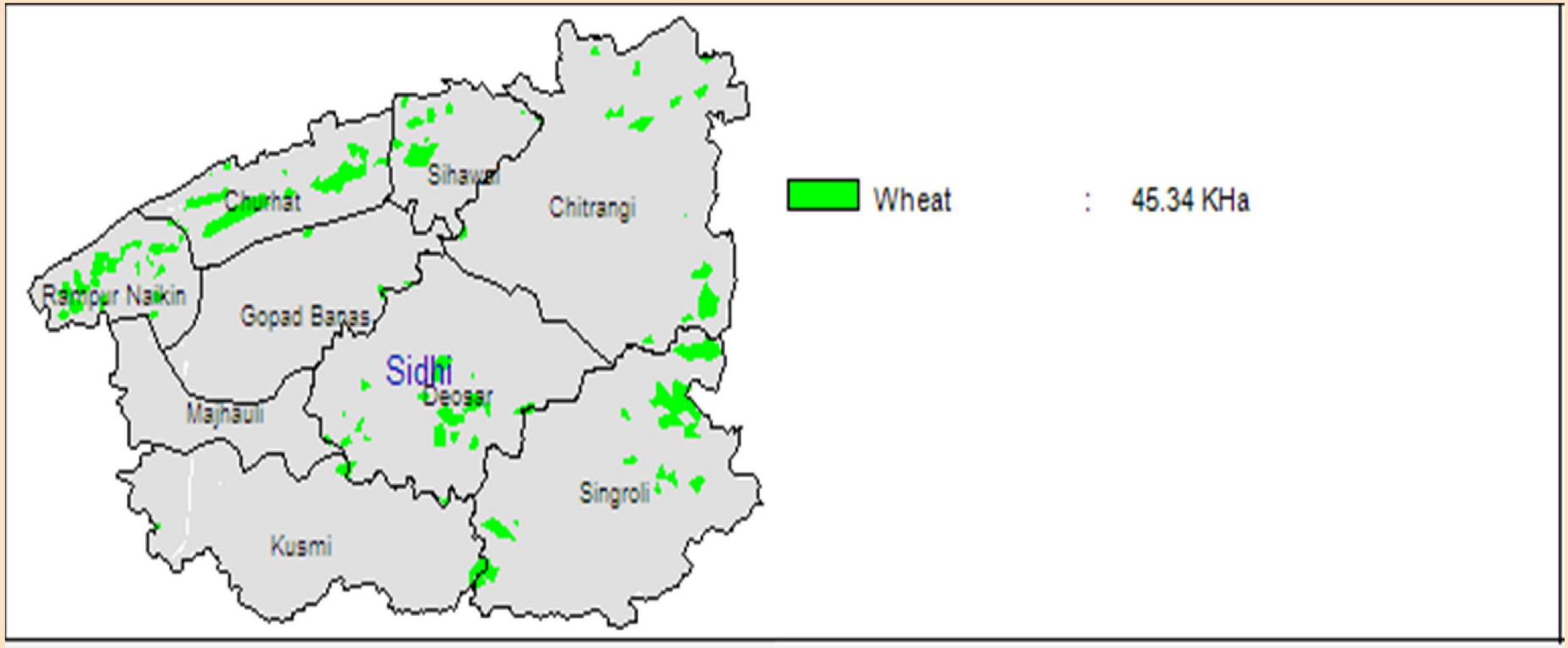
Biomass Computation for Agro, Forest & Waste land

- The Biomass surplus assessed separately for agro, forest and waste land are integrated into a database.
- The database is further queried to provide aggregated biomass data with power potential for any combination such as- (Agro & Forest), (Agro & Wasteland), (Agro & Forest & Wasteland), etc.
- The biomass data generated is further used to generate image maps for each state indicating the biomass production index over the respective spatial region of the state (Slides follow).

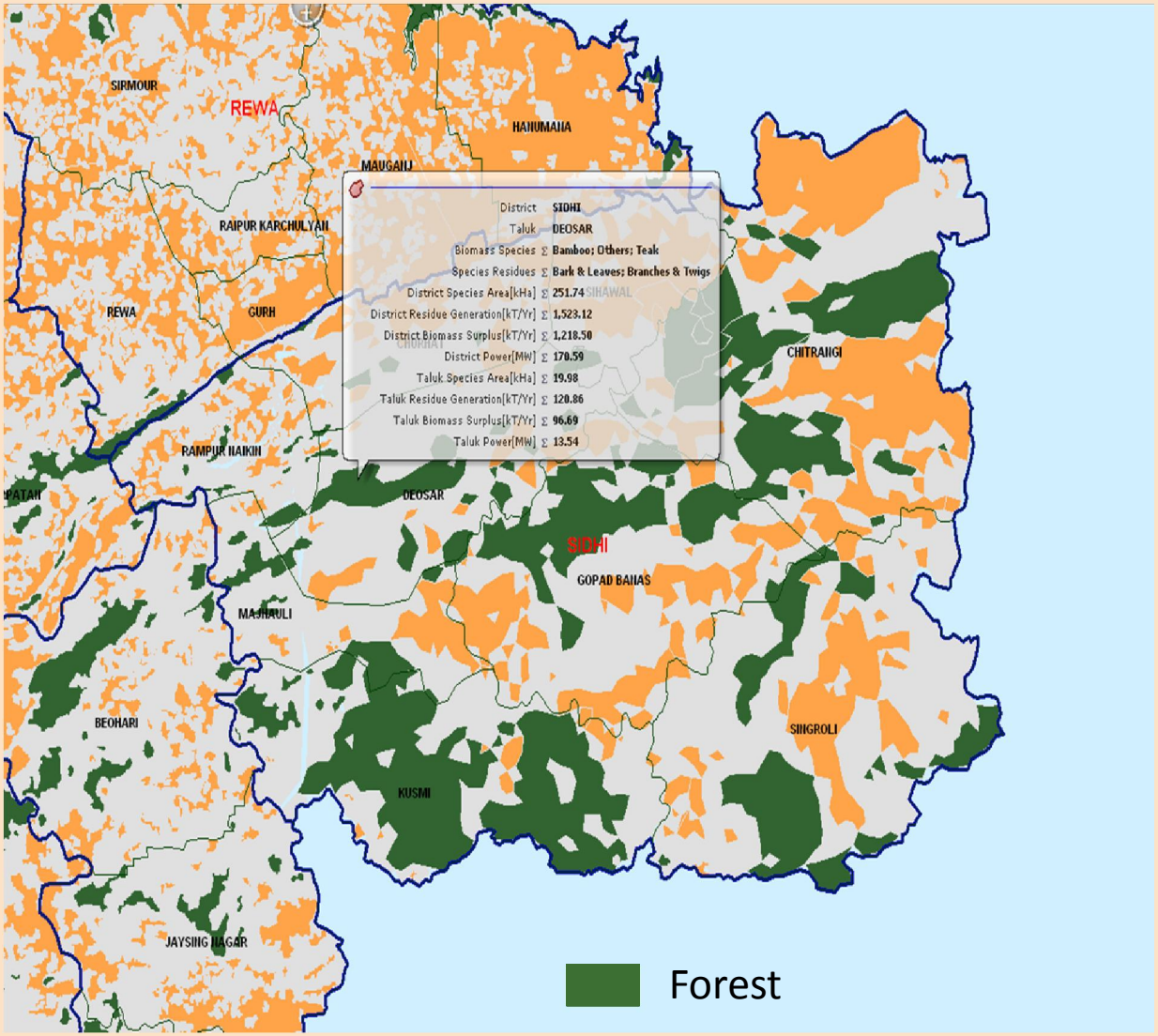
Sidhi of Madhya Pradesh Spatial Agro Kharif



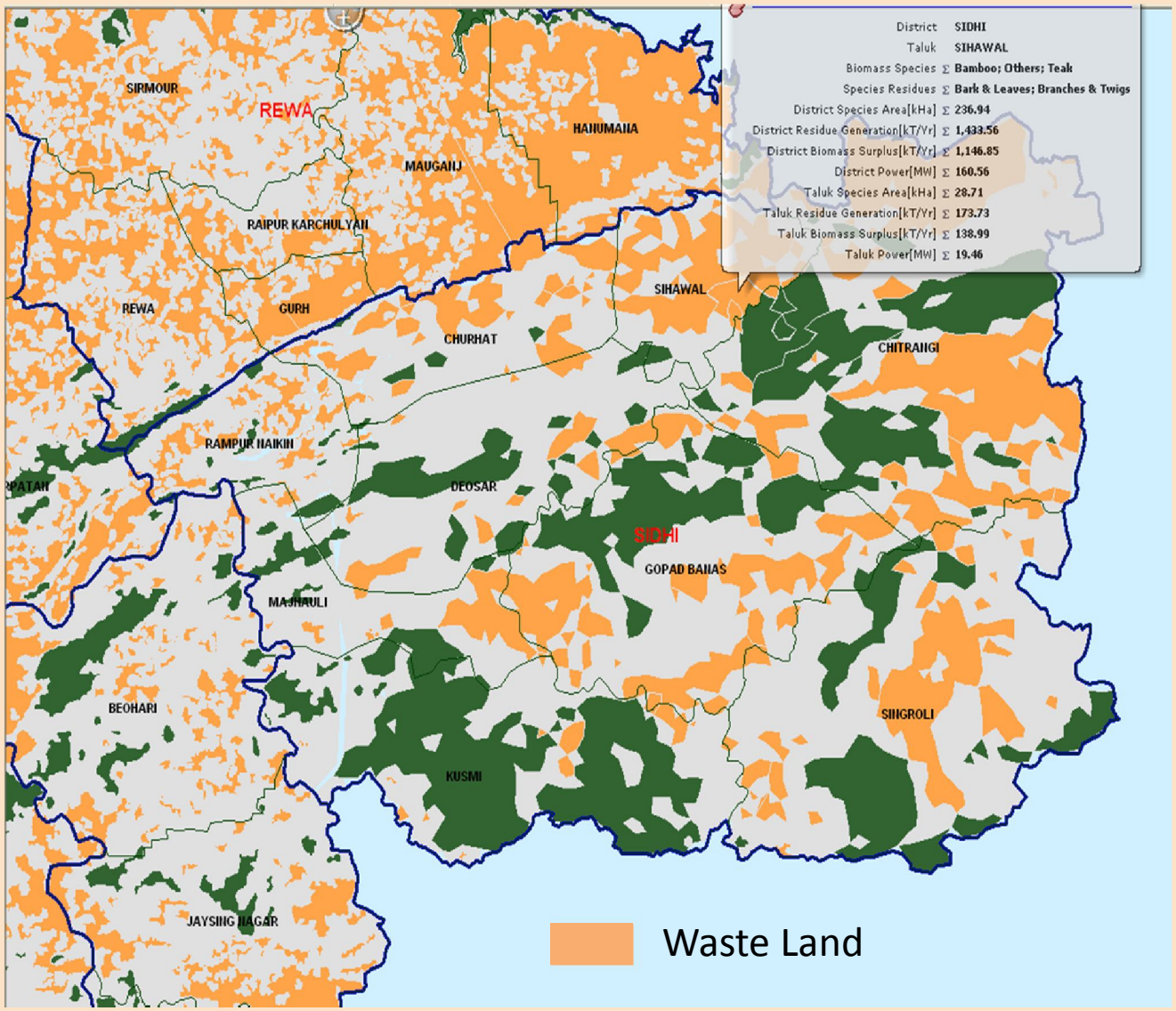
Sidhi of Madhya Pradesh Spatial Agro Rabi



Sidhi of Madhya Pradesh Spatial Forest



Sidhi of Madhya Pradesh Spatial Wasteland



Sidhi of Madhya Pradesh Agro Biomass

ResidueWise Data - State : Madhya Pradesh ; District : Sidhi ; Year : 2001-02 ; Biomass Class : Agro

Crop	Residue	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Arhar	Stalks	38.1	19	47.2	28.3	3.68
Paddy	Straw	123.9	138.8	207.6	20.8	2.49
Paddy	Husk	123.9	138.8	27.7	22.1	2.44
Wheat	Stalks	45.3	37.2	54.4	10.9	1.42
Maize	Stalks	33.4	45.4	88.6	8.9	1.15
Wheat	Pod	45.3	37.2	10.5	5.3	0.74
Small millets	Stalks	61.6	24.6	29.5	2.95	0.38
Jowar	Stalks	13.2	8.7	14.1	2.82	0.37
Maize	Cobs	33.4	45.4	19.7	1.97	0.28
Arhar	Husk	38.1	19	4.58	2.29	0.27
Jowar	Cobs	13.2	8.7	4.14	0.83	0.12
Total		**315.5**	**273.8**	**508.1**	**107.1**	**13.3**

Sidhi of Madhya Pradesh Agro & Forest Biomass

ResidueWise Data - State : Madhya Pradesh ; District : Sidhi ; Year : 2001-02 ; Biomass Class : Agro & Forest

Species	Biomass	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)	Biomass Class
Arhar	Husk	38.1	19	4.58	2.29	0.27	Agro
Arhar	Stalks	38.1	19	47.2	28.3	3.68	Agro
Bamboo	Leaves	33.6	NA	0.012	0.008	0.001	Forest
Bamboo	Leaves	85.8	NA	0.079	0.053	0.007	Forest
Bamboo	Leaves	132.3	NA	0.34	0.23	0.032	Forest
Bamboo	Stalk	33.6	NA	0.32	0.21	0.03	Forest
Bamboo	Stalk	85.8	NA	2.04	1.36	0.19	Forest
Bamboo	Stalk	132.3	NA	8.8	5.9	0.82	Forest
Jowar	Cobs	13.2	8.7	4.14	0.83	0.12	Agro
Jowar	Stalks	13.2	8.7	14.1	2.82	0.37	Agro
Maize	Cobs	33.4	45.4	19.7	1.97	0.28	Agro
Maize	Stalks	33.4	45.4	88.6	8.9	1.15	Agro
Others	Bark	33.6	NA	1.92	1.28	0.18	Forest
Others	Bark	85.8	NA	12.3	8.2	1.14	Forest
Others	Bark	132.3	NA	52.9	35.3	4.94	Forest
Others	Branches	33.6	NA	1.92	1.28	0.18	Forest
Others	Branches	85.8	NA	12.3	8.2	1.14	Forest
Others	Branches	132.3	NA	52.9	35.3	4.94	Forest
Others	Leaves	33.6	NA	2.24	1.49	0.21	Forest
Others	Leaves	85.8	NA	14.3	9.5	1.33	Forest
Others	Leaves	132.3	NA	61.7	41.1	5.8	Forest
Others	Twigs	33.6	NA	1.92	1.28	0.18	Forest
Others	Twigs	85.8	NA	12.3	8.2	1.14	Forest
Others	Twigs	132.3	NA	52.9	35.3	4.94	Forest
Paddy	Husk	123.9	138.8	27.7	22.1	2.44	Agro
Paddy	Straw	123.9	138.8	207.6	20.8	2.49	Agro
Small millets	Stalks	61.6	24.6	29.5	2.95	0.38	Agro
Teak	Bark	33.6	NA	0.28	0.19	0.026	Forest
Teak	Bark	85.8	NA	1.77	1.18	0.17	Forest
Teak	Bark	132.3	NA	7.7	5.1	0.71	Forest
Teak	Branches	33.6	NA	0.28	0.19	0.026	Forest
Teak	Branches	85.8	NA	1.77	1.18	0.17	Forest
Teak	Branches	132.3	NA	7.7	5.1	0.71	Forest
Teak	Leaves	33.6	NA	0.32	0.22	0.03	Forest
Teak	Leaves	85.8	NA	2.07	1.38	0.19	Forest
Teak	Leaves	132.3	NA	8.9	6	0.83	Forest
Teak	Twigs	33.6	NA	0.28	0.19	0.026	Forest
Teak	Twigs	85.8	NA	1.77	1.18	0.17	Forest
Teak	Twigs	132.3	NA	7.7	5.1	0.71	Forest
Wheat	Pod	45.3	37.2	10.5	5.3	0.74	Agro
Wheat	Stalks	45.3	37.2	54.4	10.9	1.42	Agro
Total	**821.1**	**522.9**	**839.5**	**328.1**	**44.3**		
Agro-Total	**315.5**	**273.8**	**508.1**	**107.1**	**13.3**		
Forest-Total	**251.7**	**NA**	**331.4**	**221**	**30.9**		

Sidhi of Madhya Pradesh Agro & Wasteland Biomass

ResidueWise Data - State : Madhya Pradesh ; District : Sidhi ; Year : 2001-02 ; Biomass Class : Agro & Wasteland							
Species	Biomass	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)	Biomass Class
Arhar	Husk	38.1	19	4.58	2.29	0.27	Agro
Arhar	Stalks	38.1	19	47.2	28.3	3.68	Agro
Bamboo	Leaves	257.9	NA	0.48	0.32	0.045	Wasteland
Bamboo	Stalk	257.9	NA	12.3	8.2	1.14	Wasteland
Jowar	Cobs	13.2	8.7	4.14	0.83	0.12	Agro
Jowar	Stalks	13.2	8.7	14.1	2.82	0.37	Agro
Maize	Cobs	33.4	45.4	19.7	1.97	0.28	Agro
Maize	Stalks	33.4	45.4	88.6	8.9	1.15	Agro
Others	Bark	257.9	NA	73.6	49.1	6.9	Wasteland
Others	Branches	257.9	NA	73.6	49.1	6.9	Wasteland
Others	Leaves	257.9	NA	85.9	57.3	8	Wasteland
Others	Twigs	257.9	NA	73.6	49.1	6.9	Wasteland
Paddy	Husk	123.9	138.8	27.7	22.1	2.44	Agro
Paddy	Straw	123.9	138.8	207.6	20.8	2.49	Agro
Small millets	Stalks	61.6	24.6	29.5	2.95	0.38	Agro
Teak	Bark	257.9	NA	10.7	7.1	0.99	Wasteland
Teak	Branches	257.9	NA	10.7	7.1	0.99	Wasteland
Teak	Leaves	257.9	NA	12.4	8.3	1.16	Wasteland
Teak	Twigs	257.9	NA	10.7	7.1	0.99	Wasteland
Wheat	Pod	45.3	37.2	10.5	5.3	0.74	Agro
Wheat	Stalks	45.3	37.2	54.4	10.9	1.42	Agro
Total		**827.3**	**522.9**	**872**	**349.8**	**47.3**	
Agro-Total		**315.5**	**273.8**	**508.1**	**107.1**	**13.3**	
Wasteland-Total		**257.9**	**NA**	**363.9**	**242.7**	**34**	

Sidhi of Madhya Pradesh Agro, Forest & Wasteland Biomass

ResidueWise Data - State : Madhya Pradesh ; District : Sidhi ; Year : 2001-02 ; for All Biomass Class							
Species	Biomass	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)	Biomass Class
Arhar	Husk	38.1	19	4.58	2.29	0.27	Agro
Arhar	Stalks	38.1	19	47.2	28.3	3.68	Agro
Bamboo	Leaves	33.6	NA	0.012	0.008	0.001	Forest & wasteland
Bamboo	Leaves	85.8	NA	0.079	0.053	0.007	Forest & wasteland
Bamboo	Leaves	132.3	NA	0.34	0.23	0.032	Forest & wasteland
Bamboo	Leaves	257.9	NA	0.48	0.32	0.045	Forest & wasteland
Bamboo	Stalk	33.6	NA	0.32	0.21	0.03	Forest & wasteland
Bamboo	Stalk	85.8	NA	2.04	1.36	0.19	Forest & wasteland
Bamboo	Stalk	132.3	NA	8.8	5.9	0.82	Forest & wasteland
Bamboo	Stalk	257.9	NA	12.3	8.2	1.14	Forest & wasteland
Jowar	Cobs	13.2	8.7	4.14	0.83	0.12	Agro
Jowar	Stalks	13.2	8.7	14.1	2.82	0.37	Agro
Maize	Cobs	33.4	45.4	19.7	1.97	0.28	Agro
Maize	Stalks	33.4	45.4	88.6	8.9	1.15	Agro
Others	Bark	33.6	NA	1.92	1.28	0.18	Forest & wasteland
Others	Bark	85.8	NA	12.3	8.2	1.14	Forest & wasteland
Others	Bark	132.3	NA	52.9	35.3	4.94	Forest & wasteland
Others	Bark	257.9	NA	73.6	49.1	6.9	Forest & wasteland
Others	Branches	33.6	NA	1.92	1.28	0.18	Forest & wasteland
Others	Branches	85.8	NA	12.3	8.2	1.14	Forest & wasteland
Others	Branches	132.3	NA	52.9	35.3	4.94	Forest & wasteland
Others	Branches	257.9	NA	73.6	49.1	6.9	Forest & wasteland
Others	Leaves	33.6	NA	2.24	1.49	0.21	Forest & wasteland
Others	Leaves	85.8	NA	14.3	9.5	1.33	Forest & wasteland
Others	Leaves	132.3	NA	61.7	41.1	5.8	Forest & wasteland
Others	Leaves	257.9	NA	85.9	57.3	8	Forest & wasteland
Others	Twigs	33.6	NA	1.92	1.28	0.18	Forest & wasteland
Others	Twigs	85.8	NA	12.3	8.2	1.14	Forest & wasteland
Others	Twigs	132.3	NA	52.9	35.3	4.94	Forest & wasteland
Others	Twigs	257.9	NA	73.6	49.1	6.9	Forest & wasteland
Paddy	Husk	123.9	138.8	27.7	22.1	2.44	Agro

Contd…

Sidhi of Madhya Pradesh Agro, Forest & Wasteland Biomass Contd…

ResidueWise Data - State : Madhya Pradesh ; District : Sidhi ; Year : 2001-02 ; for All Biomass Class							
Species	Biomass	Area (kHa)	Crop Production (kT/Yr)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)	Biomass Class
Paddy	Straw	123.9	138.8	207.6	20.8	2.49	Agro
Small millets	Stalks	61.6	24.6	29.5	2.95	0.38	Agro
Teak	Bark	33.6	NA	0.28	0.19	0.026	Forest & wasteland
Teak	Bark	85.8	NA	1.77	1.18	0.17	Forest & wasteland
Teak	Bark	132.3	NA	7.7	5.1	0.71	Forest & wasteland
Teak	Bark	257.9	NA	10.7	7.1	0.99	Forest & wasteland
Teak	Branches	33.6	NA	0.28	0.19	0.026	Forest & wasteland
Teak	Branches	85.8	NA	1.77	1.18	0.17	Forest & wasteland
Teak	Branches	132.3	NA	7.7	5.1	0.71	Forest & wasteland
Teak	Branches	257.9	NA	10.7	7.1	0.99	Forest & wasteland
Teak	Leaves	33.6	NA	0.32	0.22	0.03	Forest & wasteland
Teak	Leaves	85.8	NA	2.07	1.38	0.19	Forest & wasteland
Teak	Leaves	132.3	NA	8.9	6	0.83	Forest & wasteland
Teak	Leaves	257.9	NA	12.4	8.3	1.16	Forest & wasteland
Teak	Twigs	33.6	NA	0.28	0.19	0.026	Forest & wasteland
Teak	Twigs	85.8	NA	1.77	1.18	0.17	Forest & wasteland
Teak	Twigs	132.3	NA	7.7	5.1	0.71	Forest & wasteland
Teak	Twigs	257.9	NA	10.7	7.1	0.99	Forest & wasteland
Wheat	Pod	45.3	37.2	10.5	5.3	0.74	Agro
Wheat	Stalks	45.3	37.2	54.4	10.9	1.42	Agro
Total		**1079.1**	**522.9**	**1203.4**	**570.8**	**78.3**	
Agro-Total		**315.5**	**273.8**	**508.1**	**107.1**	**13.3**	
F & W-Total		**509.7**	**NA**	**695.3**	**463.7**	**64.9**	

Estimated Forest Biomass Production

Madhya Pradesh Forest Biomass Power Potential Bamboo:Others:Teak : Bark:Branches:LeavesStalkTwigs				
District	Area kHa	Residue Generation kT/Yr	Biomass Surplus kT/Yr	Power Mwe
Balaghat	589.5	1135.5	757.3	106.03
Sheopur	399.4	470.1	313.5	43.90
Dindori	298.8	440.4	293.7	41.12
Seoni	225.3	428.2	285.6	39.98
Mandla	277.9	390.7	260.6	36.48
Chhindwara	287.7	380.9	254.0	35.56
Betul	276.0	361.3	241.0	33.74
Shivpuri	256.2	351.7	234.6	32.84
Sidhi	251.7	331.4	221.0	30.94
Umaria	162.0	283.7	189.2	26.49
Satna	150.9	269.0	179.4	25.11
East Nimar	147.2	250.0	166.8	23.35
Raisen	173.0	249.4	166.3	23.28
Panna	200.5	245.1	163.5	22.89
Hoshangabad	230.5	244.8	163.3	22.86
Shahdol	168.5	243.3	162.3	22.72
Gwalior	165.5	230.0	153.4	21.48
Katni	171.2	221.3	147.6	20.66
Narsinghpur	96.1	177.6	118.4	16.58
Chhatarpur	94.9	177.4	118.3	16.57
Sagar	119.8	151.1	100.8	14.11
Damoh	130.0	147.5	98.4	13.77
Dewas	93.4	138.2	92.2	12.90
Jabalpur	85.9	113.8	75.9	10.62
Sehore	64.3	106.2	70.9	9.92
West Nimar	42.2	77.7	51.8	7.26
Rewa	39.8	70.3	46.9	6.56
Harda	70.5	66.7	44.5	6.23
Indore	33.4	51.2	34.1	4.78
Morena	34.7	48.1	32.1	4.49
Guna	35.9	45.4	30.3	4.24
Vidisha	19.7	31.0	20.7	2.90
Jhabua	13.5	26.6	17.8	2.49
Ratlam	10.8	17.1	11.4	1.60
Bhopal	8.5	15.7	10.5	1.47
Rajgarh	8.7	13.6	9.1	1.27
Neemuch	9.2	13.3	8.9	1.24
Shajapur	7.1	11.8	7.9	1.10
Dhar	8.6	11.4	7.6	1.07
Tikamgarh	4.3	6.5	4.3	0.61
Barwani	4.9	5.6	3.7	0.52
Ujjain	3.1	4.6	3.1	0.43
Mandsaur	1.4	2.0	1.4	0.19
Datia	0.7	1.0	0.6	0.09
Bhind	0.1	0.3	0.2	0.02
Total	**5473.2**	**8058.2**	**5374.7**	**752.5**

Estimated Waste Land Biomass Production

Madhya Pradesh Wasteland Biomass Power Potential Bamboo:Others:Teak : Bark:Branches:LeavesStalkTwigs				
District	Area kHa	Residue Generation	Biomass Surplus	Power Mwe
Shivpuri	401.8	566.8	378.0	52.9
East Nimar	333.8	471.0	314.1	44.0
Barwani	320.7	452.5	301.8	42.3
Rewa	314.8	444.1	296.2	41.5
Shahdol	307.4	433.6	289.2	40.5
Jhabua	304.0	428.9	286.1	40.1
Rajgarh	298.5	421.2	280.9	39.3
West Nimar	290.4	409.7	273.3	38.3
Guna	265.9	375.2	250.2	35.0
Sidhi	257.9	363.9	242.7	34.0
Shajapur	248.9	351.2	234.3	32.8
Betul	224.2	316.4	211.0	29.5
Dhar	221.7	312.8	208.6	29.2
Tikamgarh	206.4	291.2	194.3	27.2
Ratlam	201.2	283.9	189.4	26.5
Satna	201.0	283.6	189.2	26.5
Sagar	200.5	282.9	188.7	26.4
Damoh	189.8	267.7	178.6	25.0
Neemuch	171.8	242.3	161.6	22.6
Chhatarpur	170.0	239.9	160.0	22.4
Chhindwara	162.5	229.3	152.9	21.4
Katni	156.0	220.1	146.8	20.6
Mandsaur	146.6	206.9	138.0	19.3
Panna	142.5	201.0	134.1	18.8
Ujjain	131.2	185.1	123.5	17.3
Sehore	123.1	173.7	115.9	16.2
Seoni	121.2	171.0	114.1	16.0
Sheopur	105.5	148.8	99.3	13.9
Dindori	102.5	144.7	96.5	13.5
Mandla	96.6	136.2	90.9	12.7
Dewas	90.1	127.2	84.8	11.9
Narsinghpur	87.2	123.0	82.0	11.5
Morena	86.1	121.5	81.0	11.3
Raisen	78.2	110.3	73.6	10.3
Gwalior	77.7	109.6	73.1	10.2
Hoshangabad	72.8	102.6	68.5	9.6
Balaghat	59.3	83.6	55.8	7.8
Harda	57.2	80.6	53.8	7.5
Bhopal	55.1	77.7	51.8	7.3
Indore	49.3	69.5	46.4	6.5
Vidisha	45.1	63.7	42.5	5.9
Umaria	42.9	60.5	40.4	5.7
Jabalpur	41.5	58.6	39.1	5.5
Bhind	39.9	56.2	37.5	5.3
Datia	28.3	40.0	26.7	3.7
Total	**7329.1**	**10340.0**	**6896.6**	**965.5**

Biomass Production Index

– After the different types of biomass are spatially distributed into different layers, it is necessary that the 'biomass concentration centers' be identified based on the aggregation of biomass surplus of all types.

–To aid this activity a reverse process of generating an image based on the total surplus biomass from all the layers- Agro, Forest and Wasteland of map data is generated.

–This is done by coloring the geographical area based on a normalized index of the total biomass surplus for each district.

Biomass Intensity Analysis

- Biomass mapping based on local potential is made spatially at different levels. This is done by computation of **biomass production (BP) based on a normalized index.** Analysis being impractical at polygon levels, grid based approach is introduced.

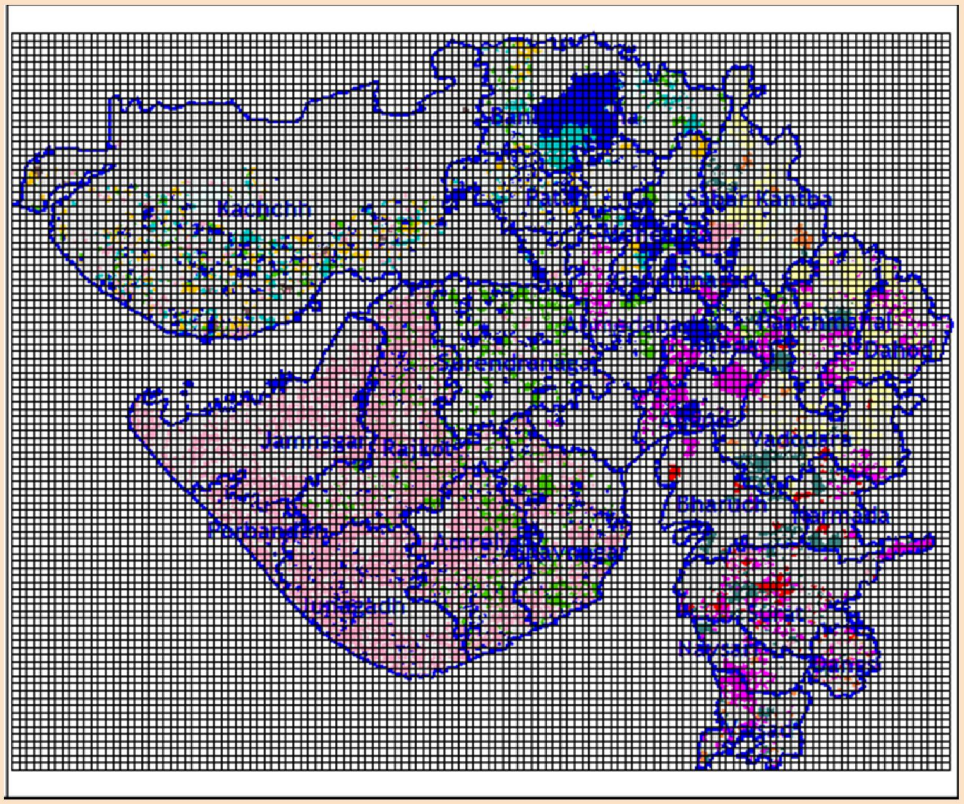
- With the computed **Biomass Production Index [BPI],** that is being developed, the combined analysis with BPI linked map-coloring is done with the developed software tool.

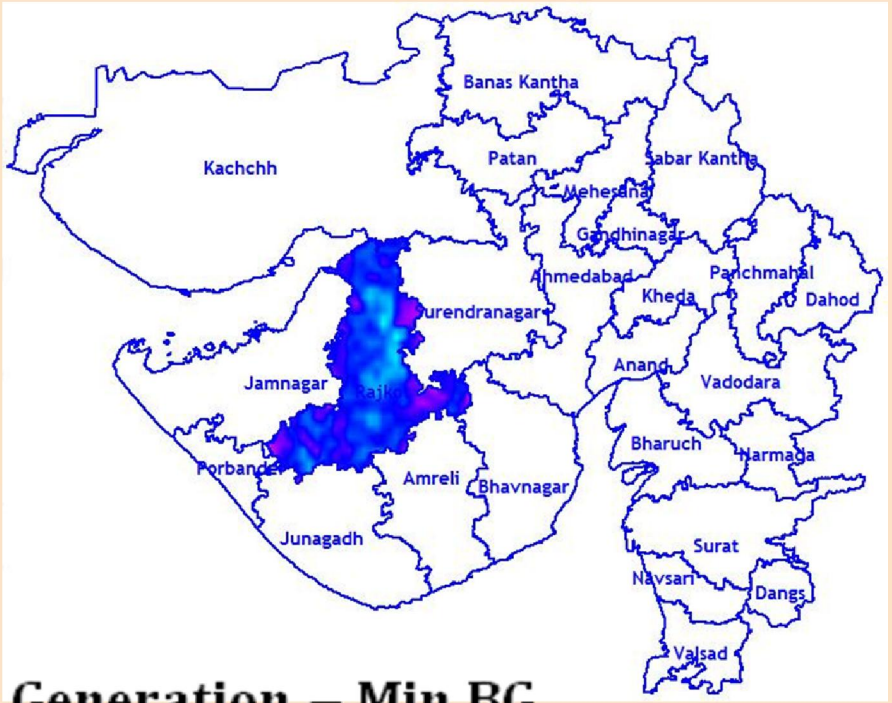
$$\text{Biomass Production Index} = \frac{\text{Biomass Production} - \text{Min BP}}{\text{Max BP} - \text{Min BP}}$$

- The necessary special tools for this approach are developed and are used for the biomass mapping and estimation in the Forest and waste lands.

- **Following slide shows a clipping….**

Grid on Gujarath and Biomass Production Index[BPI] based spatial coloring for Rajkot District





$$\text{Biomass Generation Index} = \frac{\text{Biomass Generation} - \text{Min BG}}{\text{Max BG} - \text{Min BG}}$$

Biomass Production Index

– In the previous slide image generated for BPI is shown as an example.

–In the district Rajkot of Gujarath it is now easy to point to the areas of high biomass concentration. The green areas are more biomass productive for the purposes of energy generation.

–This is also verified by making a graphical query on this chosen geographical area. For example if a query is made on the red region it shows low energy-useful biomass production.

Computed Biomass Production Index [BPI]

Polygon Identifier	Taluk	Area [kHa]	Avg Residue Yield (T/Ha)	BPI
373998	Tankara	30.35	0.9029	0.5609
374030	Jetpur	1.13	0.9029	0.5609
375244	Rajkot	1.30	0.6588	0.4299
374008	Rajkot	2.39	0.6588	0.4299
374052	Rajkot	1.81	0.6588	0.4299
374044	Jetpur	1.15	0.6588	0.4299
374047	Jetpur	4.61	0.6588	0.4299
374003	Paddhari	7.18	0.5125	0.3981
374028	Lodhika	1.06	0.5125	0.3981
374050	Gondal	2.22	0.5125	0.3981
374034	Rajkot	0.59	0.5125	0.3981
374056	Gondal	0.26	0.5125	0.3981
375258	Rajkot	0.60	0.6588	0.3769
374055	Kotdasangani	0.83	0.6588	0.3769
374045	Gondal	2.29	0.6588	0.3769
374005	Paddhari	2.38	0.4595	0.3608
375297	Rajkot	0.17	0.4595	0.2734
374011	Paddhari	2.16	0.5125	0.2603
374733	Morvi	0.11	0.5125	0.2603
374032	Gondal	0.12	0.5125	0.2603
374025	Gondal	0.07	0.5125	0.2603
374024	Jetpur	0.01	0.5125	0.2603
374002	Vankaner	0.01	1.1051	0.0823
374678	Morvi	1.45	1.1051	0.0823
374720	Morvi	1.45	1.1051	0.0823
375259	Rajkot	0.01	1.1051	0.0823
374013	Paddhari	0.06	1.1051	0.0823
374014	Paddhari	26.06	1.1051	0.0823
374015	Rajkot	65.16	1.1051	0.0823
374016	Vankaner	84.11	1.1051	0.0823
374041	Jetpur	0.58	1.1051	0.0823
374730	Morvi	0.07	0.1138	0.0533
374734	Morvi	0.11	0.1138	0.0533
374021	Gondal	0.14	0.1138	0.0533
375250	Rajkot	0.24	0.4281	0.0297
374048	Gondal	0.68	0.7425	0.0062
374046	Lodhika	0.21	0.7425	0.0062

World Scenario for Forest

Forest cover and per Capita Availability in Different Regions/ Countries		
Region / Country	Percentage of Forest Cover to Land Area (1995)	Per Capita Forest(ha)
World	26.60	0.64
Asia	16.40	0.10
Africa	17.70	0.70
Europe	41.30	1.30
China	14.30	0.10
Pakistan	2.30	0.01
Nepal	33.70	0.20
Bangladesh	7.80	0.02
Sri Lanka	27.80	0.10
Indonesia	60.60	0.60
Malaysia	47.10	0.80
Philippines	22.70	0.10
Japan	66.80	0.20
USA	23.20	0.80
India	15.70	0.06

State wise Forest & Scrub land Area (FSI & NRSA)

Extent of Dense forest, Open forest and Mangrove in States/UTs						
						(sq.km)
State/UT	Dense Forest	Open Forest	Mangrove	Total Forest	Percent of Geographic Area	Scrub
Andhra Pradesh	24190	19642	397	44229	16	9559
Arunachal Pradesh	57756	11091	0	68847	82	104
Assam	14517	9171	0	23688	30	324
Bihar	13274	13200	0	26474	15	1914
Delhi	35	53	0	88	6	3
Goa	995	251	5	1251	34	16
Gujarat	6430	5504	1031	12965	7	2948
Haryana	449	515	0	964	2	191
Himachal Pradesh	9120	3962	0	13082	24	566
Jammu & Kashmir	11019	9422	0	20441	9	3089
Karnataka	24832	7632	3	32467	17	4489
Kerala	8429	1894	0	10323	27	91
Madhya Pradesh	81619	50211	0	131830	30	3853
Maharashtra	26613	19951	108	46672	15	7160
Manipur	5936	11448	0	17384	78	177
Meghalaya	5925	9708	0	15633	70	261
Mizoram	3786	14552	0	18338	87	125
Nagaland	5137	9027	0	14164	85	14
Orissa	26073	20745	215	47033	30	5439
Punjab	517	895	0	1412	3	107
Rajasthan	4309	9562	0	13871	4	6921
Sikkim	2363	755	0	3118	44	386
Tamil Nadu	8659	8398	21	17078	13	2836
Tripura	2228	3517	0	5745	55	38
Uttar Pradesh	22902	11114	0	34016	12	1177
West Bengal	3565	2672	2125	8362	9	98
A&N Islands	6515	125	966	7606	92	0
Chandigarh	6	1	0	7	6	0
Dadra & Nagar Haveli	159	43	0	202	41	10
Daman & Diu	0	3	0	3	3	0
Lakshdweep*	0	0	0	0	0	0
Pondicherry*	0	0	0	0	0	0
Total	**377358**	**255064**	**4871**	**637293**		**51896**
No discernible forest cover.						

Waste Land

State	Crop Area kHa
Andhra Pradesh	4523.9
Arunachal Pradesh	1326.1
Assam	1407.3
Bihar	542.7
Chhattisgarh	759.2
Gujarat	2035.1
Haryana	329.9
Himachal Pradesh	2830.5
Jammu & Kashmir	7039.0
Jharkhand	1043.0
Karnataka	1331.8
Kerala	107.3
Madhya Pradesh	5709.8
Maharashtra	4927.5
Manipur	1298.9
Meghalaya	348.6
Mizoram	446.7
Nagaland	385.9
Orissa	1860.5
Punjab	145.3
Rajasthan	10145.9
Sikkim	407.6
Tamil Nadu	1719.9
Tripura	131.0
Uttar Pradesh	1714.7
Uttaranchal	1609.6
West Bengal	439.9
Total	**54567.6**

Concluding Remarks

- The mapped biomass resource atlas is hosted on a internet site and is available for an end user to access from his end anywhere.
- The usage of the atlas has been reasonable both by the power plant entrepreneurs and administrators in decision making.
- Expansion of the data sets and features are on the way for a better usage in the time to come.
- The mapping has provided a strong basis of building sustainable biomass power plants – a strong and emerging renewable alternative energy source to come.
- The study points out that availability of biomass as fuel is not hindrance for its wider energy application but a proper policy addressing the barrier could be gap, as of today.