Assessment of Biomass Resource and its Power Potential using Remote Sensing Data for Karnataka State and Nation-wide in General

Sheshagiri G S, Rajan N K S and Mukunda H S
CGPL, Aerospace Dept., Indian Institute of Science, Bangalore

Abstract: Biomass has been gaining impetus in the Renewable energy aspects in the recent times. In India, the surplus biomass potential is recognized as an important renewable source and has proved viable industrially both for captive and grid linked power application. This background necessitates having a nation-wide assessment of different types of biomass distributed geographically. The availability of biomass varies geographically widely and so, it is necessary to have special study on this keeping India's geography in focus, to support the decision makers involving the market dynamics, and to build-up the tradition of using biomass and agricultural residues more productively. Keeping these factors in view the work reported here was initiated to make an assessment of biomass based power potential, nation-wide. This activity is now in an advanced stage of integration and the outcome of this is as an electronic atlas to be made available over Internet apart from a stand–alone application that can work on a Desktop PC.

Key words: **Biomass, Gasifier, Biomass Power, Electrical power, Thermal power, Geography, Resource Assessment, Power Potential**

Biomass as energy is gaining importance as a renewable source and goes well with the Gandhian principles of taking technology to villages to strengthen the nation's agriculture as a prime player in Indian economy. The use of biomass for thermal energy is age old but the use of "modern biomass" (implying clean combustion process) is more recent. In the last three decades, several developments in the country, more particularly finances for research and development, extensive meetings and discussions between all researchers and manufacturers at the instance of the ministry of new and renewable sources of energy sources (MNRE, as it is called at present) have led a condition by which India is considered a leader in the development of "gasification systems" meant for high grade heat or power. In most of these developments, CGPL, IISc is at the forefront bringing its knowledge on advanced combustion processes to handling solid fuels. In this context it is necessary that the Biomass availability is assessed after

the existing traditional usages such as domestic fuel, thatching and manure. The MNRE project NBRAP [National Biomass Resource Assessment Program] was taken up by CGPL [Combustion Gasification & Propulsion Laboratory] to develop a software tool to estimate the power generation potential augmenting the site suitability studies for biomass based power plants. CGPL is considered as NFP [National Focal Point] for the purpose of assessing the data and its integration. Under this context Taluk survey was initiated by MNRES with an aim of obtaining the residue yield for all the crops depending on the crop yield and other parameters, and most importantly, the current usage trend in terms of nature and magnitude. The survey was conducted by selected consultants monitored by Apex institutions [AI]. It was planned to be executed in 4 phases consisting of strategically selected taluks [about 500] spread all over the country. Each phase helped to improve upon the surveying quality during the next phase and develop a data base to be usable for biomass assessment. The survey reports give us Crop Yield [Tons/Hectare], CRR [Crop Residue Ratio = Residue yield (Tons/Ha) / Crop Yield (Tons/Ha)], the surplus biomass available after basic uses such as fodder, fuel etc. Having known the power output per unit quantity of biomass (typically, 1 kWh for every 0.9 to 1.4 kg of sun-dry bioresidues, this variation being due to the ash content in the biomass) we can then assess the power generation potential using the excess biomass. *Karnataka alone has an Agro based Biomass power generation potential of about 7% of that at the Country level. Karnataka could contribute above 900 MWe, whereas Country as a whole has a power potential of above 13000 MWe. This is exclusive of Biomass from Bamboo, Coffee, Tea, Non-edible Oil cakes, urban wastes, Wood, Agro-forestry and Waste land. The Biomass Power available in the country due to the Biomass generation in Waste lands alone is estimated to be 30000^{+}MW.*

The Crop parameters CRR, Crop Yield, Surplus factor and factor for power generation have to be assessed carefully before the availability of biomass is distributed spatially on to the map. After the analysis of Taluk level data lot of inconsistencies were found in crop parameters. The direct extensibility of such a data to state level distribution of crops to compute biomass availability was found to be inappropriate at least for some of the important crops like cotton, coconut, and jowar etc. *Number of interactions with apex institutions and consultants revealed that excess biomass projected should be viewed at district level as the biomass moves out of the taluks considerably*. Also a

larger geographical area provides a better average of the crop parameters. So, the utilization factor is better visualized at district level. In fact MOA [Ministry of Agriculture] provides district level crop area and production in a year. An initial district survey was launched for the purpose in selected 3 states- Karnataka, Andhra Pradesh and Maharashtra. The district survey reports prepared for the states continued to show inconsistencies in CRR [Crop Residue Ratio] for some of the crops for which attempts were made to arrive at reasonable parametric values again with proper interactions with the apex institutions. Presently, the biomass data embedded in the atlas is based on Agricultural crop residues published by MOA for the year 1998-99. This is used as the reference year of assessment. The data for the year 2000-01 obtained from district survey is being analyzed and will be adopted for 15 major states including Karnataka once the 'noise' in the reported data is refined after further discussions. One important question arises: what is the use of the data of 1998-99 in 2007? The agricultural pattern in most places does not change dramatically unless some policy initiatives or global impacts cause a change in view points of a whole community of farmers. Even in cases where we can claim we have known the ground reality, changes in crops between paddy and sugarcane would take place almost without any public system being aware until agricultural statistics collected from several sources are collated and clarified. Also some major crops like sugarcane and paddy cannot be changed since they are located where significant water bodies like river based channels make available the water. In view of all these, the present data can be taken as valid for an initial estimate of the availability of the biomass. Aim to set up a power plant should necessarily be accompanied by a site survey in and around the location.

Why Geographical Information System?

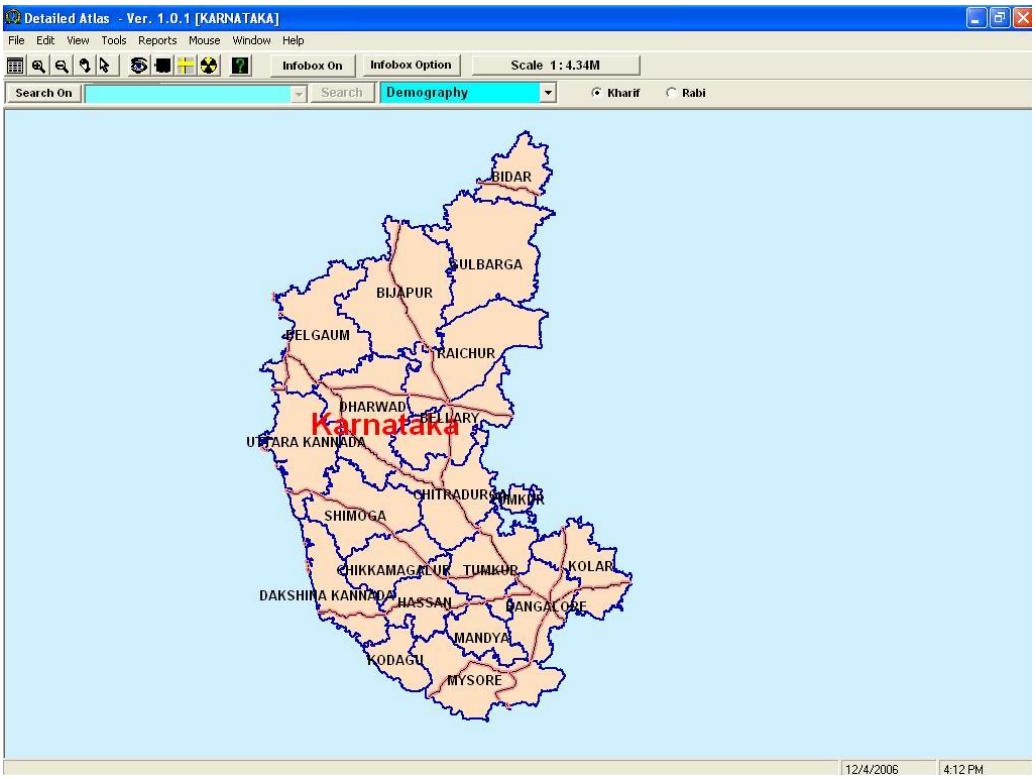
The biomass is geographically distributed [spatial] and has to be transported to power generation centers economically. It is not enough that a simple data base is provided with conventional queries to assess the biomass. The biomass assessment has to be done geographically based on the location of 'use centers'. Additionally, Biomasses are of different types and exhibit different power generation characteristics. These features prompt the use of Geographical Information System [GIS] to asses the biomass along with conventional information data bases. This is done in two ways to make it available to the users. One is a stand-alone digital atlas queriable on the user's PC and the other is web

enabled atlas. The statistical data doesn't provide us the land [or spatial] distribution of the availability of biomass and is rarely available at taluk level. This is essential for anybody to set up power generating plant because they need to know the approach and location of availability of biomass. Location, transportation & type of biomass are the major issues in such an application. The digital atlas embedding the satellite data, statistical data of crops by MOA at district level, Survey data for biomass and data from various other sources for biomass was successfully demonstrated for the purpose of biomass assessment for the states of Karnataka and Uttar Pradesh in the beginning. The resulting 'Intelligent' distribution of Biomass in the Atlas can be used to query the Biomass availability at taluk level to a considerable accuracy. Integration of the processed maps for all the states into the digital atlas is also completed.

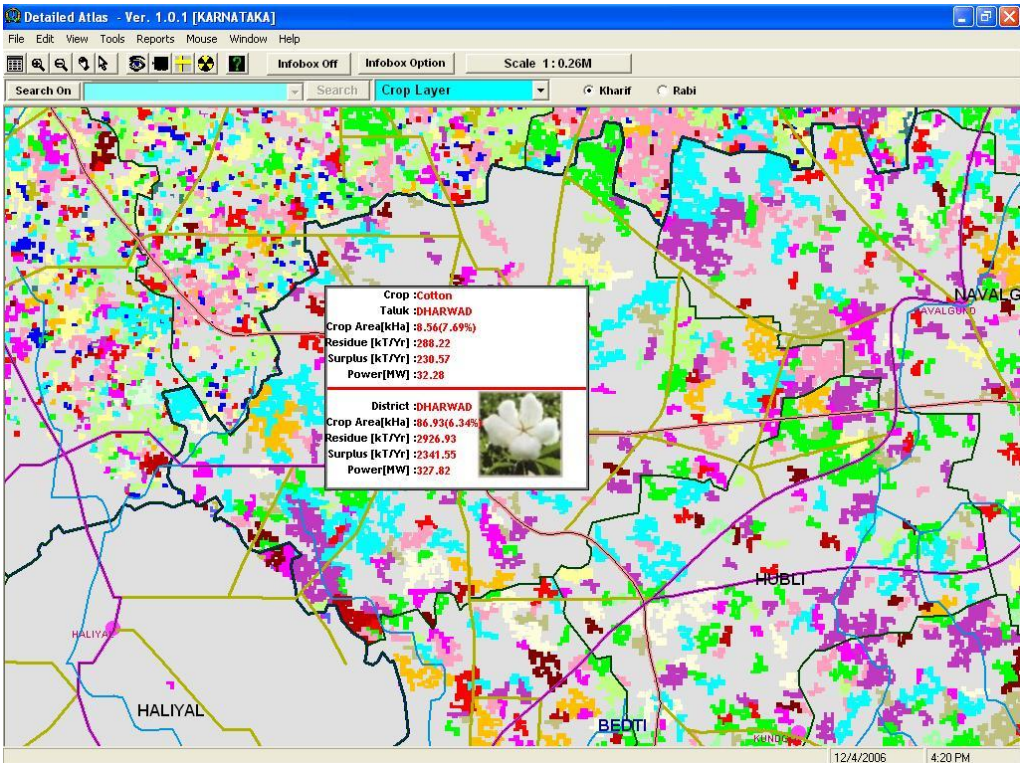
Indian Bio-Residue Map (IBRM) as a stand alone package

This is redistributable software which can be installed on the client PC which will contain a one time specific spatial biomass data. Any body conversant in using Personal computers running under Windows can open the digital Biomass atlas with ease for geographical assessment. The different types of Biomass can be assessed in the circle of interest to forecast the power generation potential for either budgetary purposes or as an input to a DPR [Detailed Project Report] to set up an energy generation center. The only problem one may face is to update the Atlas if the year of assessment required is far away from that of the year of formation of the Atlas.

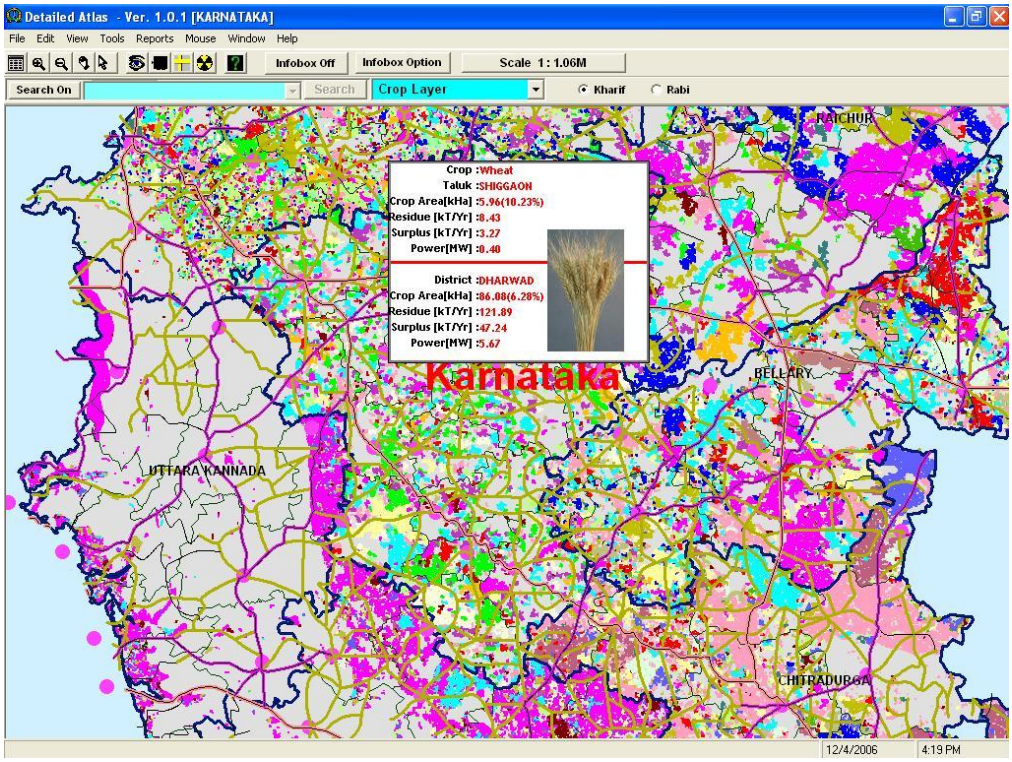
Excerpts of Atlas outputs [Sample clippings from a stand alone PC]



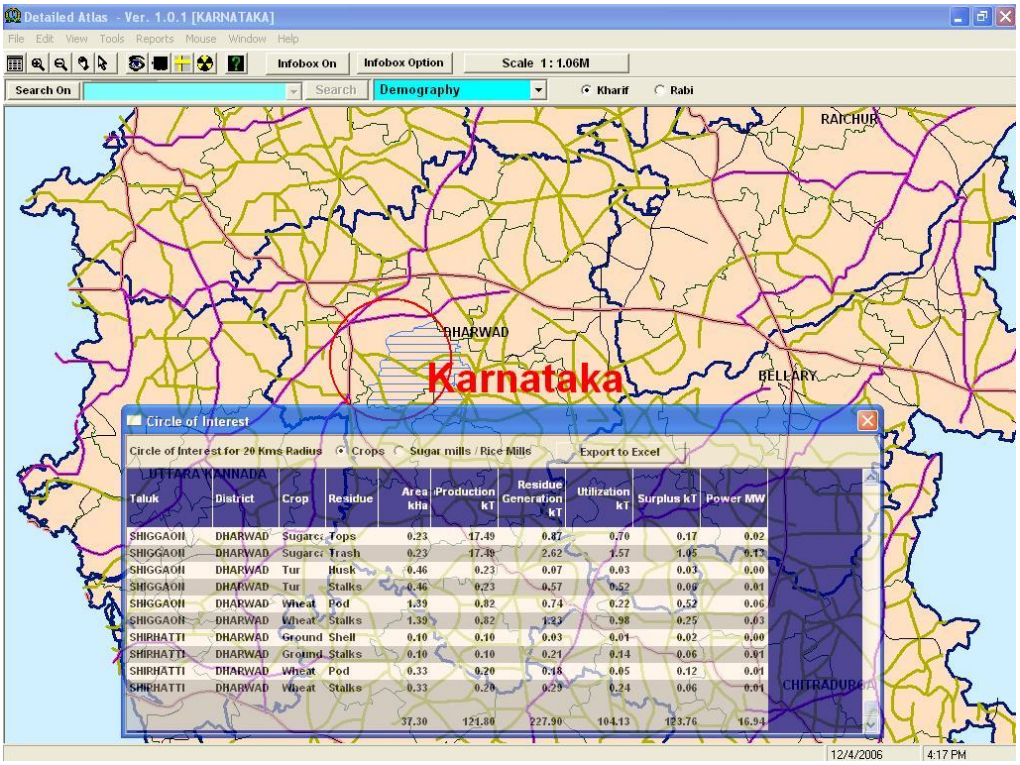
Districts and High ways of Karnataka



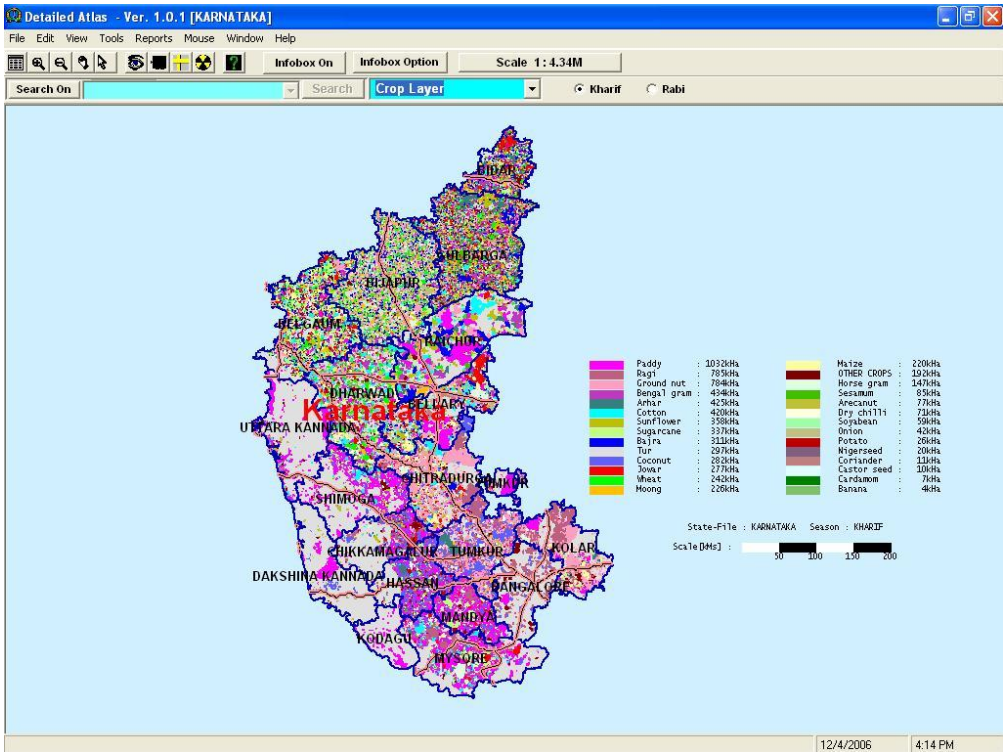
Taluk level View of Biomass Data with Geographical-tool-tip



District level View of Biomass Data with Geographical-tool-tip



Biomass assessment in the Circle of Interest

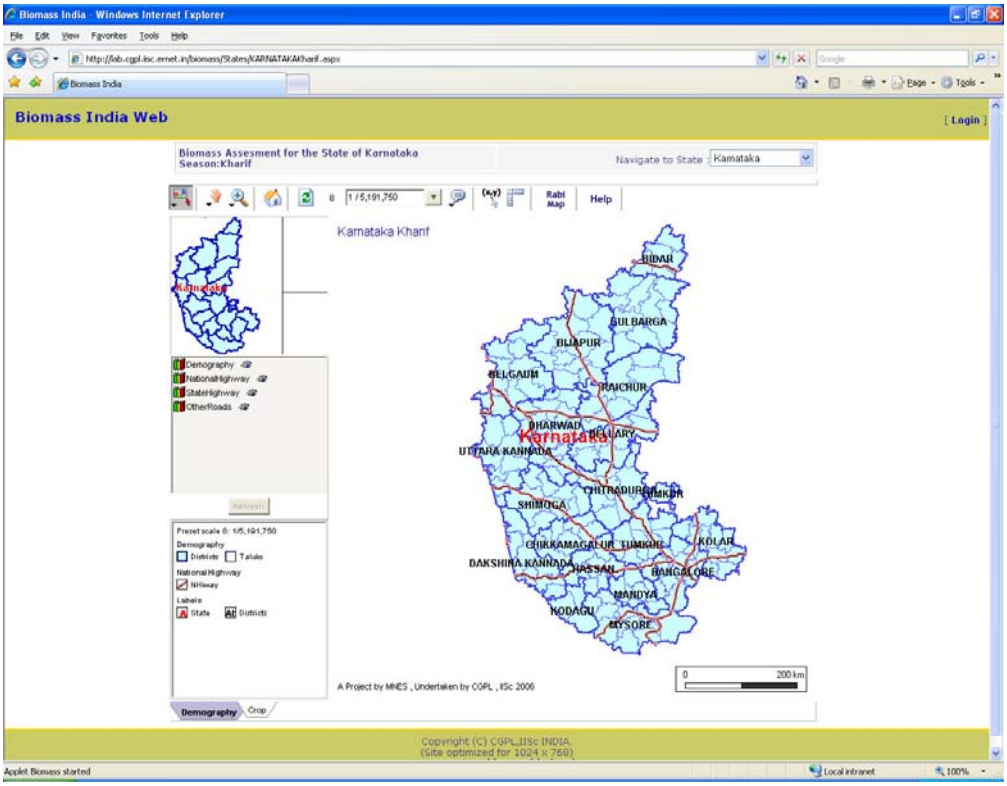


State level Biomass view with legend

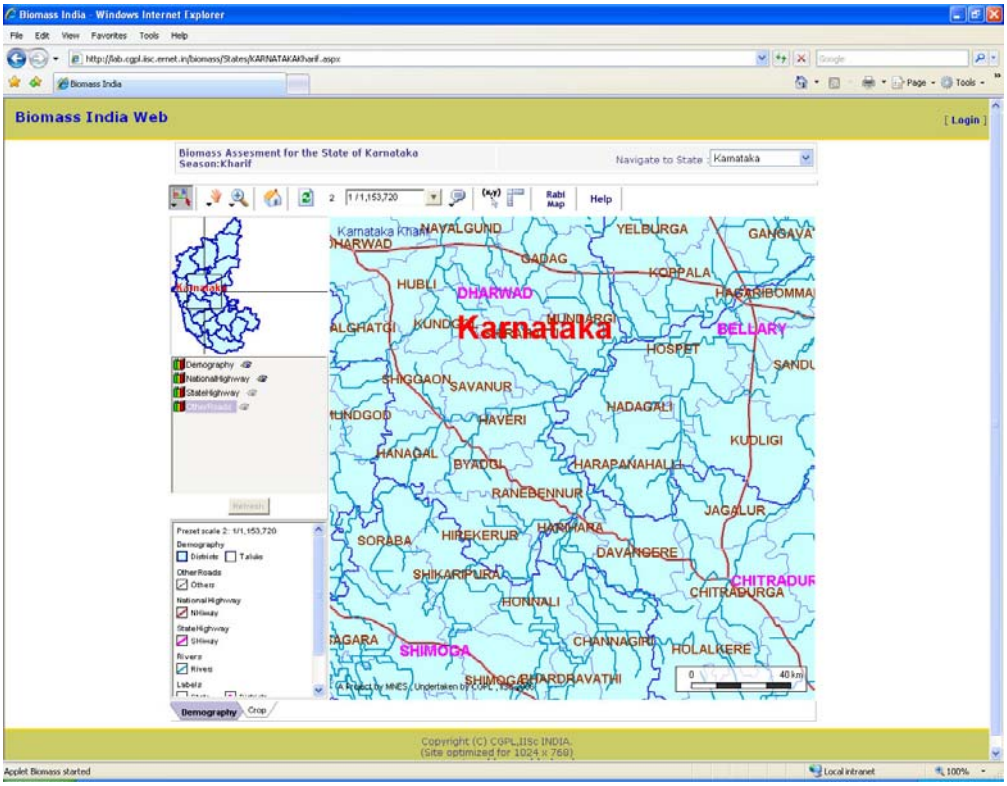
Map work for WEB

Web access of Digital maps has been realized for all the states. This has been done to enable remote Biomass Analysis through Internet. Further work is going on to update maps regularly. The Web Atlas is Windows based and any body knowing to use a Personal computer for browsing can easily view the Atlas and make interactions to assess the biomass. The greatest advantage of Web based biomass assessment is that the updated information is immediately extended and available to the users through Internet. This is not possible in the case of the stand alone Digital atlas software package. Additional detailed online queries are also under development. Following are the sample clippings of maps showing agro-based biomass distribution. By suitably clicking on the map online biomass reports can be had on the internet both at taluk and district levels.

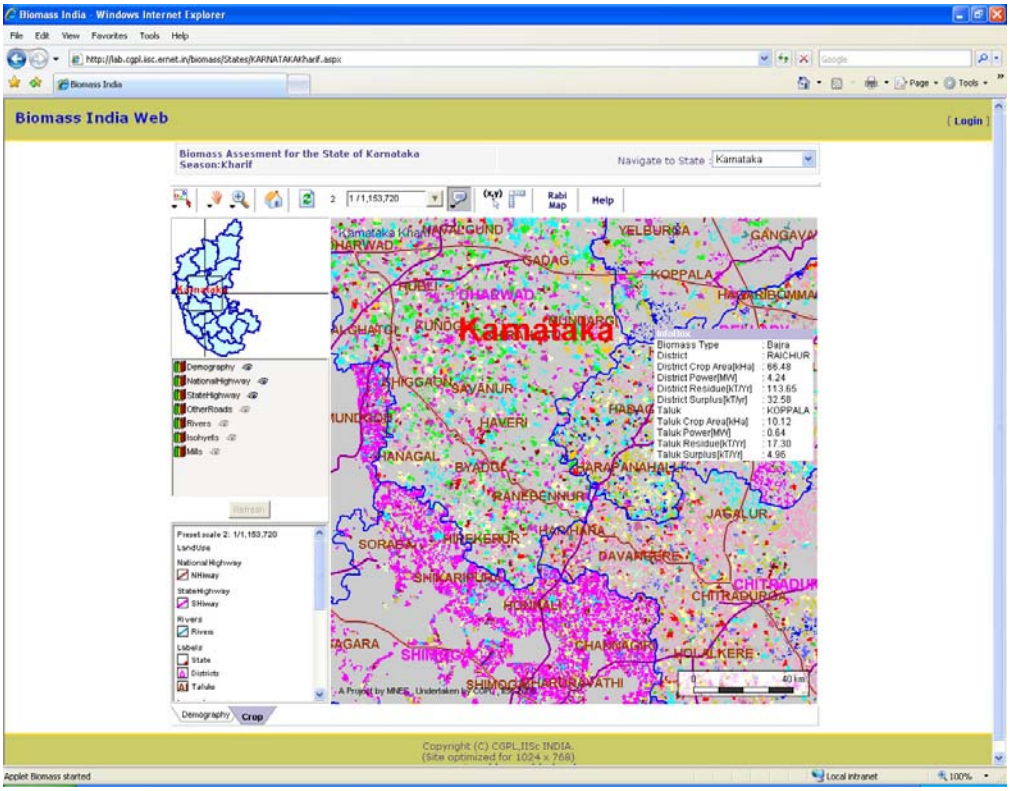
Excerpts of Web Atlas outputs [Sample clippings through Internet]



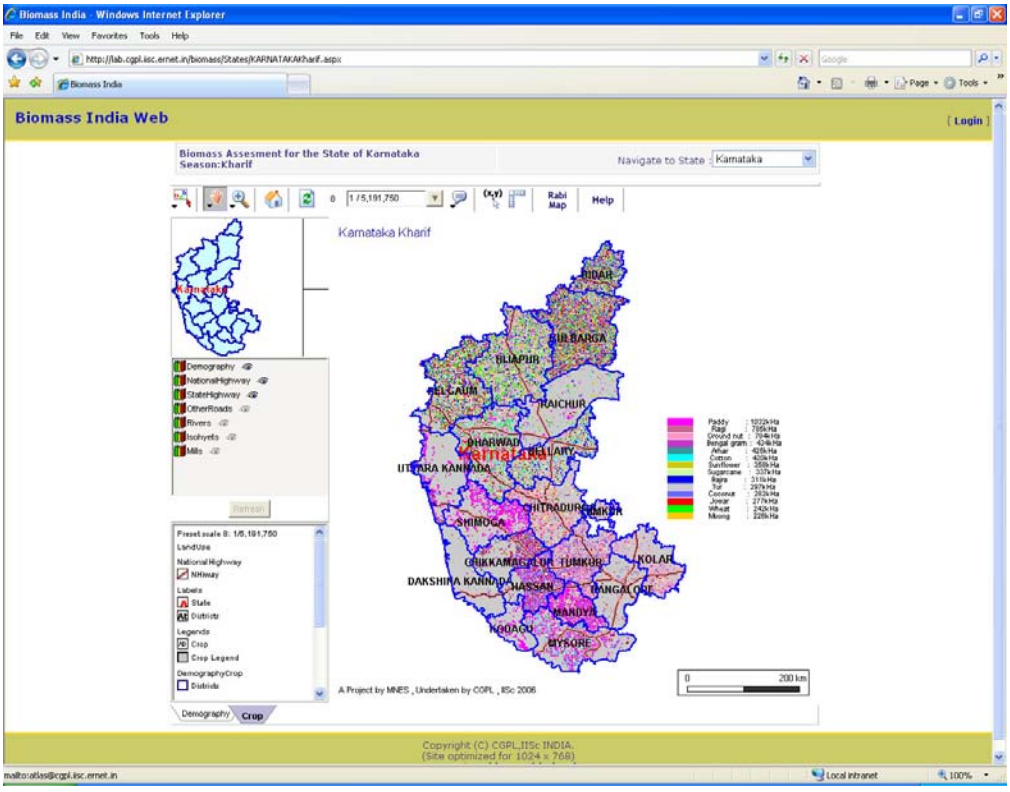
Demography of Karnataka



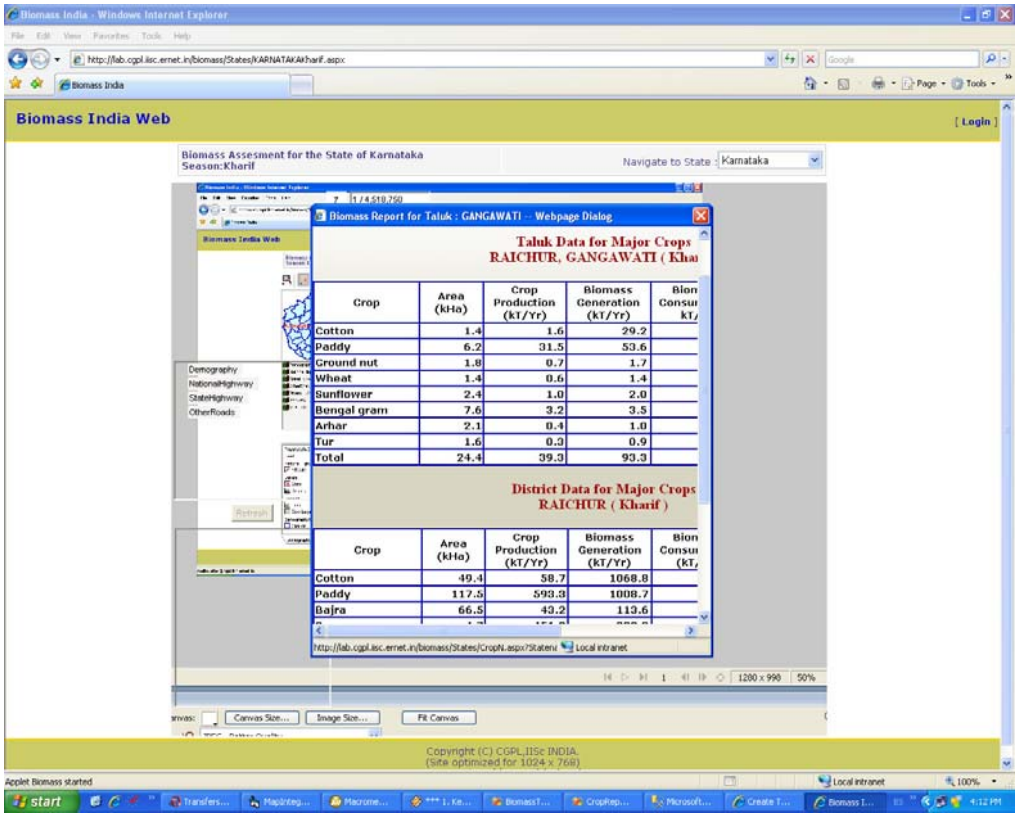
District level View of Karnataka



Biomass Data in a Geographical-tool-tip



State level Biomass view with legend



District level and Taluk level Biomass Reports

Web enabled Indian Bio-Residue Map (IBRM).

Unlike the stand alone package this is directly available to any remote client dynamically on his desk top PC [Personal Computer]. The updates on the biomass information will be seamlessly available to the users as the data sits on a central information server. The rest of the features are common with a difference that the circle of interest will be introduced in the next phase. The web Atlas is cautiously designed keeping in view the internet response to every query of the client. The atlas can be accessed through normal internet browsers.

After a brief study and discussions with consultants in the area of Bamboo it was interesting to know that substantial amount of bamboo get wasted in the forests due to natural degeneration. It is a fact that they re-grow with a possible yearly harvesting if properly planned. For e.g. if the data for Bamboo is made available for Karnataka it is possible to geographically distribute it to assess the bamboo biomass for generation of power. Care has been taken to distribute the crops into the map with a software feature to update the crop distribution of crops whenever necessary at the district level. This

way the digital map integration can progress with proper control over the built in data. Following are the tabulated Biomass availability and excerpts extracted from Atlas for the state of Karnataka. Please note that the Taluk level Biomass data has been resolved from the map. *Following are the tables consolidated for surplus biomass and its power potential for different types of agro-biomass at taluk level, district level and state level for the Karnataka state and Country as a whole. The totals compared between district wise and residue wise data show a small difference which is due to aggregation querying through data base.*

Talukwise Biomass Power Potential for Karnataka [1998-99]					
District	Taluk	Biomass Area (kha)	Biomass Generation (kT/Yr)	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Bangalore	Anekal	4.3	12.4	1.2	0.2
Bangalore	Bangalore north	9.7	24.0	5.2	0.4
Bangalore	Bangalore south	5.8	14.3	3.5	0.2
Bangalore	Channapatna	5.3	32.4	10.7	1.2
Bangalore	Devanhalli	8.6	30.5	8.3	0.8
Bangalore	Dod ballapur	12.7	101.5	32.5	3.8
Bangalore	Hoskote	6.0	41.6	12.6	1.5
Bangalore	Kanakapura	13.1	39.2	13.7	1.2
Bangalore	Magadi	10.4	43.7	11.0	1.2
Bangalore	Nelamangala	5.9	24.2	5.5	0.6
Bangalore	Ramanagaram	9.9	62.4	12.4	1.4
Belgaum	Athni	196.9	766.3	238.3	29.2
Belgaum	Bailhongal	83.8	334.5	107.3	13.2
Belgaum	Belgaum	55.7	235.0	73.5	9.1
Belgaum	Chikodi	116.7	444.2	138.1	17.0
Belgaum	Gokak	122.1	452.7	139.8	17.3
Belgaum	Hukeri	67.5	211.8	63.6	7.9
Belgaum	Khanapur	30.9	164.2	49.6	6.2
Belgaum	Ramdurg	97.1	371.4	115.5	14.3
Belgaum	Raybag	74.9	276.2	83.5	10.3
Belgaum	Saundatti	116.7	435.1	134.5	16.5
Bellary	Bellary	149.4	349.3	88.9	11.5
Bellary	H.hadagalli	44.7	121.0	30.9	4.0
Bellary	Hagaribommanahalli	40.0	111.4	29.4	3.9
Bellary	Harpanahalli	67.6	201.6	58.6	7.6
Bellary	Hospet	51.7	91.2	22.0	2.8
Bellary	Kudligi	83.8	423.6	82.3	9.6
Bellary	Sandur	39.1	172.7	40.8	5.0
Bellary	Siruguppa	83.5	158.8	45.9	5.9
Bidar	Aurad	77.1	99.9	27.9	3.4
Bidar	Basavakalyan	92.6	113.1	28.4	3.5
Bidar	Bhalki	113.1	213.0	58.0	7.1
Bidar	Bidar	66.2	113.0	31.3	3.8
Bidar	Homnabad	79.2	207.7	61.6	7.5

Bijapur	Badami	61.4	148.5	45.1	5.5
Bijapur	Bagalkot	49.7	103.7	30.5	3.8
Bijapur	Basavana bagevadi	139.0	391.6	113.9	14.0
Bijapur	Bijapur	87.0	213.7	66.7	8.2
Bijapur	Bilgi	40.6	105.8	31.7	3.9
Bijapur	Hungund	101.9	215.6	65.8	8.1
Bijapur	Indi	146.3	299.9	82.4	10.2
Bijapur	Jamkhandi	67.3	183.2	55.6	6.8
Bijapur	Muddebihal	109.7	291.5	90.4	11.0
Bijapur	Mudhol	62.4	158.9	48.7	5.9
Bijapur	Sindgi	148.2	334.7	95.5	11.7
Chikmagalur	Chikmagalur	44.6	147.8	32.2	3.4
Chikmagalur	Kadur	108.3	346.0	80.7	9.1
Chikmagalur	Koppa	9.8	22.3	4.8	0.4
Chikmagalur	Mudigere	1.8	5.9	1.1	0.1
Chikmagalur	Narasimharajapura	2.3	9.7	2.3	0.2
Chikmagalur	Sringeri	2.6	8.9	2.5	0.3
Chikmagalur	Tarikere	66.8	191.0	45.9	5.1
Chitradurga	Challakere	71.1	182.1	66.6	8.2
Chitradurga	Chitradurga	71.1	221.5	78.7	9.4
Chitradurga	Davangere	48.7	137.4	48.3	5.7
Chitradurga	Harihar	27.7	69.5	19.3	2.2
Chitradurga	Hiriyur	78.1	175.1	43.9	5.1
Chitradurga	Holalkere	50.5	166.4	57.5	6.9
Chitradurga	Hosdurga	55.2	155.6	52.7	6.3
Chitradurga	Jagalur	49.8	150.3	49.7	6.3
Chitradurga	Molakalmuru	44.2	94.6	47.2	2.8
Dakshinkannada	Bantval	4.4	44.0	7.1	0.8
Dakshinkannada	Beltangadi	1.5	8.3	1.3	0.1
Dakshinkannada	Karkala	3.6	41.1	6.5	0.7
Dakshinkannada	Kundapura	6.8	115.1	30.3	3.9
Dakshinkannada	Mangalore	2.0	28.3	4.5	0.5
Dakshinkannada	Puttur	2.8	39.6	6.3	0.7
Dakshinkannada	Sulya	0.6	2.3	0.8	0.1
Dakshinkannada	Udupi	9.0	124.9	20.4	2.3
Dharwad	Byadgi	19.9	45.7	11.0	1.4
Dharwad	Dharwad	52.9	123.0	33.6	4.3
Dharwad	Gadag	42.8	92.4	25.5	3.3
Dharwad	Hangal	33.3	130.7	46.3	6.0
Dharwad	Haveri	29.0	74.1	19.7	2.4
Dharwad	Hirekerur	33.0	74.7	17.9	2.3
Dharwad	Hubli	26.2	53.4	14.7	1.9
Dharwad	Kalghatgi	20.5	63.3	18.8	2.4
Dharwad	Kundgol	27.9	58.5	14.5	1.8
Dharwad	Mundargi	32.3	69.1	20.7	2.7
Dharwad	Nargund	17.2	45.0	12.3	1.6
Dharwad	Navalgund	60.7	118.3	30.7	3.9
Dharwad	Ranibennur	33.5	77.7	18.7	2.3
Dharwad	Ron	60.0	118.0	30.7	4.0
Dharwad	Savanur	18.7	55.5	16.1	2.0

Dharwad	Shiggaon	17.9	40.8	11.4	1.4
Dharwad	Shirhatti	38.9	83.9	23.1	2.9
Gulbarga	Afzalpur	137.4	167.7	35.1	4.4
Gulbarga	Aland	161.7	200.8	45.4	5.7
Gulbarga	Chincholi	134.4	168.9	40.1	5.1
Gulbarga	Chitapur	206.0	233.1	48.6	6.1
Gulbarga	Gulbarga	166.2	184.0	36.0	4.5
Gulbarga	Jevargi	214.8	238.6	47.2	6.0
Gulbarga	Sedam	111.7	126.7	26.3	3.3
Gulbarga	Shahpur	151.7	176.4	39.7	5.0
Gulbarga	Shorapur	175.1	197.8	42.9	5.4
Gulbarga	Yadgir	127.4	141.4	29.3	3.6
Hassan	Alur	18.6	69.8	19.8	1.8
Hassan	Arkalgud	53.6	157.0	38.9	3.9
Hassan	Arsikere	69.1	250.0	61.7	5.9
Hassan	Belur	33.5	108.7	28.5	2.9
Hassan	Channarayapatna	69.6	274.7	66.9	6.9
Hassan	Hassan	62.3	209.2	52.0	5.3
Hassan	Holenarsipur	46.4	133.6	29.1	2.9
Hassan	Sakleshpur	2.0	9.0	2.7	0.3
Kodagu	Madikeri	10.6	71.5	11.3	1.2
Kodagu	Somvarpet	7.8	52.7	8.4	0.9
Kodagu	Virajpet	15.3	103.6	16.5	1.8
Kolar	Bagepalli	54.6	159.2	19.9	2.5
Kolar	Bangarapet	29.6	117.7	34.6	4.3
Kolar	Chikballapur	8.0	31.6	8.7	1.1
Kolar	Chintamani	33.2	71.4	25.3	3.2
Kolar	Gauribidanur	46.8	177.1	29.7	3.5
Kolar	Gudibanda	14.1	15.3	3.0	0.4
Kolar	Kolar	36.8	124.0	32.5	4.2
Kolar	Malur	23.6	101.9	29.7	3.7
Kolar	Mulbagal	10.4	37.8	10.2	1.3
Kolar	Sidlaghatta	39.1	125.3	19.2	2.4
Kolar	Srinivaspura	7.0	36.6	9.3	1.1
Mandya	Krishnarajpet	44.2	352.0	96.1	11.0
Mandya	Maddur	41.0	266.4	67.5	7.6
Mandya	Malavalli	44.6	303.8	75.4	8.5
Mandya	Mandya	39.5	354.1	103.1	12.0
Mandya	Nagamangala	52.5	260.3	55.1	6.3
Mandya	Pandavapura	27.3	271.9	81.8	9.6
Mandya	Shrirangapattana	19.7	140.5	37.5	4.2
Mysore	Chamrajanagar	47.9	289.8	82.6	10.2
Mysore	Gundlupet	41.3	175.8	44.0	5.2
Mysore	Heggadadevankote	50.3	192.2	48.3	5.7
Mysore	Hunsur	36.8	168.5	40.8	5.0
Mysore	Kollegal	46.3	243.4	56.8	6.7
Mysore	Krishnrajanagara	29.1	96.2	23.0	2.7
Mysore	Mysore	39.6	157.3	36.4	4.4
Mysore	Nanjangud	62.2	367.0	100.5	11.4
Mysore	Piriyapatna	31.0	136.0	37.3	4.5

Mysore	Tirumakudal narsipur	31.4	138.6	31.8	3.9
Mysore	Yelandur	13.1	59.5	14.1	1.7
Raichur	Deodurga	64.9	148.0	39.0	5.2
Raichur	Gangawati	62.4	129.1	21.4	2.6
Raichur	Koppala	57.6	147.9	32.3	4.0
Raichur	Kushtagi	59.2	141.9	24.6	2.9
Raichur	Lingsugur	93.4	261.6	55.0	6.6
Raichur	Manvi	125.7	252.4	49.0	6.0
Raichur	Raichur	66.2	96.7	19.6	2.4
Raichur	Sindhnur	116.7	496.9	87.1	10.0
Raichur	Yelbarga	64.7	178.2	37.7	4.6
Shimoga	Bhadravati	25.9	183.9	47.9	5.7
Shimoga	Channagiri	57.4	398.3	90.6	10.5
Shimoga	Honnali	42.3	282.9	70.6	8.4
Shimoga	Hosanagara	11.3	71.8	18.6	2.2
Shimoga	Sagar	9.6	74.8	20.5	2.4
Shimoga	Shikarpur	41.2	297.9	72.3	8.6
Shimoga	Shimoga	29.2	187.5	45.7	5.3
Shimoga	Sorab	34.5	255.3	60.4	7.0
Shimoga	Tirthahalli	6.1	43.1	8.5	1.0
Tumkur	Chiknayakanhalli	65.7	154.3	47.8	4.7
Tumkur	Gubbi	71.4	192.3	65.9	5.8
Tumkur	Koratagere	39.3	97.8	42.8	3.0
Tumkur	Kunigal	77.3	179.3	58.4	6.1
Tumkur	Madhugiri	66.5	174.3	42.8	4.9
Tumkur	Pavagada	55.2	275.8	46.6	5.1
Tumkur	Sira	76.8	183.4	47.9	4.3
Tumkur	Tiptur	51.1	143.6	42.1	4.3
Tumkur	Tumkur	58.9	135.6	45.3	4.8
Tumkur	Turuvekere	50.6	137.7	44.3	4.2
Uttarakannada	Ankola	0.7	4.2	2.1	0.2
Uttarakannada	Bhatkal	0.4	2.6	1.3	0.1
Uttarakannada	Haliyal	0.1	0.4	0.2	0.0
Uttarakannada	Honavar	0.5	2.8	1.4	0.2
Uttarakannada	Karwar	0.9	5.2	2.6	0.3
Uttarakannada	Kumta	0.6	3.7	1.9	0.2
Uttarakannada	Mundgod	2.0	11.9	5.9	0.7
Uttarakannada	Sirsi	0.2	1.3	0.7	0.1
Uttarakannada	Supa	0.2	1.0	0.5	0.1
	Total	**8946.2**	**26354.4**	**6950.6**	**821.3**

Districtwise Biomass Power Potential for Karnataka [1998-99]

District	Area (kha)	Crop Production (kT/Yr)	Biomass Generation kT/Yr	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Belgaum	970.3	10585.4	4434.1	1381.1	171.5
Bijapur	1035.3	7401.1	2696.9	811.1	99.4
Mysore	433.1	3330.1	2144.7	531.4	63.3
Bellary	568.0	1629.1	2015.6	490.4	61.9

Mandya	272.8	5345.7	1972.1	520.1	59.8
Chitradurga	505.2	1686.4	1558.5	515.3	59.3
Gulbarga	1586.4	1416.0	2082.8	445.5	56.2
Dharwad	588.7	1745.2	1523.4	425.5	54.0
Tumkur	620.1	1226.0	1806.9	531.3	53.3
Shimoga	260.9	2863.2	1826.2	445.7	52.4
Raichur	714.4	1451.9	2011.2	410.9	50.0
Hassan	368.7	2119.2	1412.2	343.1	35.2
Bidar	436.4	2220.5	992.9	255.4	31.3
Kolar	305.0	1048.7	1081.9	251.7	31.2
Dakshinkannada	31.9	96.6	883.6	176.4	20.9
Chikmagalur	238.2	553.2	794.9	188.0	20.9
Bangalore	93.6	373.1	458.1	128.2	13.9
Kodagu	33.7	134.1	227.9	36.2	4.0
Uttarakannada	5.6	26.5	33.4	16.7	1.9
Total	**9068.2**	**45252.2**	**29957.5**	**7904.0**	**940.5**

Residuewise Biomass Power Potential for Karnataka [1998-99]						
crop	**Residue**	**Area (kHa)**	**Crop Production (kT/Yr)**	**Biomass Generation kT/Yr**	**Biomass Surplus (kT/Yr)**	**Power Potential (MWe)**
Arecanut	Fronds	67.1	90.9	221.4	106.3	14.9
Arecanut	Husk	67.1	90.9	31.6	16.8	1.8
Arecanut	Shell	67.1	90.9	5.3	4.2	0.6
Arhar	Stalks	418.7	200.4	501	100.2	13
Arhar	Husk	418.7	200.4	60.1	30.1	3.3
Bajra	Stalks	307.3	196.4	392.7	78.5	10.2
Bajra	Cobs	307.3	196.4	64.8	51.8	6.7
Bajra	Husk	307.3	196.4	58.9	17.7	2.3
Bengal gram	Stalks	427.8	213	234.3	23.4	2.8
Castor seed	Stalks	10.3	8.7	35	3.5	0.5
Castor seed	Husk	10.3	8.7	0.9	0.4	0.1
Coconut	Shell	252.8	708.3	115.5	92.4	12.9
Coconut	Fronds	252.8	708.3	97.7	48.8	6.6
Coconut	Husk	252.8	708.3	318.4	304	2
Cotton	Stalks	417.8	705.4	1587.7	476.3	66.7
Cotton	BollShell	417.8	705.4	16.3	6.5	0.9
Dry chilli	Stalks	71.5	115.6	172.9	17.3	2.3
Gram	Stalks	290.8	163.7	180	18	2.2
Ground nut	Stalks	906.9	890.4	1780.7	534.2	69.5
Ground nut	Shell	906.9	890.4	267.1	213.3	25.6
Horse gram	Stalks	230.9	115	148.7	14.9	1.8
Jowar	Stalks	1379.6	1210.6	2056.6	205.7	26.7
Jowar	Cobs	1379.6	1210.6	583.2	116.7	16.3

Jowar	Husk	1379.6	1210.6	94	47	5.6
Maize	Stalks	251.8	677.8	1354.9	541.9	70.5
Maize	Cobs	251.8	677.8	203.2	142.3	19.9
Moong	Stalks	229.1	50.4	55.4	5.5	0.7
Moong	Husk	229.1	50.4	7.6	3.8	0.5
Onion	Stalks	42.1	303	15.2	1.5	0.2
Other crops	Residue	285.5	1518.1	1790.9	655.4	78.9
Paddy	Stalks	1002.4	4091.9	6294.3	611.8	67.3
Paddy	Husk	1002.4	4091.9	839.2	503.6	55.4
Potato	Leaves	28.6	346.4	263.3	26.3	3.6
Potato	Stalks	28.6	346.4	17.3	3.5	0.5
Ragi	Stalks	810.8	346.4	2036.1	203.6	26.5
Sesamum	Stalks	82.7	37.1	63.7	6.4	0.8
Soyabean	Stalks	56.1	62.1	105.6	10.6	1.4
Sugarcane	Trash	329.1	31621.7	4743.2	1897.3	227.7
Sugarcane	Tops	329.1	31621.7	1581.1	316.2	38
Sunflower	Stalks	568.3	213.2	425.5	85.1	11.1
Tur	Stalks	295.5	119.6	299	29.9	3.9
Tur	Husk	295.5	119.6	35.9	17.9	2
Wheat	Pod	405.6	315.8	284.2	199	23.9
Wheat	Stalks	405.6	315.8	473.7	94.7	11.4
Total		**9169.0**	**43975.0**	**29914.1**	**7884.3**	**939.5**

Country wide Statewise Biomass Power Potential [1998-99]					
State	**Crop Area (kha)**	**Crop Production (kT/Yr)**	**Biomass Generation kT/Yr**	**Biomass Surplus (kT/Yr)**	**Power Potential (MWe)**
Punjab	5268.3	20365.1	42593.6	18291.1	2117.4
Uttar pradesh	20735.9	62056.6	73384.9	14260.6	1691.0
Rajasthan	12885.9	14203.2	30728.0	9223.7	1159.9
Maharashtra	15621.0	44981.3	36360.0	8418.3	1049.4
Madhya pradesh	13928.3	16965.9	32604.1	8222.5	1039.8
Karnataka	9068.2	45252.2	29957.5	7904.0	940.5
Andhra pradesh	11278.6	30530.5	39081.3	7624.9	922.0
Haryana	3132.5	9044.1	13346.6	7351.1	844.2
Gujarat	6556.0	22172.7	27548.2	6486.1	814.2
Tamil nadu	5715.6	18318.3	27194.1	7067.1	754.0
Kerala	766.3	3141.8	4571.5	3583.1	501.0
Bihar	4412.2	9509.3	16197.0	3782.1	441.4
Chattisgarh	4873.0	4441.5	14351.3	2672.7	299.9
West bengal	4031.4	15236.5	19068.9	2255.5	274.9
Orissa	4335.5	6021.1	9427.7	1965.8	226.4
Assam	2885.9	6971.6	9734.8	1808.4	204.7
Uttaranchal	1280.7	9235.5	4554.5	1116.8	131.8
Himachal pradesh	761.9	1445.2	3032.1	1022.6	130.1
Jammu & kashmir	817.5	902.6	2106.3	465.5	58.4

Jharkhand	465.7	935.7	1282.7	285.6	34.2
Meghalaya	158.4	422.4	541.4	98.0	11.9
Arunachal pradesh	155.5	253.5	403.7	78.5	9.2
Nagaland	179.5	223.3	392.1	66.7	7.5
Manipur	186.6	157.7	249.1	46.3	5.1
Sikkim	69.5	83.2	160.7	17.4	2.2
Mizoram	5.0	7.2	9.6	2.0	0.2
Tripura	6.2	2.6	1.2	0.8	0.1
Total	**129581.3**	**342880.5**	**438882.8**	**114116.9**	**13671.4**

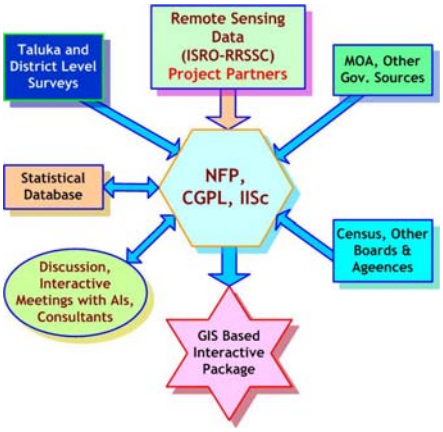
Country wide Residuewise Biomass Power Potential [1998-99]

Crop	Residue	Crop Area (kha)	Crop Production (kT/Yr)	Biomass Generation kT/Yr	Biomass Surplus (kT/Yr)	Power Potential (MWe)
Arecanut	Fronds	187	190	433	204	29
Arecanut	Husk	187	190	32	17	2
Arecanut	Shell	187	190	5	4	1
Arhar	Stalks	2479	1675	4259	844	110
Arhar	Husk	2479	1675	511	256	28
Bajra	Stalks	7781	6127	12254	1972	256
Bajra	Cobs	7781	6127	2022	982	128
Bajra	Husk	7781	6127	1838	440	57
Banana	Residue	28	1821	5463	1564	47
Barley	Stalks	566	1049	1942	299	38
Bengal gram	Stalks	428	213	234	23	3
Cashew Nut	Stalks	105	57	103	24	3
Castor seed	Stalks	334	558	2231	1097	148
Castor seed	Husk	334	558	56	28	3
Coconut	Fronds	1430	6554	5750	914	128
Coconut	Shell	1430	6554	1310	335	47
Coconut	Husk	1430	6554	3200	304	2
Coriander	Stalks	51	11	13	1	0
Cotton	Stalks	4942	1841	18781	5634	789
Dry chilli	Stalks	263	451	676	68	9
Dryginger	Stalks	58	19	1	0	0
Garlic	Sheath	10	67	17	14	2
Garlic	Stalks	10	67	3	3	0
Gram	Stalks	4832	3603	4941	1187	141
Ground nut	Stalks	6319	7753	15554	2365	307
Ground nut	Shell	6319	7753	2333	1380	166
Horse gram	Stalks	364	150	194	20	2
Jowar	Stalks	8874	7362	12514	1376	179
Jowar	Cobs	8874	7362	3659	703	98
Jowar	Husk	8874	7362	1324	662	79
Jute	Stalks	822	1302	2673	276	39
Jute	Leaves	822	1302	67	7	1
Linseed	Stalks	470	123	181	18	2
Maize	Stalks	4982	8093	16435	2955	384
Maize	Cobs	4982	8093	2465	1044	146
Masoor	Stalks	583	428	770	77	10

Mesta	Stalks	3	4	7	2	0
Minor Crops	Stalks	24	15	1	0	0
Moong	Stalks	1493	649	713	71	10
Moong	Husk	1493	649	97	13	2
Moth	Stalks	31	9	17	2	0
Nigerseed	Stalks	35	13	13	1	0
Onion	Stalks	66	679	34	3	0
Other crops	Residue	2934	9827	12224	3584	430
Paddy	Stalks	37682	71970	113218	22922	2521
Paddy	Husk	37682	71970	15116	10874	1196
Peas & Beans	Stalks	586	604	302	149	19
Potato	Leaves	634	11954	9085	1338	181
Potato	Stalks	634	11954	598	182	25
Pulses	Stalks	2243	1146	1490	149	19
Ragi	Stalks	1271	2107	2740	383	50
Rapeseed & Mustard	Stalks	4013	3650	6536	1996	270
Rubber	Primary Wood	496	496	1488	1339	188
Rubber	Secondary Wood	496	496	992	893	125
Sesamum	Stalks	701	241	415	48	6
Small millets	Stalks	1230	626	830	121	15
Soyabean	Stalks	6087	6422	10944	3536	477
Sugarcane	Trash	1948	122761	12803	4602	552
Sugarcane	Tops	1948	122761	5299	950	114
Sunflower	Stalks	878	412	824	125	16
Sweet potato	Stalks	21	42	4	0	0
Tapioca	Stalks	153	3741	2693	1885	264
Tobacco	Stalks	203	237	237	24	3
Tur	Stalks	296	120	299	30	4
Tur	Husk	296	120	36	18	2
Turmeric	Stalks	5	34	10	1	0
Urad	Stalks	1470	764	840	105	13
Urad	Husk	1470	764	153	76	9
Wheat	Stalks	24098	57420	86587	15731	1871
Wheat	Pod	24098	57420	32037	14168	1700
Total		**134511**	**345387.8**	**442922**	**112412**	**13466**

An Overview of the development of National Biomass Resource Atlas

This software package that is developed at CGPL, IISc, as the National Focal Point (NFP) provides information on excess biomass residues form agro-crops, that can be used for distributed energy generation in Spatial and Statistical form



District Survey instituted by MNRES was done during 2002-04 for 15 districts country wide. The MOA crop data was collated with that of the reported data for the year 2000-01 (also verified with earlier MOA data of 1998 – 99) and an updated crop data at the district level is used as an input to construct the Biomass Atlas. Biomass utilization for societal purposes as well as crop-to-residue ratios were derived from the taluk Study that was initiated by MNRES and conducted during 1999-2001 for strategically selected taluks (of about 500) across the country. The residue generation based on agricultural output is used to compute the surplus Biomass available for Energy production after accounting for the societal uses such as Fodder, Domestic Fuel, and Thatching. While all the use for fodder and thatching is considered unavailable for energy generation, use for domestic fuel is decided based on the district level surveys conducted with MNRES support.

The Scheme of the Work

NFP has integrated these crop related data [Year 2000-01] into a data base to be used for creating the Spatial atlas- Indian Bio-Residue Map (IBRM). The spatial maps providing the Land use were obtained from RRSSC (ISRO) for the year 1999-2000 through their satellite imagery at a ground resolution of 184x184 m. Based on the fact that the spatial change in the agricultural area will not be considerable within one year, the crop data has been distributed on to the map. This was then set into GIS (Geographical Information System) by the NFP to use the statistical crop data for spatial distribution at district level. AI based on Fuzzy Logic is adopted for distributing the polygons (with the appropriate crop names) by combining the information on the areas from the land-use with the statistical data on the crop area. The Maps were re-processed to embed the District and taluk level spatial data extracted from the same crop distributed map.

IRS - P3 WIFS CAMERA	
Sensor Characteristics	
Sensor	WiFS
Resolution	188 x 188 m (B3 & B4)
	188 x 246 (B5)
Swath	770 km
Repetitively	24 days
Spectral Bands	0.62 - 0.68 microns (B3)
	0.77 - 0.86 microns (B4)
	1.55 - 1.69 microns (B5)

A Conservative Estimate of Biomass Resources from the Waste land in the Country state-wise and the derived potential for power generation from it

The waste land has been assessed based on Land data obtained from RRSSC. The wasteland is found to be useful to plants suitable for Biomass generation which is otherwise is not being used for agricultural production. A very conservative assessment shows that a power potential of about 50kMW is possible at the country level and around 2.5kMW is possible for the state of Karnataka if properly organized and harnessed. Please see the note below the table for the method of estimates and assumptions used.

State	Geo-graphic Area (MHa)	Crop Area (MHa)	Surplus Agro-Biomass (MT/Yr)	Agro Biomass Based Power Potential (MWe)	Waste Land (MHa)	Woody Biomass (MT/Yr)	Woody Biomass Based Power Portential (MWe)	Total Biomass Power Potential (MWe)
Andhra Pradesh	27.5	12	7.1	830	4.1	28.3	3956.9	4786.9
Arunachal Pradesh	8.2	0.2	0.1	7	0.6	5.0	692.3	699.3
Assam	7.9	3.2	1.9	214	1.2	9.1	1268.7	1482.7
Bihar	9.4	7.1	5.7	655	0.4	3.6	504.3	1159.3
Chattisgarh	13.5	4.5	1.3	150	0.1	0.6	87.0	237.0
Gujarat	18.6	8.4	7.4	916	1.9	13.5	1884.2	2800.2
Haryana	4.4	4.9	7.5	884	0.3	1.6	225.7	1109.7
Himachal Pradesh	5.6		0	0	0.0	0.3	44.4	44.4
Jammu Kashmir	22.2	0.8	0.5	59	0.8	6.3	887.3	946.3
Jharkhand	8	1.9	0.9	106	1.0	7.8	1099.8	1205.8
Karnataka	19.2	8.9	6.9	859	1.1	8.6	1204.7	2063.7
Kerala	3.9	1.6	4.9	640	0.1	4.5	552.2	1192.2
Madhya Pradesh	30.8	14.7	8.4	1,059	5.1	41.3	5789.8	6848.8
Maharashtra	30.7	19.4	13.1	1,711	4.4	27.8	3886.4	5597.4
Manipur	2.2		0	0	1.2	8.9	1263.1	1263.1
Meghalaya	2.2	0.2	0.1	13	0.3	2.4	335.3	348.3
Mizoram	1.8	0	0	1	0.3	2.7	372.2	373.2
Nagaland	1.6		0	0	0.3	1.3	172.6	172.6
Orissa	15.3	5.2	1.9	208	1.6	6.6	885.2	1093.2
Punjab	5	6.9	18.3	2,092	0.0	0.1	10.6	2102.6
Rajasthan	42.7	15.5	10.3	1,289	5.5	20.6	2893.8	4182.8
Sikkim	0.7	0.1	0	2	0.1	0.4	58.2	60.2
Tamil Nadu	13	10.2	13.7	1,186	1.4	8.8	1237.0	2423.0
Tripura	1.1		0	0	0.1	0.8	112.5	112.5
Uttar Pradesh	24	24.1	26.5	3,169	0.7	4.8	670.4	3839.4
Uttaranchal	5.4	0.9	0.8	95	0.5	5.2	468.3	563.3
West Bengal	8.9	7.9	4.7	563	0.4	2.3	316.5	879.5
Total	333.6	158.9	142	16,709	33.6	223.3	30879.5	47587.5

Table.1

Note: The areas reported are derived from satellite imagery (obtained from RRSSC, ISRO) and NRSA published data for waste lands showing sub classifications. Some of these

sub class wasteland areas belonging to 'tough terrains' are not considered as available for Biomass generation as in the states of Maharashtra and Madhya Pradesh. The consistency and concurrence of the estimates has been verified with SOI Data for the Geographic Area. The Agricultural Crop Area and Waste Land Area are verified with reported statistical data from Governmental and other agencies and are found to agree fairly well (within about 10-20%). A reasonable match can be expected among these data sets has been obtained between the reports from Governmental and other reported sources and since the Remote Sensing Data (RSD) is dynamic in nature its spatial distribution is more scientifically managed, it is used for the analysis here. However, to get a conservative estimate on the power potential lower bound limits are applied to work out the projections made in the table. The following points provide clarity on the approach used in the estimates.

1. The Surplus Agro-Biomass is termed as the quantity of Biomass available for power generation from the residues generated from the agro-crops and is applied with corrections for the local variations on the crop yields and is accounted for the social and other utilizations that are considered important that include applications like fodder and thatching. Only the remaining part projected as available for the power generation and termed as surplus.

2. The power potential is termed as the power that could be generated if the biomass is used in the efficient processes like Biomass Gasification. Appropriate factors for variations in calorific value of the residues, typical operating plant load factors and other parameters influencing the efficiencies of power generation components are taken into account while estimating the power potential. The power potential is given in terms of electrical output, only to provide a quick reference to other power plants and demand based analysis. However, for thermal application, the power potential in MWth can be obtained by multiplying the MWe with a factor of 3.5.

3. The Waste Lands areas for getting estimated woody biomass exclude the reserved forests, cultivable (agricultural) fallow lands, water bodies, grass lands, built-up areas (townships), snow covered areas and other lands whose classifications have either known with a clear usage pattern or deemed to not fit for Biomass growth. Though the data are time-variant, the information being derived out of the RSD is believed to be

reasonably consistent and is considered good enough for a first-cut estimate for projecting the area covered under this category.

4. The biomass that could be generated from the waste lands can have different species; some of them considered include Prosopis Julifora, Casuarina, Ipomoea and Eucalyptus. There could be many other fast growing and high yielding species, if the waste lands are converted to energy forests. In the worst scenario, in the current state of growth, the yield from the biomass growth in these lands is considered to be in the range of 3 to 10 tons per hectare and it is known to touch as high as 25 tons per hectare. To ensure a conservative estimate, 3 to 10 tons per hectare (depending on the species) is considered to be the production of the Woody Biomass from the waste lands. Further, allowing for the consumption of this biomass in the ongoing social activities and usages, 20% of this production is considered as not available for power generation, making the estimates to be on the safer side of the operational feasibility.

5. The power generation potential from this the equivalent conversion of the Woody Biomass, corrected with its moisture and ash content, when used with high conversion devices like Biomass Gasifiers. Other factors of this estimate remain identical to what is mentioned for Agro Biomass as mentioned in the point 2 above.

Concluding Remarks, Recommendations and Planned Future Activities

With the changing patterns in the agro-crops, climatic and rainfall and other socio-economic factors influencing the crop pattern as well as the quantities, it is essential that the data needs a periodic update. The design of the work done allows for such updates and it is intended that the data & maps would be updated by procuring the additional data for further period than reported so far as and when they are available. Contributions from different sources such as residue generation from Coffee plantations will also be considered.

It is worth noting that Karnataka alone has an Agro based Biomass power generation potential of about 7% of that at the total in the Country. Karnataka could generate more than 900 MWe [Country's power potential is above 13000 MWe], if the resources with properly planned and utilized. This estimate excludes Biomass residues from Bamboo, Coffee, Tea, Non-edible Oil cakes, urban wastes, Wood, Agro-forestry and

Waste land. If the waste land could be properly and judiciously utilized for biomass growth, it leads to a substantial increase [nearly to 1500 MWe] in the power potential from biomass. The excess biomass (other than the fraction used for essential purposes, value added products or other societal factors) generated from bamboo or other plants / trees could well be accounted to make the study on biomass resource assessment to reach close to reality and this is possible if the concerned agencies and groups generate the data on growing area and other related statistics and publish them suitably.