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The crux of our efforts lies in locating forests and other natural resources within the prevailing economic, social and ecological dynamics in rural landscapes and in intertwining principles of conservation and local self governance for the protection of the natural surroundings and improvement in the living conditions of the poor. By working on systemic issues that can bring about a multiplier change, we strive for a future where the local communities determine and move towards desirable land use that is based on principles of conservation and social justice.

Working Paper 9

BIOMASS ASSESSMENT IN SADHUKONDA RESERVE FOREST AND ADJOINING AREAS, MADANAPALLE, ANDHRA PRADESH, INDIA

The purpose of coming up with this Working Paper is to record our experiences and eventually build on them through discussion, feedback and comments. The contents of the paper can be cited or quoted with acknowledgement.

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1. Background

Biomass may be broadly defined as the weight of all living organisms in a given population, area, volume or other units being measured (Johnson, 1986). However, in this report we shall limit it to mean the weight of above ground dry matter of plants, i.e. phytomass. It is this phytomass that is the basis of all life forms on earth. It forms the base of the food chain, and fulfils a variety of needs of humans as well as animals.

In the context of the project, increase of biomass is one of the major outcomes of the initiatives of communities in the management of common property resources. Apart from performing ecological functions, including biodiversity, biomass fulfils the two most important needs of the communities, fodder and fuel wood. From this need arises the incessant pressure of extraction which if in excess of the rate of growth results in decline of the resource. The decline in vegetation results in the destabilization of soil and moisture regime of the resource. Therefore, it is imperative to know if the demand pressure on a resource is commensurate to the rate of growth. It is in this context that the biomass study has been undertaken.

2. Objectives

The study has been undertaken with the following objectives in mind,

- To estimate the stock and flow of biomass in the Papagni project area.
- To understand the species composition in the study area, particularly the Reserve Forest (RF), and its role in the ecosystem, implications on resource use pattern and *vice-versa*.
- To assess if the biomass utilization is in excess of sustainable limits.
- To estimate per capita biomass availability and demand.
- To analyse the soil nutrient status in the study area.
- To assess the impact of fire on the availability of biomass.

The area of study is about 6,500 Ha in the RF alone. The standard research methodologies suggest that we take one sample of 100 Sq.m. per Ha of RF. This means that we would have had to take roughly 6,400 sample plots! Each of these would have to be surveyed before and after the monsoon. However, keeping in mind the constraints of time and people, and the limited scope of the study, we have adapted the methodology as detailed in a subsequent chapter. Thus, while the data generated is useful for arriving at an understanding of the dynamics of the biomass-livelihood linkage of the region, it would fail the standard tests for error and representativeness. The study was to capture what is possible within the available time, data and resources rather than make a comprehensive assessment in all dimensions. Another guiding

principle was that while statistical accuracy needs to be maintained, the analysis was to observe the trends and inform future course of action rather than to make incontrovertible statements or claims. However, the availability of advanced statistical techniques through GIS enables us to analyse the data on a large spatial scale. The temporal variations would surface after another round of sampling in 4-5 years' time.

A comprehension of the stock and flow situation as well as the per capita requirements of biomass would enable the team[1] to introduce these aspects in the discussions with the communities, so that the latter are able to relook at their resource needs as well as usage patterns. This can only lead to a better management of their resources by the communities. A primary objective of the study therefore is to inform the communities on the quantitative aspects of their biomass dependence. Similarly, a quantification of the losses due to fire in a forest or wasteland would also bring out the finer aspects of it and would hopefully lead to communities taking preventive measures. Of course, a large number of communities are already involved in protection against fire, in which case the discussions would only strengthen their resolve.

The biomass usage can be divided broadly into 4 categories - Fuelwood, Fodder, Timber and Non-Timber Forest Produce (NTFP). Of these, only timber is sourced from the RF alone, whereas the rest are available from private lands and wastelands also. NTFP extraction is generally low in the region and hence it is not being focussed upon here. Even the literature we have surveyed regarding biomass studies do not focus on shrubs and grasses. Therefore, we do not have as yet the methodologies for estimating the sustainable harvest limits for the same. Moreover, the multiple sources for these also complicate the estimation of the extraction patterns in the short period that the study was conducted in.

This biomass study has been a process of learning for the team and in that sense an important objective has also been to develop a system of monitoring vegetation in various habitats in the project area. In developing the methodology for this study, other FES teams were consulted (Natural Resource Accounting System in Anand and Chintamani, Biomass studies in Udaipur) and their learnings were incorporated into it. It is now being shared with other teams and they can undertake similar studies in their project areas.

3. Study area

The project area of the spearhead team in Andhra Pradesh is the catchment of the river Papagni, a tributary of river Pennar. With a strategic shift from working in scattered

[1] FES implements projects in nine locations across India through multi-disciplinary spearhead teams (SHT) of 20-30 people each.

wasteland plots to a watershed (catchment of river Papagni), the project area has been redefined in 1996 to a more hydrologically, socially, politically and economically inter-related area. The project area falls in two districts of Anantapur and Chittoor. These two regions have their own socio-cultural contexts. However, the livelihood-related aspects are by and large the same, and to that extent the entire project area may be taken as one unit.

The Sadhukonda RF in the project area has been selected for the study as the team has already been working with the communities dependent on it for their fodder, fuel wood and other NTFP requirements, since 1991. Sadhukonda is a contiguous hill forest with a high amount of anthropogenic pressure and degrading at an alarming rate over the years. There have been incidents of fire in this forest almost every summer, which has affected the available vegetative biomass and this risk in future could be detrimental to the entire ecosystem. This RF and its dependent villages have been chosen as the study area as this happens to be one of the last patches in the region with relatively better vegetation and a sizeable population dependent on it.

Sadhukonda Reserve Forest (lat 13^0 46' 21.87" and 13^0 54' 35.15" N; long 78^0 25' 13.57 " and 78^0 32' 13.15" E) spread over an area of 6,331 ha. is a tropical mixed dry deciduous forest with patches of thorny scrub. This forest is located in South-Western Andhra Pradesh and in the region where the Deccan plateau meets the broken ranges of the Eastern Ghats with the altitude ranging from 470 to 1128 mt. above mean sea level (MSL). The annual average rainfall is about 650 mm. and the temperature varies from a minimum of 15^0C in winter to a maximum of 45^0C during summer. The soil condition is poor and the forest composition does not show zonations. The laterite soils in the forest are formed by the composition of gneisses, reddish brown in colour, and are rapidly permeable and well drained and are said to be generally poor in organic matter and plant nutrients like nitrogen, phosphate, and potash. The vegetation in the forest is of miscellaneous type and has sub-types based on species associations like *Anogeissus latifolia-Hardwickia binata, Wrightia tinctoria-Chloroxylon swietenia, Wrightia tinctoria-Dolichandrone atrovirens,* and *Acacia sundra*. Part of the Reserve Forest is also a sacred grove with a temple located on a hilltop. The bulk of vegetation consists of co-dominant trees of high drought resistance and thorny scrub. The trees begin to shed their leaves by about December and between February and May the forest looks very open but no area is completely leafless at any one time of the year.

Flowering and fruiting are generally far advanced before the first flush of new leaves appears with the pre-monsoon showers in April-May. The common mammals in the forest include Black-naped Hare (*Lepus nigricollis nigricollis*), Wild boar *(Sus scrofa*), Four-horned Antelope (*Tetracerus quadricornis*), and the Sloth Bear (*Melursus ursinus*).

Species Composition

Some of the typical tree species in the forest are *Anogeissus latifolia, Boswelia serrata, Dolichandrone atrovirens, Chloroxylon swietenia, Diospyros melanoxylon, Albizzia amara, Dalbergia paniculata, Hardwickia binata, Terminalia tomentosa, Ixora parviflora, Grevia rotundifolia, Elaeodendron glaucum, Soumida febrifuga, Premna tomentosa,* etc. *Wrightia tinctoria, Erythroxylon monogynum, Diospyros Montana, Bauhinia racemosa, Strychnos potatorum, Zizyphus mauritiana, Cassia fistula*, etc. are the smaller trees found in this forest.

Common shrub species include *Dodonea viscosa, Flacourtia sepiaria, Plectronia parviflora, Diospyros chloroxylon, Rhus mysorensis, Chomelia asiatica, Randia dumetorum, Pterolobium indicum*, etc.

The ground flora is mostly seasonal and includes *Achyranthes aspera, Anisomeles malabaricum, Solanum indicum, Abutilon indicum, Tephrosia purpurea, Cymbopogan coloratus*, etc.

4. Methodology and data collection

In order to understand the supply-demand pattern of vegetative biomass, we studied the Reserve Forest, Revenue Wastelands, and Private lands. The availability of biomass was estimated from these three types of resources. The requirement of biomass was assessed from the household survey using schedules as well as using standard factors and secondary data. The contribution of biomass from each of these resources was estimated in meeting the biomass requirement of the communities.

Reserve Forest

Various standard sampling methods such as stratified sampling, line transects, belt transects, random sampling and justified random sampling methods applied by various scientists and research organizations were elaborately reviewed. Out of these available methods, justified random sampling of modified Whittaker method was adopted, considering the forest type, topography, species composition, and types of available microhabitats. The field data was collected between October 2002 and February 2003 covering the post-monsoon and winter seasons.

Project Area Map

Study Area Map

Revenue Wastelands

The Revenue Wastelands around the Sadhukonda R.F. were chosen for the estimation of biomass. There are about 200 hamlets around this forest, which could be dependent on it based on their proximity to this resource. Those villages falling within a radius of 2 km have been assumed as the core areas of consumption/utilisation and those more than 2 km are considered as fringe areas. However, the availability of secondary data is only at the revenue village level[2], and so for purposes of extrapolation, we have taken adjoining revenue villages as the core areas of consumption.

Seven hamlets meeting the above criteria around Sadhukonda RF have been selected for a detailed study. The wastelands in these hamlets are considered for the estimation of biomass in addition to the Reserve Forest area. Trees, shrubs, and ground flora have been taken into consideration and their biomass was calculated using the same methodology adopted for the Reserve Forest.

Private lands

Household survey has been conducted in these villages in order to understand the day-to-day requirement of fodder, fuel wood, timber, and NTFP. Data has been collected on family size, landholding, livestock, and consumption of vegetative biomass for their livelihood needs.

Agriculture area was taken from Census 1991 and Standard multipliers used by the local agriculture department were taken to estimate the crop biomass of major crops like paddy for wetlands, and groundnut for dry lands.

GIS

In order to have a synoptic view of the study area a Digital Elevation Model has been created for the Sadhukonda Reserve Forest range and used for planning. Information on altitude, land cover, microhabitat types and proximity to the villages were considered for the study. Global Positioning Systems were used to record the spatial location of the sample plots. Five distinct microhabitats have been identified and a total of 152 plots were sampled representing all these microhabitats of the study area.

[2] A revenue village is the smallest administratively recognized unit in Andhra Pradesh. One revenue village would typically consist of 10-15 hamlets. Although FES works with institutions at the hamlet level, the lack of administrative recognition of this level of habitation means that data such as land holdings are not available for each hamlet.

5. Analysis and Interpretation

The RF and wasteland survey data was entered into and analysed in a customized software 'Ecoinfo for FES' Version 1.3, built by Thematics, Bangalore. The village survey data has been analysed separately in MS-Excel 2000. In all 152 plots have been sampled in the RF and 31 in the 6 protected wastelands.

Table 1: Number of species in the study area

S. No.	Form	No.
1.	Trees	121
2.	Shrubs	58
3.	Herbs and Grasses	73

A total of 252 species of all forms were encountered in the survey as shown in Table 1. Majority of them are found in small numbers and have therefore been excluded from the detailed analysis. The focus here is on 15 species of trees, which contribute to almost 70 % of total population, basal area and density. These 15 species have been selected on the basis of Importance Value Index (IVI).

Importance Value Index (IVI)

Anogeissus latifolia is the most commonly found species and exhibits the maximum relative frequency of occurrence as well as basal area and is almost evenly spread on the slopes and at the lower parts of the forest, resulting in the highest IVI. *Acacia sundra*, ranking second, is the densest and is seen in large colonies and most dominant at the foothills and on some slopes. *Dolichandrone atrovirens*, ranking third is also sometimes seen in association with *Acacia sundra*, with almost same values of relative density and frequency of occurrence, but compared to the other two, has a relatively low basal area. Most of them are young and regenerating and have low girth.

Table 2: Importance Value Index Calculation for top 15 tree species

S. No.	Species Name	Relative Density (RD)	Relative Frequency of Occurrence (RFO)	Relative Basal Area (RBA)	IVI (RD+RFO+RBA)	Rank
1	*Anogeissus latifolia*	7.24	19.52	15.53	42.28	1
2	*Acacia sundra*	11.11	17.15	12.61	40.87	2
3	*Dolichandrone atrovirens*	10.08	10.76	5.23	26.07	3
4	*Chloroxylon swietenia*	5.94	11.84	5.83	23.60	4
5	*Terminalia tomentosa*	3.10	3.53	3.74	10.37	5
6	*Grewia rotundifolia*	4.01	2.14	2.53	8.68	6
7	*Gymnosporea emarginata*	4.13	2.81	1.10	8.05	7
8	*Wrightia tinctoria*	3.36	1.88	2.44	7.67	8
9	*Dalbergia paniculata*	1.55	0.85	5.26	7.66	9
10	*Cassia fistula*	3.75	2.28	1.40	7.42	10
11	*Hardwickia binata*	1.16	0.89	4.53	6.58	11
12	*Ixora parviflora*	2.45	1.74	2.29	6.48	12
13	*Premna tomentosa*	2.97	1.21	2.09	6.27	13
14	*Diospyros montana*	0.90	0.40	4.63	5.94	14
15	*Elaeodendron glaucum*	2.07	1.30	2.11	5.48	15

Suitability of species to environmental pressures

Apart from natural pressures like drought, poor soil, the RF also faces anthropogenic pressure including fires. It is therefore pertinent to examine the dominant species against these factors. The ratings are, the higher the number (range 1 to 10), the better it is and higher the quality for that use, relative to others.

Considering the resistance to drought, fire, ability to do well in shallow and rocky soils, importance as fuel wood, and use for timber it was found that *Hardwickia binata* is the most important species, yet is relatively less abundant probably because most of them have been felled in the past. They are also not allowed to attain their maximum size because of heavy lopping for fodder, and stripping of bark for fibre.

Anogeissus latifolia or Axle wood Tree occupies the second place in overall ranking and it also happens to be one of the most abundant and preferred species for its valuable timber and NTFP and forms one of the major components of the dry deciduous forests. The wood is also locally used in making parts of the bullock-cart and ploughshares and the gum that exudes from the bark is one of the NTFP collected by the locals and sold to the confectionery industry.

Diospyros melanoxylon or Indian Ebony stands third in the overall ranking and its leaves are harvested and used for rolling *beedis* and gives a fair income to the villagers. This species is extremely fire-hardy and seldom allowed to grow to its maximum size, useful for timber, instead, constantly hacked or burnt to get broad leaves that would fetch a better price.

Wrightia tinctoria or Ivory Wood Tree and *Acacia sundra* stand fifth in the overall ranking and are of considerable economic importance. Locally the leaf of *Wrightia tinctoria* is preferred as green manure and the lightwood is used in turnery, for making toys, kitchenware, and being soft is also preferred for woodcarving. The latex has medicinal use and the leaves and seeds yield an indigo-like dye. *Acacia sundra* that is found commonly on degraded soils and growing in large communities is a principal source of fuel wood and wood being of high calorific value is also used as fuel in the brick kilns.

These 15 species have high resistance to fire and drought. With the laterite soils that are poor in organic content and low in plant nutrients, all these species do well in poor and rocky soils. Almost all of them are found to be good for fuel wood. Although some of them are good timber varieties, in the given conditions, they do not attain the size suitable to be used for timber.

Table 3: Ranking of species against environmental pressures

S No.	Scientific Name	Fire Hardiness	Drought Resist.	Soil Suitability		Economic Importance		Overall Rank
				Shallow Soils	Rocky Soils	For Fuel	For Timber	
1.	*Wrightia tinctoria*	5	10	7	8	4	3	5
2.	*Anogeissus latifolia*	8	8	6	8	7	7	2
3.	*Acacia Sundra*	7	10	5	4	9	2	5
4.	*Chloroxylon swietenia*	8	8	6	6	4	2	8
5.	*Diospyros melanoxylon*	8	8	5	6	4	8	3
6.	*Dolichandrone atrovirens*	6	5	6	6	4	6	9
7.	*Hardwickia binata*	6	8	8	8	8	8	1
8.	*Dalbergia paniculata*	3	7	5	5	6	9	7
9.	*Terminalia tomentosa*	5	6	4	5	6	8	8
10.	*Albizzia amara*	8	7	5	5	7	4	6
11.	*Ixora parviflora*	7	7	5	6	8	5	4
12.	*Grewia rotundifolia*	5	6	7	7	5	4	8
13.	*Elaeodendron glaucum*	5	6	6	5	4	2	10
14.	*Premna tomentosa*	6	6	7	7	5	4	7
15.	**Erythroxylon monogynum**	7	7	6	7	7	2	6

Species with high frequency of occurrence

The 15 most common tree species that occurred in the forest are, *Wrightia tinctoria, Anogeissus latifolia, Acacia sundra, Chloroxylon swietenia, Diospyros melanoxylon, Hardwickia binata, Dalbergia paniculata, Terminalia tomentosa, Albizzia amara, Ixora parviflora, Grewia rotundifolia, Elaeodendron glaucum, Premna tomentosa, Terminalia chebula,* and *Erythroxylon monogynum.* Most of these species are fire-hardy and drought resistant and commonly found in the mixed dry deciduous forests in this semi-arid region.

Table 4: Species (and families) occurring with maximum frequency in the Reserve Forest

S.No.	Scientific Name	Family
1.	*Wrightia tinctoria*	Apocynaceae
2.	*Anogeissus latifolia*	Combretaceae
3.	*Acacia sundra*	Leguminoseae-Mimosoideae
4.	*Chloroxylon swietenia*	Rutaceae
5.	*Diospyros melanoxylon*	Ebenaceae
6.	*Dolichandrone atrovirens*	Bignoniaceae
7.	*Hardwickia binata*	Leguminoseae-Caesalpinoideae
8.	*Dalbergia paniculata*	Leguminoseae-Papilionoideae
9.	*Terminalia tomentosa*	Combretaceae
10.	*Albizzia amara*	Leguminoseae-Mimosoideae
11.	*Ixora parviflora*	Rubiaceae
12.	*Grewia rotundifolia*	Tiliaceae
13.	*Elaeodendron glaucum*	Celastraceae
14.	*Premna tomentosa*	Verbenaceae
15.	*Erythroxylon monogynum*	Linaceae

Of the tree and shrub species represented by 58 families, *Mimosoideae* is dominating with 18 species followed by *Combretaceae* and *Papilionaceae* with 11 species each, while *Caesalpinoideae* and *Rubiaceae* were represented by 10 species each.

Table 5: Family-wise break-up of species in the RF

S.No.	Family	No. of Species
1.	Leguminoseae-Mimosoideae	18
2.	Combretaceae	11
3.	Leguminoseae-Papilionoideae	11
4.	Leguminoseae-Caesalpinoideae	10
5.	Rubiaceae	10
6.	Rutaceae	9

Species Abundance

During the survey it was found that the most abundant species is *Acacia sundra* with a relative density of 11.11. They occupy most of the foothills and dominate the degraded parts of the forest. They contribute to a large extent as good fuel wood. The wood is also used for making furniture and in the brick kilns as fuel. This is followed by *Dolichandrone atrovirens*, which seem to do well in this kind of soils with a relative abundance value of 10.07. *Anogeissus latifolia*, usually found in colonies is the third most abundant species with a relative density value of 7.23.

Table 6: Abundance of tree species

S. No.	Species Name	No. in All the Plots	No. in Total Area (Ni)	Species Density	Relative abundance (%)
1	*Anogeissus latifolia*	437	19,10,564	291	7.24
2	*Acacia sundra*	384	16,78,848	256	11.11
3	*Dolichandrone atrovirens*	241	10,53,652	161	10.08
4	*Chloroxylon swietenia*	265	11,58,580	177	5.94
5	*Terminalia tomentosa*	79	3,45,388	53	3.10
6	*Grewia rotundifolia*	48	2,09,856	32	4.01
7	*Gymnosporea emarginata*	75	3,27,900	50	4.78
8	*Wrightia tinctoria*	42	1,83,624	28	3.36
9	*Dalbergia paniculata*	19	83,068	13	1.55
10	*Cassia fistula*	51	2,22,972	34	3.75
11	*Hardwickia binata*	20	87,440	13	1.16
12	*Ixora parviflora*	39	1,70,508	26	2.45
13	*Premna tomentosa*	27	1,18,044	18	2.97
14	*Diospyros Montana*	9	39,348	6	0.90
15	*Elaeodendron glaucum*	29	1,26,788	19	2.07

Diversity Index

The values of 0.079 on the Simpson's index and 1.418 on the Shannon-Wiener's index mean that a number of species are represented in good numbers rather than any one species dominating.

Abundance of Shrub Species

During the survey it was found that among all the shrubs *Acacia sundra* is dominating with a relative abundance of 19.65 as it happens to be a major component of the degraded sites in the area and also this species has a colonizing behaviour, followed by

Randia dumetorum with 14.53 and this happens to be an indicator species of degradation of the forest ecosystem. As we move up from the foothills towards the higher elevations, the abundance decreases. *Chloroxylon swietenia* with 14.44 ranks third among the five most dominant shrubs.

Table 7: Species abundance for Shrubs in the RF

S. No.	Species Name	Species Density	Relative abundance (%)
1.	*Acacia sundra*	143	19.65
2.	*Randia dumetorum*	106	14.53
3.	*Chloroxylon swietenia*	105	14.44
4.	*Grewia rotundifolia*	64	8.77
5.	*Lantana camara*	62	8.50

Woody Biomass

The standing woody biomass of *Anogeissus latifolia* is the highest at 10.31 T/ha and this is about 2 T/ha more than *Acacia sundra*, which stands second. The growth of *Anogeissus latifolia* has been good in the last four years of protection from anthropogenic pressures. Its basal area is much higher than that of *Acacia sundra*, which is found to colonize most of the foothills in large patches. Together, these two species contribute to about 58% of the total standing woody biomass.

The sample plots have been digitised into the GIS and a database has been created. Using kriging, a statistical technique in GIS, the biomass values of the plots have been used to interpolate the values for points all over the RF. For calculating the biomass of each point, the values of the 12 closest sample plots have been considered. ***The total biomass of the RF thus calculated is 524,803 MT, which includes 472,315 MT of Tree biomass, 43,647 MT of shrub biomass and 8,841 MT of grass and herb biomass. Considering the total area of the RF, which is 6,558 Ha, the average tree biomass is 80 MT/Ha.*** Research studies[3] indicate that the normal average biomass for a dry deciduous forest is 70-80 MT/Ha. This suggests that the Sadhukonda RF is slowly regenerating due to efforts of communities in protection and management, although it is still in a degraded state.

[3] Murali, KS, Bhat, DM, and Ravindranath, NH (..); Biomass Estimation Equations for tropical deciduous and Evergreen forests. CES Technical Report No. 81. Centre for Ecological Sciences, Bangalore.

Table 8: Woody biomass status for the 15 dominant tree species in RF

S.No.	Species Name	Basal Area (m^2)	Basal Area (m^2/Ha.)	Standing Woody Biomass (T/Ha.)	Annual Woody Biomass Increment (T/Ha/Yr) (2.84%)	Potential Harvestable Limit (T/Ha/Yr)	Harvestable Limit for RF (MT/Yr)
1	*Anogeissus latifolia*	2.19	1.44	10.31	0.29	0.10	634
2	*Acacia sundra*	1.78	1.17	8.05	0.23	0.08	495
3	*Dolichandrone atrovirens*	0.74	0.49	2.35	0.07	0.02	144
4	*Chloroxylon swietenia*	0.82	0.54	2.81	0.08	0.03	173
5	*Terminalia tomentosa*	0.53	0.35	1.20	0.03	0.01	74
6	*Grewia rotundifolia*	0.36	0.23	0.26	0.01	0.00	16
7	*Gymnosporea emarginata*	0.18	0.12	0.00	0.00	0.00	0
8	*Wrightia tinctoria*	0.34	0.23	0.19	0.01	0.00	12
9	*Dalbergia paniculata*	0.74	0.49	2.37	0.07	0.02	146
10	*Cassia fistula*	0.20	0.13	0.00	0.00	0.00	0
11	*Hardwickia binata*	0.64	0.42	1.81	0.05	0.02	111
12	*Ixora parviflora*	0.32	0.21	0.08	0.00	0.00	5
13	*Premna tomentosa*	0.29	0.19	0.00	0.00	0.00	0
14	*Diospyros montana*	0.65	0.43	1.89	0.05	0.02	116
15	*Elaeodendron glaucum*	0.30	0.20	0.00	0.00	0.00	0

Note: A 'Nil' biomass value indicates that the basal area of the species is less than the minimum limit for the regression equation used to calculate the value of biomass.

Carbon Sequestration

One of the functions of a forest, which is receiving a lot of focus these days, is Carbon Sequestration. Sadhukonda RF has better vegetative cover than the other RFs in the project area. It is also a single large contiguous area with tree cover and hence its role in sequestering Carbon is critical for the entire region. The total woody biomass in Sadhukonda being 524,803 MT, the amount of Carbon being sequestered is 89,217 MT per annum.

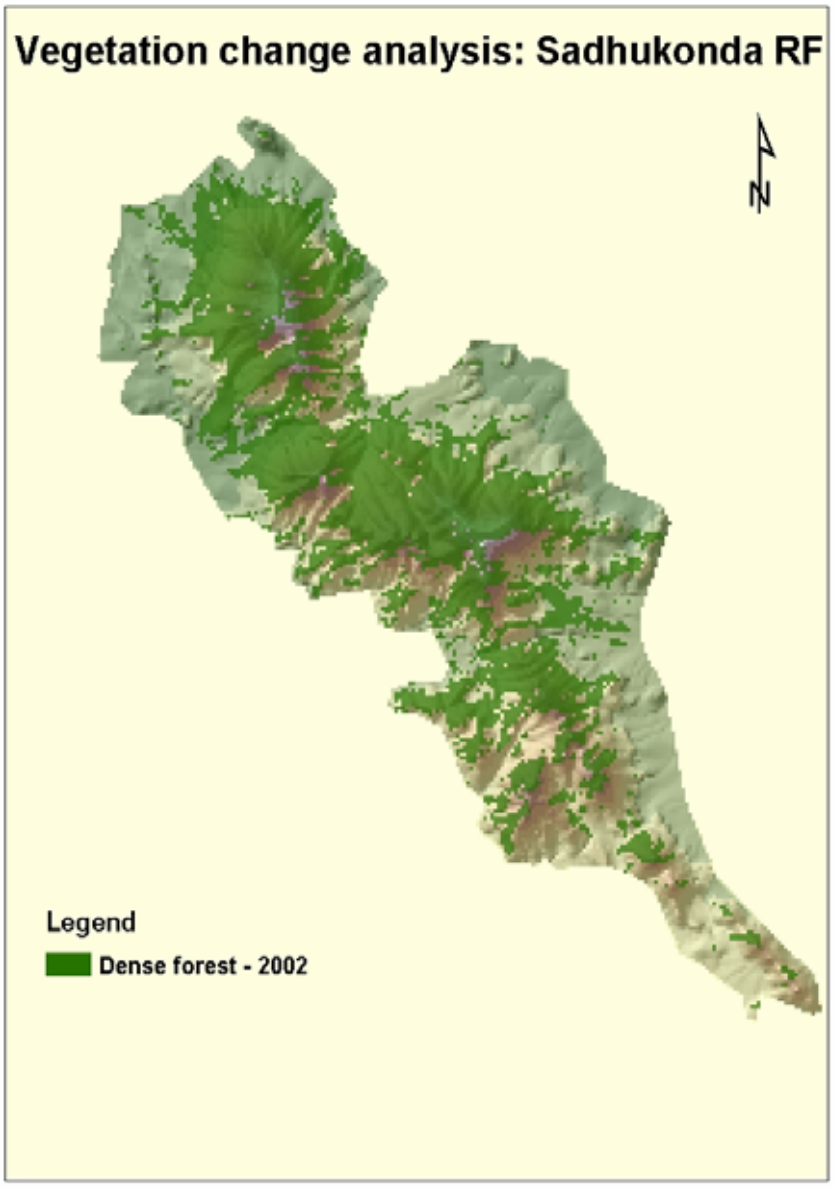
Distribution of trees in different girth classes across microhabitats

The tree species have been classified into four girth classes viz. Seedlings (GBH 0-5 cm.), Saplings (5-10 cm.), Regenerating (10-30 cm.), and Timber (>30 cm.). The five microhabitats identified in the study area are Drain, Foothill, Hill Slope, Plateau, and Ridgeline. Across all these microhabitats it was observed that more than 50 % of the species counts show that they are in the Regenerating class due to the protection during the last 5 years. The Seedling category is found most along the slopes and drains, probably due to the available light, moisture, humus, and less pressure from the herbivores. Saplings, which are about 20% of the total count, also are found highest along the drains and slopes, possibly for the same reasons. Even the regeneration appears highest along drains and slopes as more than 50% of the counts fall under this class in these two microhabitats. The timber class contributes to almost 20% of the total and most of them are found again at the slopes and the drains, and poor accessibility could have contributed to their survival. The overall distribution also shows that most numbers fall in the regenerating category and more than 54% of the counts fall in the height class of 1.8 to 4.3 meters as it is a regenerating forest and the trees do not attain their full size in this dry deciduous forest, semi-arid regions, and shallow soils.

Table 9: Microhabitat-wise distribution of dominant tree species

Micro Habitat	Class	Count	Micro Habitat	Class	Count
Drain	0 to 10 cm	157	Hill Slope	0 to 10 cm	151
	10 to 30 cm	396		10 to 30 cm	462
	More than 30 cm	135		More than 30 cm	167
Foothill	0 to 10 cm	51	Plateau	**0 to 10 cm**	23
	10 to 30 cm	120		10 to 30 cm	70
	More than 30 cm	25		More than 30 cm	20
Ridgeline	0 to 10 cm	79	Total	0 to 10 cm	461
	10 to 30 cm	220		10 to 30 cm	1268
	More than 30 cm	82		More than 30 cm	429

Dense forest cover as classified by using Satellite imagery of December, 2002



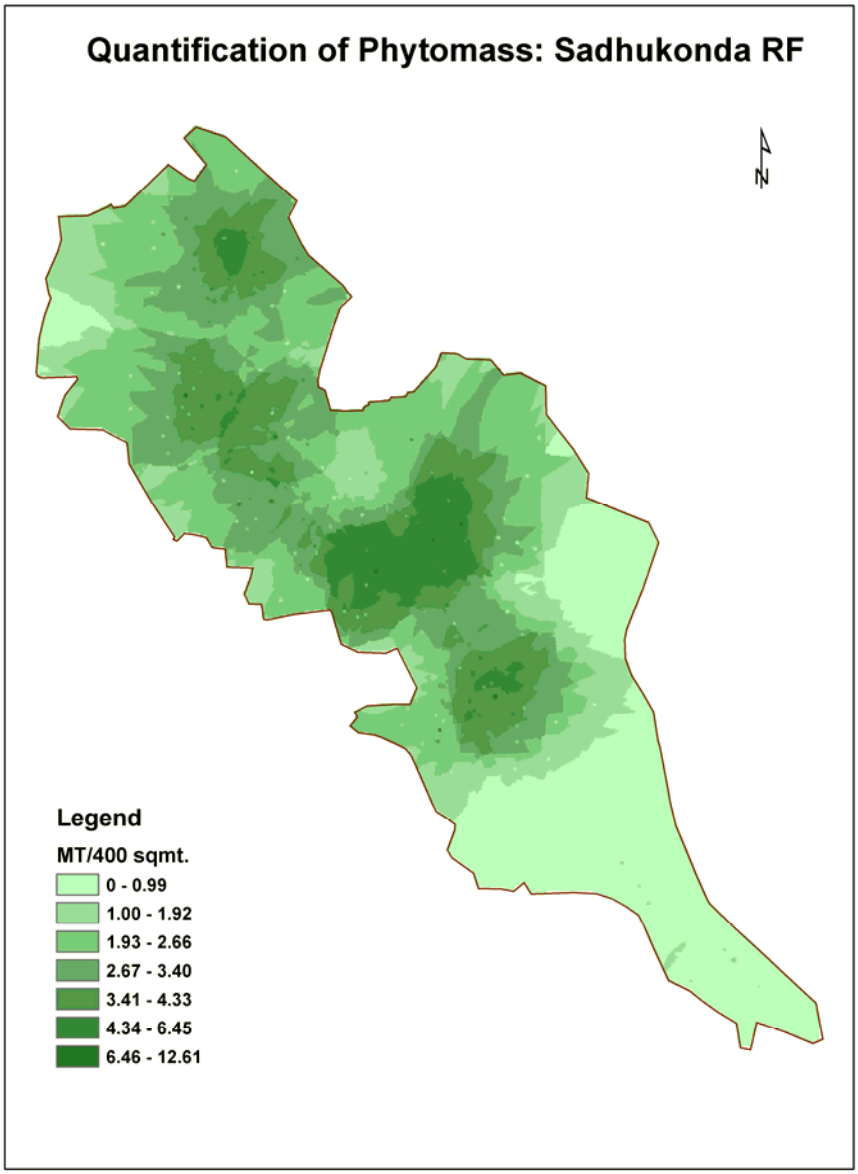

Quantification of Phytomass: Sadhukonda RF
N
Legend
MT/400 sqmt.
0 - 0.99
1.00 - 1.92
1.93 - 2.66
2.67 - 3.40
3.41 - 4.33
4.34 - 6.45
6.46 - 12.61

Table 10: Distribution of tree species as per height classes

Height class (m)	Numbers	Percentage
< 1.8	151	7
1.8 - 4.3	1210	54
4.3 - 6.8	553	25
6.8 - 9.3	202	9
> 9.3	123	5

Note: The height classes are based on Mean =4.3 and SD = 2.5.

Biomass Distribution across the microhabitats

Of the total estimated biomass, a major portion (70%) is available along the drains and the hill slopes probably due to the available moisture and nutrients along the drains and the larger area contributed by the hill slopes in this forest.

Table 11: Tree biomass distribution across microhabitats

S. No.	Micro - habitat	No. of Plots	Basal Area (Sq. M)	Biomass (MT/Ha)	Total Estimated Biomass (MT/Ha)	% of total Biomass
1	Drain	40	10.9	89.3	156,151	32
2	Foothill	19	5.0	39.8	33,093	7
3	Hill Slope	44	12.0	98.1	188,792	38
4	Plateau	6	13.3	109.0	28,587	6
5	Ridgeline	29	8.4	68.5	86,910	18

IVI and other parameters for the major tree species across the microhabitats

The Importance Value Index rating of the tree species across the microhabitats shows that *Anogeissus latifolia* ranks the highest in most of the microhabitats like Drains, Hill Slopes, Plateau, and Ridgeline. The value is the highest in the drains. Once again it appears that due to availability of more moisture and organic content in the soil along the drains, *Anogeissus latifolia* seem to do better along the drains than in other microhabitats and the lowest is recorded at the foothills where anthropogenic pressure is the highest. The relative density of this species also is recorded lowest at the foothills.

In drains, the highest relative frequency is of *Acacia sundra*, relative density and dominance is of *Anogeissus latifolia*. The former is more frequent than others probably because of the rate and speed at which they spread and they do not seem to allow other species to establish. At the foothills, *Acacia sundra* has the highest relative frequency and density, probably because of the large areas they have occupied while *Hardwickia binata* has highest relative dominance because of higher girth size. On the hill slopes, *Dolichandrone atrovirens* has the highest relative frequency while *Anogeissus latifolia* has the highest relative density and dominance. On the plateau, both *Chloroxylon swietenia* and *Acacia sundra* have equally high relative frequency, *Chloroxylon swietenia* with highest relative density, and *Anogeissus latifolia* with highest relative dominance. On the ridgeline, *Dolichandrone atrovirens* has the highest relative frequency; *Anogeissus latifolia* with highest relative density and *Diospyros montana* has the highest relative dominance.

Overall, *Acacia sundra* is the most frequent in drains, foothills, and plateau, while *Dolichandrone atrovirens* is the most frequent in the hill slopes and ridgelines. *Anogeissus latifolia* has the highest relative density in the drains, hill slopes, and the ridgeline while *Acacia sundra* has the highest in foothills and *Chloroxylon swietenia* on the plateau. *Anogeissus latifolia* has the highest relative dominance in drains, hill slopes, and plateau while *Hardwickia binata* has the most relative dominance at the foothills, and *Diospyros montana* on the ridgeline.

6. Faunal Evidence in Sadhukonda RF

The Peninsular region is the home of the true Indian fauna of which the Spotted deer, the Blackbuck, the Four-horned antelope, and the Sloth bear are typical representatives. Considering the varied conditions under which they live, it is seen that they share with all other living things, the strong natural tendency to increase their sphere of action and to extend their territory. The knowledge of animal life gives us a better understanding of the ecological and bio-geographic history of the region. It reveals changes, which have taken place in the distribution of land and water, and shows how the present distribution of land animals has been brought about. Some of the factors have influenced this distribution or produced changes in or the extermination of numerous forms. In our day, the agency that accelerates these changes is man. Habitat loss and anthropogenic pressure on the forest, along with the prevailing drought conditions, has to a large extent affected the density and distribution of fauna.

During the study, it was found that the most common small mammal in this forest is the Indian Hare. The second most frequently occurring mammal is the Indian Wild boar, followed by the Four-horned Antelope and the Sloth Bear. Out of 152 sample plots, direct or indirect evidence of the Indian Hare occurred in 47 plots, Wild boar in 23, Four-horned Antelope in 18, and Sloth Bear in 8 plots.

The Indian Hare (*Lepus nigricollis nigricollis*) is distinctive in having a dark brown or black patch on the back of its neck from the Common Indian Hare. These hares are two different races and the latter is usually confined to the plains while the Black-naped Hare is common in the hills of the region and wherever the habitat is suitable, they are numerous. Large tracts of bush and jungle alternating with patches of grassland offer them ideal conditions. They are nocturnal but not exclusively so. They scoop out a hollow in patches of grass where they rest during the day. They breed chiefly between October and February. Hunting by locals with guns, snares, and the habitat destruction by fire are the major threats to these animals in this forest.

The Indian Wild boar (*Sus scrofa*) lives in grass or scanty bush jungle, sometimes in forest. They are omnivorous, living on crops, roots, tubers, insects, snakes, offal, and carrion. They feed in the early morning and late in the evening and, when much disturbed, chiefly at night. Wild Boars are highly prolific. They apparently breed at all seasons. Usually four to six young are born at a time. After breeding, the big boars live alone or in company with another of equal size or with one or two sows. They are known to damage the crops, especially groundnut at the foothills of this forest, which brings them into conflict with farmers. This fact, apart from this being the most relished of game meat, makes it the most hunted animal in this forest.

The Four-Horned Antelope (*Tetracerus quadricornis*) is distinguishable from the true antelopes by several characters. Among the more obvious points of distinction is the structure of the horns, which are not ringed as in true antelopes, instead, are keeled in front. The females are hornless. This is the only member of this group with two pairs of horns and presence of glands between the false hooves of the hind legs. They are distributed where the country is wooded and hilly, but not too densely forested. This antelope lives in undulating or dry hill country, shelters in tall grass, which is often *Cymbopogan coloratus*, and open jungle. These little animals drink regularly and are much more dependent on water than others of their kind and seldom live far from it. They do not gather in large herds, and are usually seen alone or in pairs. Before the rains one or two fawns may accompany the female; sometimes two old animals and two young will be seen together, or even a buck with four or five does. They have a habit of defecating in one place, which seems to act as marking of the territory and communication within the community. The breeding season is in the hot weather and during the early monsoon and young are born from October to February. Local hunters wait in hides with guns near the waterholes, which they frequent, to hunt them.

The Sloth Bear (*Melursus ursinus*) are found in the forest where food is available and favour places where outcroppings of rock and tumbled boulders offer them shelter during the hot weather or rains. They come out shortly before sunset, hunt for food all night, and retire in the morning. Their food, in this forest mainly consists of fruits of *Cassia fistula, Zizyphus mauritiana, Lantana camara, Syzigium cuminii, Gardenia gummifera*, etc., insects, and honey when available. They are also known to raid

groundnut fields when the pods are ready. What they eat depends upon locality and season. Dug out termite mounds are evidence that these bears are around. Young are born between December and January. The young live with the mother for 2-3 years till they attain maturity.

7. Biomass availability and extraction patterns

In order to assess the demand for biomass and the patterns of extraction, 7 hamlets were surveyed. A number of parameters were considered for the sampling such as,

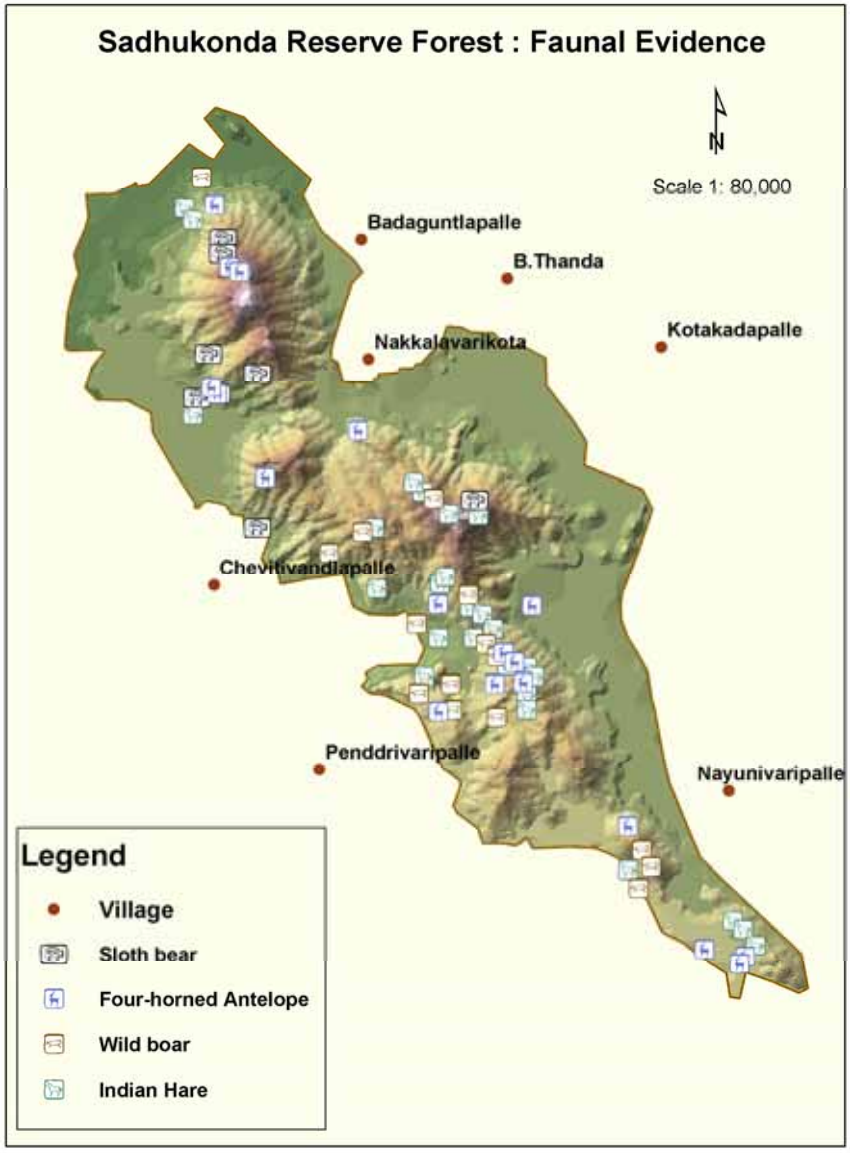
- Extent of RF managed,
- Extent of Wasteland accessed,
- No. of Households,
- Proximity to RF, and
- Relative economic status.

The sample villages and their characteristics are given below:

Table 12: Characteristics of sample hamlets

S No.	Name of hamlet	Extent of RF mana-ged (Ha)	Extent of wasteland accessed (Ha)	No. of HHs	Proximity to RF (km)	Relative Economic status
1	Penderivaripalle	110	60	42	1.600	High
2	Nayunivaripalle	0	48	39	0.900	Medium
3	Bodhaguntlapalle	190	20	12	0.350	Poor
4	Chevitivaripalle	50	40	**25**	0.925	Medium
5	Kotakadapalle	56	60	78	2.250	Medium
6	Bathinigaripalle Tanda	120	68	**24**	1.000	**Poor**
7	Nakkalavarikota	226	0	47	0.325	Poor

The land availability in the dependent revenue villages are given below:


Sadhukonda Reserve Forest : Faunal Evidence
N
Scale 1: 80,000
Badaguntlapalle
B.Thanda
Nakkalavarikota
Kotakadapalle
Chevitivandlapalle
Penddrivaripalle
Nayunivaripalle
Legend
Village
Sloth bear
Four-horned Antelope
Wild boar
Indian Hare

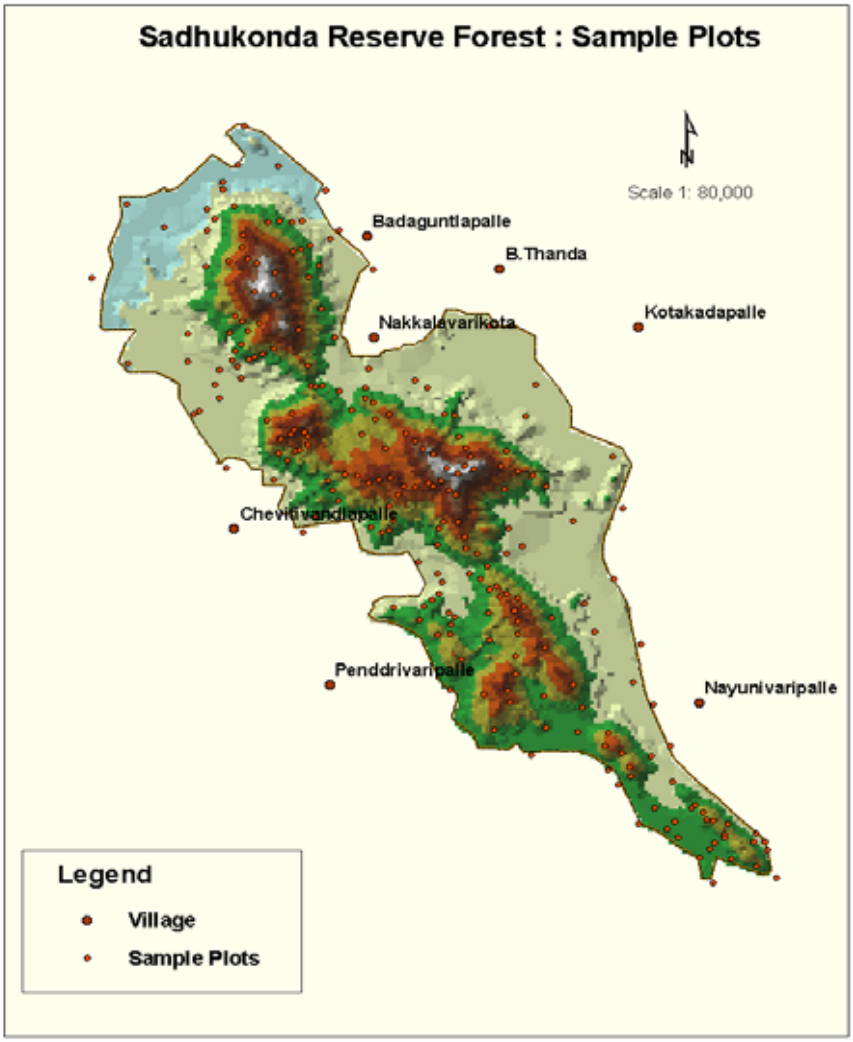

Sadhukonda Reserve Forest : Sample Plots
N
Scale 1: 80,000
Badaguntlapalle
B.Thanda
Nakkalavarikota
Kotakadapalle
Chevilivandlapalle
Penddrivaripalle
Nayunivaripalle
Legend
Village
Sample Plots

Table 13: Land availability in dependent revenue villages

S No.	Revenue Village	Dryland (Ha)	Wetland (Ha)	Wasteland (Ha)
1	Bandrevu	1192	121	637
2	Kotala	688	215	1316
3	Kalicherla	1920	187	2317
4	Gopidinne	1831	83	211
5	Siddavaram	368	93	206
6	Thambalapalle	2348	132	1106
7	Veligallu	1096	231	703
8	Eddulavaripalle	677	34	119
9	Kotakonda	758	108	343
10	Renimakulapalle	1307	153	125
	Total	**12185**	**1357**	**7083**

The livestock population in the surveyed hamlets is as given below:

Table 14: Livestock population in surveyed hamlets

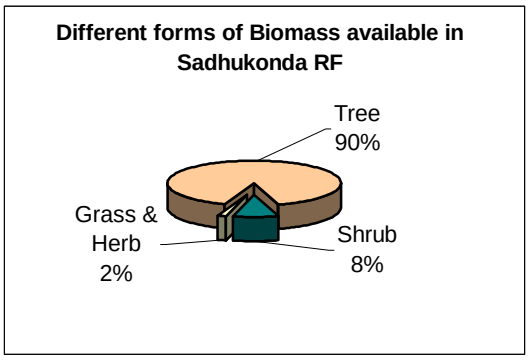
S No.	Hamlets	Cattle	Calves	Sheep	Goats
1	Penderivaripalle	79	32	243	129
2	Nayunivaripalle	56	19	270	48
3	Bodhaguntlapalle	19	7	0	26
4	Chevitivaripalle	22	12	40	10
5	**Kotakadapalle**	112	17	590	10
6	Bathinigaripalle Tanda	30	10	40	5
7	Nakkalavarikota	41	12	85	186
	Total	**359**	**109**	**1268**	**414**

Availability of biomass

As mentioned earlier, the biomass estimation of RF based on data from 152 sample plots, and then kriging in GIS, yielded the following biomass distribution in the RF:

Table 15: Estimated biomass availability of Sadhukonda RF

Form of Biomass	Qty (MT)
Tree Biomass	472,315
Shrub Biomass	43,647
Grass & Herb Biomass	8,841
Total Biomass	**5,24,803**



Based on the survey data of wastelands the biomass availability of these hamlets is estimated as given below:

Table 16: Extent of different types of biomass in wastelands of surveyed hamlets

S No.	Hamlet	Tree (MT)	Shrub (MT)	Grass (MT)
1	Penderivaripalle	714	541	66
2	Nayunivaripalle	1,023	601	39
3	Bodhaguntlapalle	572	346	8
4	Chevitivaripalle	463	280	24
5	Kotakadapalle	1,037	1,667	99
6	Bathinigaripalle Tanda	1,758	509	75
7	Nakkalavarikota	0	0	0
	Total	**5,567**	**3,944**	**312**

Table 17: Biomass availability in Wastelands of dependent revenue villages

S. No.	Revenue Village	Biomass availability		
		Tree (MT)	Shrub (MT)	Grass (MT)
1	Bandrevu	12,371	8,614	603
2	Kotala	25,559	17,796	1,246
3	Kalicherla	45,000	31,333	2,193
4	Gopidinne	4,098	2,853	200
5	Siddavaram	3,993	2,780	195
6	Thambalapalle	21,480	14,957	1,047
7	Veligallu	13,660	9,511	666
8	Eddulavaripalle	2,311	1,609	113
9	Kotakonda	6,662	4,638	325
10	Renimakulapalle	2,428	1,690	118
	Total	**137,562**	**95,781**	**6,706**

In case of biomass from agricultural fields, the variation in flora on the bunds is too high to be estimated by any sampling method. The biomass from the crops have been estimated with the help of standard multipliers and these are given below:

Table 18: Extent of biomass available from agricultural fields

S.No.	Hamlet	Crop biomass (MT)	Residue (MT)
1	Penderivaripalle	65	92
2	Nayunivaripalle	59	63
3	Bodhaguntlapalle	20	33
4	Chevitivaripalle	11	18
5	Kotakadapalle	91	106
6	Bathinigaripalle Tanda	20	39
7	Nakkalavarikota	16	43
	Total	**282**	**395**

Note: For Paddy, 60% of the area is assumed to be under double cropping.

Table 19: Biomass availability in agricultural fields of dependent revenue villages

S. No.	Revenue Village	Crop Biomass (MT)	Residue (MT)
1	Bandrevu	349	762
2	Kotala	464	1,560
3	Kalicherla	549	2,670
4	Gopidinne	352	269
5	Siddavaram	208	267
6	Thambalapalle	497	1,291
7	Veligallu	538	880
8	Eddulavaripalle	136	147
9	Kotakonda	278	427
10	Renimakulapalle	421	201
	Total	**3,792**	**8,475**

Note: For Paddy, 60% of the area is assumed to be under double cropping.

The contribution from field bunds for fuel wood is only occasional, as and when a tree may be cut or in the form of dry twigs of small shrubs. After the harvest of crops, the fields are a preferred grazing area for cattle. The grass and dry leaves left after harvest

of groundnut would meet the grazing requirement of the livestock for as long as a month. The crop residue from Groundnut, Jowar, and Redgram is used as fodder during the rest of the summer.

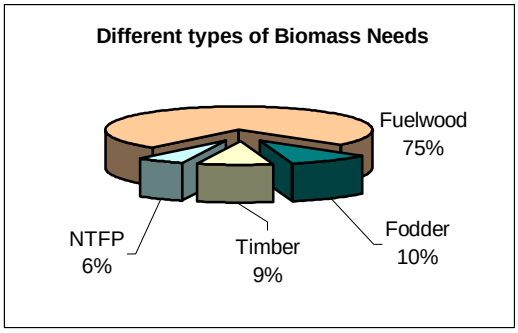
Demand for Biomass

The recurring drought in the last few years has scaled up the pressure on the resources and particularly the RF. The failure of agriculture this year has meant that even the families, which were not directly dependent on the RF for their livelihoods in normal years, are now depending on the RF for NTFP, fuelwood and fodder. This may have resulted in the exaggeration of the average per capita extraction rates we have estimated in this study. The table given below summarises the biomass needs of the surveyed hamlets.

Table 20: Biomass Extraction levels in surveyed hamlets

S. No.	Name of the hamlet	Biomass Extraction (kg)				Total Qty (kg)
		Fuelwood	Timber	NTFP	Fodder	
1	Penderivaripalle	55,180	1,770	800	26,125	83,875
2	Nayunivaripalle	1,17,060	630	3,125	18,013	1,38,828
3	Bodhaguntlapalle	76,880	8,223	4,302	6,188	95,593
4	Chevitivaripalle	2,57,680	2,320	212	7,700	2,65,824
5	Kotakadapalle	1,82,125	70,147	17,928	33,138	3,33,153
6	Bathinigaripalle Tanda	1,12,545	18,960	15,826	9,625	1,56,956
7	Nakkalavarikota	46,425	1,645	23,826	12,925	84,821
	Total	**8,47,895**	**1,03,695**	**66,019**	**1,13,714**	**11,59,050**

Fuelwood and fodder are the most critical biomass requirements for the communities and this is underlined by the fact that they account for 85% of the total extraction. Timber, Green manure and Non-Timber Forest Produce are having a negligible impact in terms of quantity of biomass, but overexploitation has the potential to affect the growth and regeneration of tree and shrub species significantly. This is due to felling of whole trees/branches, extraction of leaves and fruits in



large quantities, etc. The assessment of impact of such extraction on the ecology of the RF and surrounding areas is beyond the scope of this study. The focus here would be on fuel wood, fodder and timber.

Fuelwood

Erythroxylon monogynum, Plectronia parviflora, Chomelia asiatica, Lantana camara, Pulachettu, and Kampachettu are the major sources of fuel wood in these hamlets. Apart from these species, *Randia dumetorum, Ixora parviflora, Flacourtia sepiaria, Cassia auriculata* are also used. Fuelwood is also available from the fields in the form of crop residue of Redgram, Mulberry, Sun hemp, and from shrubs on the bunds. Villagers collect more of shrubs for fuel wood than trees, because of the large quantity available at the foothills and ease of access.

Fodder

The most commonly used species for fodder are Jonnalu (*Sorghum bicolour)*, Gariki *(Cynodon dactylon)*, Kondagaddi, Vedurugaddi (*Panicum ramosum*), Yerrakasi, Kukataku (*Sapindus emarginatus*), Konda Ragi (*Ficus arnottiana*), Dussaraaku (*Cocculus hirsutus*), Ragi (*Eleusine coracana*), Maanukatta, Utlagaddi, Gurugaku (*Celosia argentea*), Galagillaaku, Oopa, Sendragaddi, Yedurudabbagaddi, Kasigaddi (*Cymbopogan caesius*), Bonthagaddi, Chippira, Thellakasi, Tapirigaddi (*Digitaria longiflora*), Bankatapiri, Bantatulagaddi, Utlagaddi, Alamuteegalu, Cenchulakku, Eerimanugaddi, Kaariaavulagaddi, and Madanakatti.

Agricultural fields are the primary source of fodder for the livestock. The livestock is dependent on the wastelands and RF throughout the year with maximum intensity during the dry summer months. Here we will be analysing the fodder requirements in the summer of 2003, which is a very critical period owing to the recurring drought situation in the region. The table given below states the deficit of fodder in the area of study considering the agricultural output.

To meet a total fodder requirement of 8,098 MT till June 2003, 1,772 MT of fodder are available from the previous crop and 716 MT are expected from the current crop (Rabi). This leaves a deficit of 5,610 MT of fodder. This deficit is reduced to 2,526 MT if we consider minimal fodder consumption (4 kg per day per animal) during drought period.

It is this deficit that has to be fulfilled by the fodder from fallow fields, bunds, wastelands and RF. This could be either grasses, herbs or leaves of *Sesbania grandiflora, Leucaenia leucocephala, Ficus arnottiana, Dalbergia paniculata, Hardwickia binata*, etc. Most of the grass available in the RF is dry *Cymbopogan coloratus* which is unfit for cattle consumption. Therefore, the pressure on the other

species available in the RF and wastelands would be enormous. However, this year the government has organised a cattle camp at Thambalapalle to provide free fodder and water for all cattle during April-June 2003. An estimated 4,100 cattle are being catered to by this camp with a daily fodder supply of 16.4 MT. The fodder is being imported from coastal region of Andhra Pradesh, and this is taking the pressure off the local resources. However, such camps are not catering to small livestock such as goats and sheep. These continue to depend on the RF and wastelands for fodder.

Timber

Most commonly harvested timber species are Neem (*Azadirachta indica*), *Yelama* (*Anogeissus latifolia*), *Yepi* (*Hardwickia binata*), *Neeruddi* (*Dolichandrone atrovirens*), *Ippa* (*Madhuca latifolia*), *Pachari* (*Dalbergia latifolia*), *Billu* (*Chloroxylon swietenia*), *Yenamaddi* (*Terminalia tomentosa*), *Udaga (Alangium salvifolium*), *Tapasi* (*Holoptelia integrifolia*), etc. The timber need of the villagers is minimal, as they require this only once in a few years. The main season for extraction is summer (April/May). Most of these species with a good straight bole useful for timber have already been felled and there are hardly any left. After initiation of protection of the forests, indiscriminate felling has almost been stopped.

The government has been promoting subsidised housing for the rural people in the last decade, which has resulted in a large number of communities building pucca houses. This has reduced the need for timber in construction. Therefore, a large number of *Anogeissus latifolia* trees have not been cut for the last 8-10 years, and these have been promoted to higher girth classes.

Non-Timber Forest Produce

The common NTFP collected from this forest are in the form of green leaf manure, fruits and berries, gums and resins, roots and tubers, bark, plate leaves, broom sticks, plant parts for various medicinal use, honey, etc. Most of them are consumed or sold, either in the local market or to the Girijan Co-operative Corporation. NTFP offers a sizable income to the local communities living close to the forest and especially to the forest-dependent village like Nakkalavarikota.

Table 21: Fodder availability and requirement for cattle in the summer of 2003

S.No.	Village	Cattle population (No.)*	Fodder requirement till June '03 (MT)	Fodder availability in stocks (MT)*	Expected fodder from present cultivation (MT)*	Crop Residue (MT)*	Fodder Deficit (MT)
1	Bandrevu	758	531	173	8	6	344
2	Kotala	1,050	735	75	31	43	587
3	Kalicherla	1,278	895	341	22	6	526
4	Gopidinne	1,681	1,177	135	12	108	922
5	Siddavaram	791	554	235	28	2	289
6	Thamballapalle	2,089	1,462	171	43	130	1,118
7	Veligallu	1,399	979	416	40	11	512
8	Yeddulavaripalle	973	681	83	2	81	515
9	Kotakonda	763	534	75	14	61	384
10	Renimakulapalle	786	550	68	**2**	66	414
	Total	**11,568**	**8,098**	**1,772**	**202**	**514**	**5,610**

*Note: Fields marked with * have been sourced from the Office of Assistant Director, Dept. of Animal Husbandry, Madanapalle.*

Leaves of *Wrightia tinctoria, Pongamia pinnata, Anona squamosa, Cassia sophera, Cassia auriculata, Chomelia asiatica, Dalbergia paniculata*, etc. are most commonly used for green manure. Green manure is collected and used during transplanting of Paddy in January and June.

Fruits and berries of *Phoenix humilis*, *Gardenia gummifera*, *Diospyros chloroxylon*, *Plectronia parviflora*, *Emblica officinalis*, *Sapindus emarginatus*, *Terminalia chebula*, *Zizyphus mauritiana, Zizyphus aenoplia, Feronia elephantum*, *Anona squamosa*, etc. are harvested almost throughout the year depending on the availability of a particular species. Gum or resin of *Anogeissus latifolia* and *Boswelia serrata* are also harvested from this forest. Roots of *Hemidesmus indicus* and tubers of *Asparagus racemosus* are collected and sold. Beedi leaf or *Diospyros melanoxylon* is harvested in large quantities and sold to private contractors. Bark of *Cassia auriculata* is sold to the tanning industries while that of *Hardwickia binata* is used for extracting fibre. Leaves of *Butea monosperma* are used for plate making. Many plants and plant parts are used for treatment of various diseases of humans as well as livestock. The medicinal applications are varying across villages and are too numerous to be documented in this study.

Demand-Supply Balance

The demand for biomass as estimated in the sampled villages has been given in Table 22 above. Considering the population pressure in these villages, the per capita demand for different forms of biomass has been calculated as:

Table 22: Population levels and per capita extraction rates of biomass

S. No.	Name of the village	HH	Population	Per capita extraction (kg/year)		
				Fuelwood	Timber	NTFP
1	Penderivaripalle	42	142	389	12	6
2	**Nayanavaripalle**	39	161	727	14	19
3	Bodaguntlapalle	11	52	1,478	158	83
4	Chevitivaripalle	25	119	2,165	19	2
5	Kotakadapalle	78	359	507	195	50
6	Bathinigaripalle Tanda	24	86	1,309	220	184
7	Nakkalavarikota	47	182	255	9	131
	Total	**266**	**1,101**	**6,831**	**629**	**474**
	Percentage			**86**	**8**	**6**
	Average (kg/person)			**976**	**90**	**68**

Thus, we find that the per capita demand for all forms of biomass is 1.1 MT per annum. This includes extraction for selling in the market. It also includes extraction from RF as well as revenue wastelands. There are obviously large variations in per capita

consumption for different hamlets. The higher figures in Bathinigaripalle Tanda, Bodhaguntlapalle and Chevitivaripalle can be explained by the fact that the economy of these hamlets is dependent on the resources to a great extent through timber and fuelwood selling. The fuelwood extraction level for a family of five (3 adults and 2 children) comes to about 4 MT per annum, which is higher than the average of 2 MT per annum quoted by other research work[4]. The extraction of fuelwood for commercial purposes is one of the reasons for the higher consumption per capita in the study area. The NTFP extraction rates are proportional to the proximity of the habitation to the RF. Barring Nakkalavarikota and Bodhaguntlapalle, the other hamlets are mainly extracting green leaf manure for their wetlands.

In order to arrive at the overall extraction level for the entire RF, we make the following assumptions, which are based on our experience so far.

- Fuelwood is mainly extracted from shrubs in RF and Wastelands. Tree biomass forms only a small percentage of the total Fuelwood extraction.
- Fodder is sourced from Private lands, wastelands and forest, in that order. The seasonal demand-supply scenario for summer of 2003 is analysed here.
- Timber is an occasional need and is sourced from the RF or rarely (relatively) from agricultural fields.
- Among NTFP, Green leaf manure has the largest share and it is extracted mainly from the RF.
- Since there are more than 200 hamlets in a radius of 10 km from the RF, identifying the hamlets, which are dependent on the RF and the extent of such dependence, was not possible. Instead all the revenue villages surrounding the RF have been taken as being dependent on it. Moreover, availability of secondary data is also at the revenue village level only.
- The Musalikunta RF, which is very close to the Sadhukonda RF, has not been included in the study. It is mainly a scrub forest with little tree biomass. Dependence for timber and NTFP are negligible. The contribution may be towards meeting Fuelwood and fodder needs of the nearby communities. This means that the demand pressure estimated in this study for the RF can only be a more conservative estimate as far as fodder and fuelwood are concerned. Rekkalakonda, Papepalle and Ellutla RFs are also in a similar state of degradation and only contribute to fuelwood and fodder needs of the nearby communities. Therefore, assessing the pressure of fuelwood and fodder on the Sadhukonda RF would require making an assessment of the contributions of these RFs to the study area.

Based on these assumptions, the total extraction of different forms of biomass for the 10 revenue villages around Sadhukonda has been estimated and is given below:
Thus, the total biomass extraction is estimated to be 68,670 MT per annum.

[4] Datye, KR (1997); Banking on Biomass. CEE, Ahmedabad.

Fuelwood

Total biomass extracted for fuelwood is 35,151 MT per annum. This is from both RF and wasteland, with agricultural fields making a very small contribution. Mostly it is dry wood from shrubs that is extracted for meeting the fuelwood need. The major source of dry wood is the wasteland for most villages, while those close to the RF are dependent on the forest.

Table 23: Extraction levels of biomass in revenue villages surrounding Sadhukonda RF

S. No.	Revenue Village	No. of HHs	Population	Extraction per year (MT)			
				Fuelwood	Fodder	Timber	NTFP
1	**Bandrevu**	795	3,532	2,720	1,660	422	212
2	Kotala	842	3,644	2,806	2,300	435	218
3	Kalicherla	2,218	10,951	8,434	2,799	1,307	657
4	Gopidinne	866	3,803	2,929	3,681	454	228
5	Siddavaram	313	1,519	1,170	1,732	181	91
6	Thambalapalle	1,902	8,790	6,769	4,575	1,049	527
7	Veligallu	1,420	6,422	4,946	3,064	767	385
8	Eddulavaripalle	415	2,028	1,562	2,131	242	122
9	Kotakonda	640	3,300	2,541	1,671	394	198
10	Renimakulapalle	283	1,654	1,274	1,721	197	99
	Total	**9,696**	**45,644**	**35,151**	**25,334**	**5,448**	**2,737**

Note: Fuelwood, timber and NTFP estimates based on per capita consumption in surveyed hamlets.

Fodder

The total fodder requirement in a year is 25,334 MT, which is sourced from all the three resources. This requirement is met primarily from agricultural fields including the crop residue, which has been estimated to be around 8,500 MT. Apart from residue the grasses on the bunds and that from fallow lands also support the cattle. The remainder of the fodder requirement has to come from the commons, especially from February to June. However, in the drought period the agricultural production is affected thereby increasing the pressure on the commons. The total availability of grass and herb biomass has been estimated to be 12,474 MT. Out of this *Cymbopogan coloratus* is the dominant species, which when dry is unfit for cattle consumption. Thus, there is a high amount of pressure on the other fodder species. The need for fresh *Cymbopogan* grass is a major reason for widespread fires in the commons.

The cattle population in the area is itself undergoing a change driven by a number of factors like,

- Recurring drought leading to uncertainty in agriculture which is resulting in people adopting dairying as a source of regular cash income,
- Government programmes like District Poverty Initiatives Programme (DPIP) promoting dairying through cattle loans (encouraging Hybrids and crossbreds, which consume more fodder per capita), and
- Private dairies setting up procurement networks in the region.

This can only lead to an increased grazing pressure on the commons in the coming years. Already there have been numerous incidents of fire in RFs and wastelands in the first four months of 2003. While the reasons for the fires may be different, their implication on fodder availability cannot be ignored. This scenario throws up a few areas, which need to be worked upon immediately and these are discussed in Chapter 9.

Timber and NTFP

The total tree biomass as mentioned above is 4,72,315 MT and the extraction per annum is 8,185 MT, which is 1.73% of standing tree biomass. Literature suggests that in a regenerating forest, the maximum permissible limit is 'one-third to half' of the mean annual increment (MAI = 2.84% of standing tree biomass). Thus, the current level of extraction seems to be well above the permissible limit. Moreover, 75% of this tree biomass extraction is for fuel wood either for use or as a means of livelihood.

If we take into consideration the possible ecological impacts of this extraction (level as well as methods of extraction) and the frequent occurrence of fire in the RF, this high level of over-extraction coupled with scanty rainfall would have a significant bearing on the regeneration and annual increment of biomass. The wastelands, due to poor vegetative cover and low potential of regeneration even if protected, cannot be expected to meet the current level of demand for tree biomass in the next few years. The prevailing continuous drought conditions for the last few years have also meant that the agricultural fields have not been a reliable source of biomass. Therefore, this situation calls for greater focus on the RF to improve its tree cover, while simultaneously working on the demand side through energy conservation measures.

8. Fire

Ground fire has been a recurring phenomenon for a very long time in the hills and hillocks of the area, including the Sadhukonda R.F. and occurs usually between February and May. During 2002, there were instances of fire even as late as October, as the forests and hillocks continued to be dry due to lack of rains. It was also observed

that the major threat is the presence of plants like *Lantana camara, Pterolobium indicum*, and grasses like *Cymbopogan coloratus*, which are dry during summer, present in large quantities, and highly combustible.

Often they (fire) occur in the revenue wastelands around the villages either deliberately set or by accident, or from the field bunds the farmers burn to clear them of scrub while preparing the dry lands for the groundnut crop. In the forests, sometimes fire is set to clear the thorny scrub to access trees for felling, for tender grass to meet part of the grazing needs during early summer, by people who leave behind burning logs in the forest after brewing liquor, by those who make charcoal in the forests, out of superstition, or sometimes just for mischief.

The protection of wastelands and forest by the communities has meant that the *Cymbopogan* grass, which would earlier have been burnt every year in the early summer, now grows to a good height and is present in a dry state throughout the summer. Thus, the time period during which the resources could catch fire has increased, in turn making the task of protecting the resources difficult. The decline in demand for *Cymbopogan* grass in adjoining Anantapur district during the last few years has also led to the grass remaining uncut in the wastelands and RF.

During the survey for biomass estimation, it was found that a substantial quantity of biomass is being lost every year due to fire. The recent fire affected areas also have a good number of wild fauna, which are driven out of their habitat due to fire. Many herbivores are rendered homeless, deprived of fodder, and are forced to flee the forest risking their lives. This being a hill forest, the entire biomass that is burnt gets washed down during the rains to the foothills, which would otherwise have contributed for an increase in soil nutrients. We still do not know the bearing of fire on the lives of minor fauna like small mammals, reptiles, and myriad invertebrates. The areas of frequent fire, especially scrublands, have left the mark on vegetation composition. The species growing in these areas have adapted characters specific to fire prone areas like stimulated germination of spines, smaller foliage, reticulated thick bark, dormant buds, quick sprouting, fire induced flowering, etc. Fire is also said to aid the growth of fodder and increase the diversity of ground flora. A major impact of fire is seen in the regenerating young trees besides disturbing wildlife habitats and movements. The status of regeneration against mature trees implies that due to frequent disturbances and occurrences of fire in the area, the recruitment to higher girth class is very slow. This dry deciduous forest has only two layers of vegetation left, the top storey and the ground flora. The middle storey comprising shrubs, saplings, small trees, and climbers is missing. Weeds like *Lantana camara* and *Pterolobium indicum* are found to be successfully invading the open gaps created by fire. This may also indicate the changes in species composition in the years to come.

During 2003, fire occurred twice in Sadhukonda Reserve Forest on the western slopes of Mallaiahkonda, a hillock at the centre of the Reserve Forest. During this, an extent of 347 ha. was burnt with complete elimination of shrubs and ground flora. By using GIS, the total biomass loss is estimated to be around 1,928 Tonnes in the affected area. Apart from this, the loss of various NTFP due to fire also has a bearing on the economy of the communities that make a fair income during the year from these forest resources. On the positive side, the fresh grass coming up here would provide much needed fodder for the cattle in nearby villages, albeit for a brief period only. The team has been working on wastelands in a contiguous area and this has resulted in synergy among the efforts of various communities. The reduction in instances of fire in wastelands and the RFs in the last few years is an indicator of this. However, in case of Sadhukonda RF there are a number of communities that have been organised as VSS by the forest department. At present there is not much communication or cooperation among the VSS organised by the department and those being funded by FES. However, the resource they are protecting is one large unit in ecological terms and concerted efforts are needed to protect and manage it. The lack of cooperation is starkly visible this year, as almost the whole of the 6,500 Ha RF has been burnt barring one patch being protected by Nakkalavarikota hamlet.

9. Inferences and Suggestions

Communities and livelihood needs

Biomass is a critical livelihood need and is therefore an entitlement for an individual. The per capita demand for biomass that has been estimated needs to be discussed with the communities and means for securing the same need to be found. The focus here has been on non-food needs, for which people are dependent on the commons. The work of the team and the efforts of the communities protecting their commons have focused thus far on protection and enrichment. With the resources regenerating and more resource units available for consumption, the aspects of equity in appropriation need to be tackled. The per capita requirement therefore suggests a basic minimum level of biomass need for any individual. In moving from a common resource to a private usage, it is necessary to safeguard this entitlement and ensure that needs are given primacy.

This study clearly shows that the RF is in a regenerating state with low density and frequency of most species. The last 4-5 years have seen many parts of the RF being brought under protection and management by village communities and this has encouraged the regeneration there. However, there is still a great deal of dependence on the commons for fuel wood and fodder needs, and this pressure can affect the rate of regeneration in the forest. The increasing human and cattle populations mean an ever-increasing demand for resource units from the commons.

Fuelwood forms a significant portion of the total biomass extraction from the commons. The market dynamics as well as multiplicity of sources for this commodity need to be understood before any efforts can be made to regulate its extraction. Energy conservation measures like smokeless *Chullahs*, biogas plants, pressure cookers etc., which reduce demand for fuel wood should be propagated on a large scale. Consumption centres like main villages, mandal towns, etc. should be covered under the energy conservation programme. Even in such places, major consumers of fuel wood like hotels, brick kilns etc. should be given priority.

In case of fodder and fuel wood supply, the role of other nearby RFs is not clear. This needs to be probed further to arrive at a clear picture of the demand pressure on Sadhukonda RF.

The task for the team in such a scenario is clearly cut out. The focus on the supply side needs to continue by encouraging protection and enrichment activities in the commons, and equally importantly prevention of fire. But, more importantly the discussions with communities need to focus on demand side management, through regulatory mechanisms for grazing, extraction of fuel wood and timber etc. The forest protection committees (VSS) would in a few years' time be able to harvest NTFP at a significant scale, and this calls for discussions and mechanisms for sustainable harvesting not only with communities but also agencies like District Poverty Initiatives Programme (DPIP) which would be involved in procurement and marketing of the produce. The resource-based fora have a crucial role to play in these discussions with the communities as well as external agencies.

By sharing the findings of this study, the communities can be made more aware of the magnitude of the demand-supply situation. The recent trend of increase in cattle population should also be discussed with the communities in terms of the 'Tragedy of Commons' perspective. These issues could also be taken up with govt. departments and programmes like (DPIP) to create awareness and prompt a rethinking in their strategies.

Critical areas such as grazing grounds and routes should be identified and intervened in through broadcasting of fodder seeds and protection from fire etc. Discussions with key stakeholders like shepherds should continue in order to address their concerns also.

Biodiversity

The species richness has been found to be high in the RF and the evenness suggests a good representation of large number of species. However, as noted earlier, mature trees (higher girth classes) are very few in number. This denotes the level of degradation and anthropogenic pressure on the forest. Repeated fires and risk of invasion by weeds such as *Lantana camara* and *Pterolobium indicum*, present a very serious threat to any

regeneration. In that sense the initiatives of the communities to protect the forests and wastelands are timely.

There is at present little emphasis on the parts of the communities or the team on the biodiversity related aspects, except say in enrichment through saplings and seeds. Any systematic effort to conserve the biodiversity of the region needs first and foremost systematic documentation at micro-level. In our case, this can be achieved by maintaining biodiversity registers at the community level. This would help in recording people's knowledge and perceptions of the status, uses, history, ongoing changes and forces driving these changes in the biodiversity resources of their own localities. This would be a first step towards the communities managing their biodiversity, along with the other resources like land, water etc.

Collective Action

There have been as many as five incidents of fire in the RF within a few months. Clearly the individual efforts by the communities around the RF have not succeeded in preventing the fire this year. Some communities have struggled to put out fires, which have occurred in some other village's plot and that too far away from their own village. Whereas some communities have stood back and watched their own protected areas being burnt. A common understanding is therefore needed among these communities to ensure that each one does their part of the task. Otherwise, there is a chance of this getting into a prisoner's dilemma situation with no community coming forward to put off the fire, thinking it would be the only one to do so while the others would not care. The team has already worked with local fora of communities protecting a contiguous resource, in case of wastelands and RFs. The same experience should be used in this case too to bring together all the communities protecting the RF, be they funded by FES or the department, onto a common platform where they can plan on tackling this menace together. Apart from fire, the forum would also grow into dealing with provision and appropriation among villages as well, which would become an issue once the flow of resource units is increased through regeneration. Moreover, issues such as biodiversity management should be taken up at the level of the RF rather than scattered VSS plots. Thus, this too calls for all the communities around the RF to work together.

References

Beddome, Major RH (1988); The Flora Sylvatica for Southern India Vols. I-III. Gantz Brothers, Madras.

Datye, KR (1997); Banking on Biomass. CEE, Ahmedabad.

Gamble, JS (1993); Flora of the Presidency of Madras Vols. I-III. Bishen Singh Mahendra Pal Singh, Dehradun.

Ganeshaiah KN, Shaanker, R Uma, and Bawa, KS (Ed.) (2001); Tropical Ecosystems – Structure, Diversity and Human Welfare. Oxford and IBH Publishing Co.Pvt. Ltd., New Delhi.

Hocking, Drake (Ed.) (1993); Trees for dry lands. Oxford and IBH Publishing Co.Pvt. Ltd., New Delhi.

Kehimkar, Isaac (2000); Common Indian Wild flowers. BNHS & Oxford University Press, Bombay.

Kumar, Ashok (2001); Botany in Forestry. Kumar Media Pvt. Ltd., Gandhinagar.

Murali, KS, Bhat, DM, and Ravindranath, NH (..); Biomass Estimation Equations for tropical deciduous and Evergreen forests. CES Technical Report No. 81. Centre for Ecological Sciences, Bangalore.

Parent, Guy (2000); Manual for Woody Biomass Inventory. Tecsult Intl. Ltd., Quebec.

Prater SH (1971); Book of Indian Animals. BNHS & Oxford University Press, Bombay.

Pullaiah, T (1997); Flora of Andhra Pradesh, Scientifc Publishers, Jodhpur.

Ravindranath, Shailaja and Premnath, Sudha (1997); Biomass Studies: Field methods for monitoring biomass. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Annexure 1: Definitions and Formulae used for estimation of various parameters

Data Collection

The formats were developed to acquire data on the consumption patterns within these villages. Experts at Indian Institute of Sciences, Bangalore and University of Agricultural Sciences, Bangalore have validated the formats. Methodologies and formats for the study were finalized after referring available literature.

The adopted methodology and formats were earlier discussed with Dr. Murali's Team at IISc. Bangalore for Forest Biomass, Prof. Bhaskar of NAEB (UAS, Bangalore) for Agri. residual Biomass. This methodology is also suggested in 'Woody Biomass Inventory' by Guy Parent, a manual developed for Min. of Agri., Govt. of Ethiopia, and 'Field manual for estimation of biomass' by Sailaja Ravindranath and Sudha Premnath.

Estimation of Woody biomass

A sample plot of 10 mt x 10 mt size was taken from each microhabitat for estimating the above ground tree biomass using non-destructive methods. For this, the GBH (girth at breast height), DSH (diameter at stump height), and height in meters were taken for all the tree species within the plot and extrapolated for the entire study area. The quantity of woody biomass is estimated by using the equation,

Biomass (MT/Ha) = (8.32 * BA) – 1.69, where BA is Basal Area in Sq m per Ha.

Estimation of Shrub biomass

Within the above plots a 5 mt. x 5 mt. plot was taken and the length, breadth, and height of shrubs was calculated for estimating the volume (LxBxH). A unit volume (1 ft. x 1 ft. x 1 ft.) of the shrubs was harvested and wet weight was taken to derive the volume-mass multipliers. While harvesting multiples of each shrub species was taken covering all the habitat types and was averaged for the unit volume of biomass.

Estimation of herb and grass biomass

For ground flora 1mt. x 1mt. quadrate plots were made within the $10m^2$ plots and from these all the herb and grass species were recorded, harvested above ground, dried and weighed.

Estimation of Fuel wood and fodder collection

Random samples were taken to estimate the quantity of fuel wood and fodder collection from the sample village. Head loads of fuel wood and bundles of green manure and fodder were weighed on site and at the village for quantifying the amount extracted.

Household Survey

Household survey was conducted in the six sample villages to estimate the requirements of biomass such as fodder, fuel wood, timber, NTFP etc. as well as the methods of collection. The data includes information on agriculture, land-holding, livestock, economy, seasons of collection, preferred species for fuel wood, quantity consumed per year, fodder, leaf manure, timber, wood for agricultural implements, etc. The results were quantified and analysed to arrive at the annual requirement/ consumption of biomass per village.

Monitoring vegetation – Trees

Trees with more than 5 cm. GBH were taken into consideration for calculation of tree biomass. Four GBH classes were identified viz. 0-5 cm. was considered as seedlings, 5-10 cm. as saplings, 10-30 cm were considered as regenerating/ establishing, and more than 30 cm. as timber. The following parameters have been collected from the study in a specific eco-system:

- GBH or DSH in Centimetres.
- Height in Metes

Using the above mentioned, the following parameters are estimated:

Importance Value Index

The Importance Value Index (IVI) is a statistical quantity, which gives an overall picture of the importance of species in the vegetative community. It considers the relative values of density, frequency, and basal area of every species in a given area. It thus incorporates three important parameters, which are measures of diversity and productivity of every species.

Thus IVI = Relative density + Relative frequency of occurrence + Relative basal area.

Species Density

Density is the number of individuals of a species in a unit area.
Density is also an indicator of the abundance of the species.
It helps to identify the dominant and rare species.
It is an indicator of the standing biomass and productivity in a region.

Basal Area Estimation

It is the area occupied by the base of a tree. It is considered as a good indicator of the size, volume or weight of a tree. The GBH measures are used to calculate the basal area.

- It provides information on the proportion or dominance of larger and smaller trees in an ecosystem.
- It is one of the most important parameters in estimating the standing biomass in a given area, which in turn, is used as a measure of productivity.
- It is an indicator of the status of the standing biomass, i.e., whether it is degrading or improving.

Species Diversity

Diversity means variety or variability. Species diversity therefore refers to the variation that exists among the different living forms. It is estimated that there are more than 50 million different species of living organisms on the earth. With the growing concerns of species going extinct at a very rapid pace, identification of the different species of plants and animals and then conserving them is of primary importance.

- This indicates the extent of biodiversity in the ecosystem.
- This data helps to study the impact of factors like livestock grazing and other anthropogenic interference on the regeneration of different species.
- It also identifies the species, which need conservation.

Species diversity is made up of two components:

1. Species richness
2. Species abundance

Diversity Index

Diversity is often represented in the form of indices. Diversity indices attempt to incorporate both richness and abundance into a single numerical value. These are therefore referred to as heterogeneity indices. A given value of diversity index can result from different combinations of species richness and abundance or evenness. It

would be difficult to separate relative importance of species richness and evenness from the given value. The two widely used indices are Simpson's index and Shannon-Wiener index.

Simpson's Diversity Index

The Simpson's index gives the probability with which when two individuals selected at random, from the habitat, will belong to different species. It considers,
The number of species
The number of individuals of each species
The total number of individuals of all species

Simpson's Index (Ds) is calculated as follows:

$$Ds = \frac{\Sigma n_i (n_i-1)}{N (N-1)}$$

Where,
Ds is the diversity index
n_i is the number of individuals belonging to a species i, and i=1 to K
K is the total number of species
N is the total number of individuals of all species
The value of Simpson's Index varies from 0 to 1. A value of 0, indicates the presence of only one species, while that of 1 means that all species are equally represented.

Shannon-Wiener Index

This index represents the average degree of uncertainty in predicting to which particular species an individual chosen at random from a sample will belong to.

This measure considers,

- The total number of individuals of all species.
- The number of individuals of every species.
- The proportion of individuals of each species in the total number of individuals of all species.

Shannon-Wiener Index is represented as follows:

$$H' = - \Sigma p_i \log p_i$$

Here
p_i is the proportion of the total number of individuals that occur in the species i, i.e.(n_i/N).

n_i is the number of individuals of a species i, and i = 1 to K.
K is the total number of species.
N is the total number of individuals of all species in the sample.

The value of Shannon-Wiener index varies from 0 to log K. A value of 0 indicates the presence of only one species, while that of log K means that all species are equally represented.

Standing Woody Biomass

Above ground standing biomass of trees, is the weight of the trees that is above the ground in a given area, if harvested at a given time. Standing biomass may be expressed in any of the following terms:
Weight: Dry Tonnes per hectare per year
Volume: Cubic meter per year. This is in the case of trees.
Mean Annual Increment (MAI): This refers to the average increase in biomass by weight or volume per year.

Importance

- It provides the quantity of biomass that is available at a given time or over a period of time in the ecosystem and is used to estimate the productivity of the area.
- It provides information on the carrying capacity of the land. For example, the productivity of grains will help to determine how many people can be fed per hectare per year.
- It helps in estimating the continuous biomass extraction.
- It is an extremely important parameter for taking decisions on change in vegetation pattern, conservation, and management.
- It also helps studies on natural regeneration.

Estimating the sustainable harvest level of tree biomass

Approximate estimates of sustainable levels of harvesting wood biomass from trees may be obtained from Mean Annual Increment (MAI) or productivity values.

- The Mean Annual Increment in the woody biomass can also be estimated from the standard biomass of trees per hectare.
- Generally 2.84 % of the standing biomass value is considered to be equal to the annual increment (Ravindranath, et al., 1996)
- 50-75% of MAI may be harvested for sustainable yields. Considering the extrapolation error of 30% for standing woody biomass, 20-45% is accepted as the permissible limit for extraction in a sustainable way, say an average of 33% of MAI, which comes to 9.37% of standing woody biomass.

Carbon Sequestration

The amount of carbon sequestered is calculated as given below,

Amount of Green Tree biomass = 77% of woody biomass above ground
Amount of dry tree biomass = 46% of total green tree biomass
Amount of carbon sequestered = 48% of total dry tree biomass

Therefore, Carbon Sequestered (MT/yr.) = 17% of woody biomass above ground.

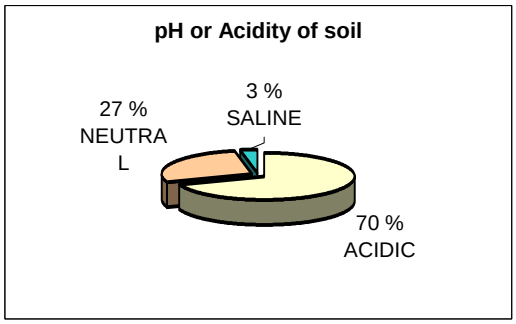
Annexure 2: Microhabitat-wise IVI rating of dominant tree species

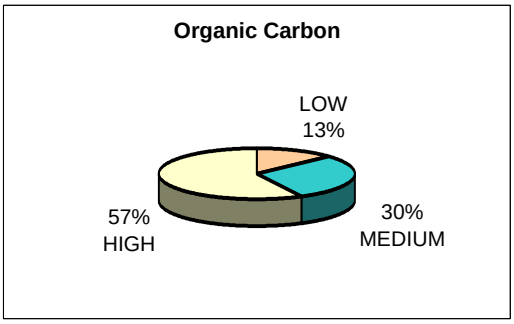
S No.	Species Name	Drains				Foothills				Hill Slope			
		RelFrq	RelDen	RelDom	IVI	RelFrq	RelDen	RelDom	IVI	RelFrq	RelDen	RelDom	IVI
1	*Anogeissus latifolia*	7.83	23.69	17.72	49.24	5.88	11.73	7.00	24.61	8.47	21.15	17.53	47.16
2	*Acacia sundra*	10.87	16.86	11.66	39.39	20.59	32.65	28.74	81.98	10.89	16.92	13.35	41.16
3	*Dolichandrone atrovirens*	9.13	8.28	3.19	20.60	11.76	10.71	4.08	26.56	12.10	13.59	6.50	32.18
4	*Chloroxylon swietenia*	4.35	11.63	4.14	20.12	4.41	12.24	12.89	29.55	8.47	13.72	6.90	29.08
5	*Terminalia tomentosa*	1.74	2.62	3.97	8.32	0.00	0.00	0.00	0.00	4.44	5.00	3.51	12.95
6	*Grewia rotundifolia*	3.91	1.60	1.15	6.66	0.00	0.00	0.00	0.00	4.03	1.54	1.53	7.10
7	*Gymnosporea emarginata*	4.78	3.05	1.17	9.01	4.41	4.08	0.85	9.34	4.84	3.46	1.49	9.79
8	*Wrightia tinctoria*	6.52	4.07	5.55	16.14	2.94	1.02	0.53	4.49	1.21	0.51	0.73	2.45
9	*Dalbergia paniculata*	1.74	1.02	4.28	7.04	0.00	0.00	0.00	0.00	1.61	0.64	7.61	9.87
10	*Cassia fistula*	6.96	3.49	2.71	13.15	1.47	0.51	0.07	2.05	2.82	2.05	0.78	5.65
11	*Hardwicikia binata*	0.00	0.00	0.00	0.00	5.88	7.14	31.53	44.56	1.21	0.51	6.03	7.75
12	*Ixora parviflora*	1.74	1.45	0.51	3.71	0.00	0.00	0.00	0.00	2.82	1.41	2.77	7.01
13	*Premna tomentosa*	3.04	1.45	5.13	9.63	1.47	0.51	0.08	2.06	2.42	0.90	0.60	3.91
14	*Diospyros Montana*	1.30	0.44	8.95	10.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	*Eleodendron glaucum*	3.04	1.74	3.76	8.55	2.94	1.02	1.40	5.36	1.61	0.90	0.94	3.45

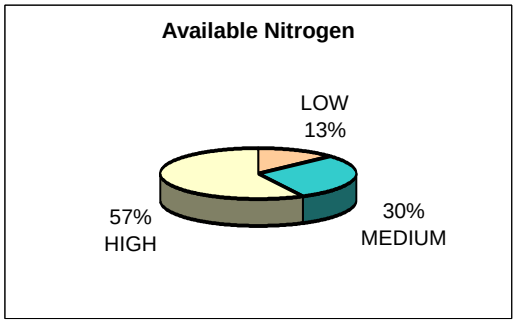
S.No.	Species Name	Plateau				Ridgeline			
		RelFrq	RelDen	RelDom	IVI	RelFrq	RelDen	RelDom	IVI
1	*Anogeissus latifolia*	7.89	18.58	20.25	46.73	5.29	16.27	9.63	31.20
2	*Acacia sundra*	13.16	10.62	7.37	31.15	5.88	11.29	6.29	23.46
3	*Dolichandrone atrovirens*	5.26	3.54	1.05	9.85	8.24	11.02	8.02	27.28
4	*Chloroxylon swietenia*	13.16	37.17	13.08	63.40	3.53	2.89	1.93	8.35
5	*Terminalia tomentosa*	2.63	3.54	3.01	9.18	4.12	4.20	5.38	13.70
6	*Grewia rotundifolia*	2.63	1.77	0.63	5.03	5.29	4.46	8.82	18.58
7	*Gymnosporea emarginata*	7.89	4.42	1.37	13.69	4.71	3.67	1.42	9.80
8	*Wrightia tinctoria*	5.26	1.77	0.64	7.67	2.35	1.57	2.17	6.10
9	*Dalbergia paniculata*	0.00	0.00	0.00	0.00	2.35	1.84	6.25	10.44
10	*Cassia fistula*	2.63	1.77	0.24	4.64	2.35	2.10	1.43	5.89
11	*Hardwicikia binata*	0.00	0.00	0.00	0.00	1.18	0.52	0.89	2.59
12	*Ixora parviflora*	0.00	0.00	0.00	0.00	4.71	4.72	6.28	15.71
13	*Premna tomentosa*	2.63	0.89	0.02	3.54	4.71	2.10	1.55	8.35
14	*Diospyros montana*	0.00	0.00	0.00	0.00	2.35	1.57	10.71	14.64
15	*Eleodendron glaucum*	2.63	0.89	2.02	5.54	1.18	1.84	2.23	5.25

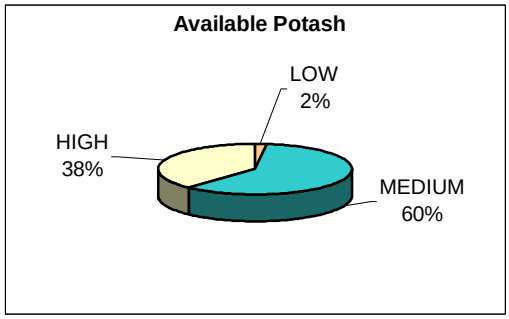
Annexure 3: Soil nutrient profile of Sadhukonda RF

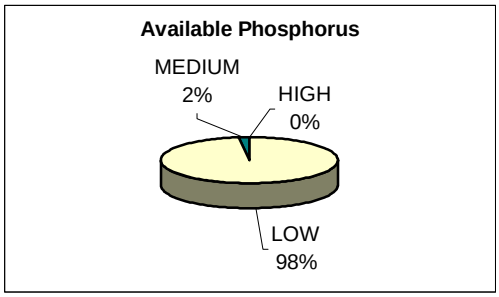
The soil status of Sadhukonda has been estimated by taking soil samples at depths of 30 cm, 60 cm and 90 cm (wherever possible) in the surveyed plots. The analysis of the samples has shown that the soil quality is poor in nutrients. The Electrical conductivity is normal and soil is generally acidic. The graphs given below show the % of total samples falling in different categories for each parameter.

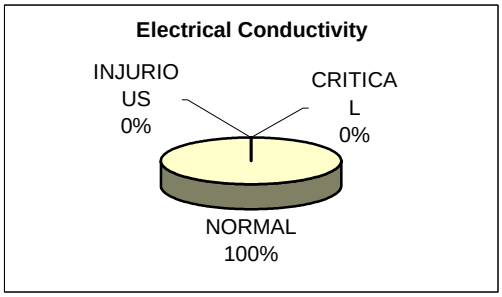












Annexure 4: List of Tree species in Sadhukonda Reserve Forest as on February, 2003:

Sr.no.	Species	Local Name1	Local Name2	Local Name3
1	Mangifera indica	Adavi Mamidi		
2	Spondias mangifera	Adavi Mamidi		
3	Millingtonia tinctora	Akasamalli		Indian Cork Tree
4	Memcylon edule	Alli		
5	Bauhinia racemosa	Ari		
6	Sesbania grandiflora	Avise		
7	Albizzia lebbeck	Baagi		Indian Walnut
8	Terminalia catappa	Badam		Indian Almond
9	Gardenia gummifera	Bikki		
10	Chloroxylon swietenia	Billu		East Indian Satinwood
11	Aegle marmelos	Bilva		Bael
12	Bambusa arundinacea	Bongu Veduru	Gattebiduru	
13	Bombax malabaricum	Buruga	Hatti	
14	Bombax ceiba	Buruga		
15	Strychons potatorum	Chilla	Chillathumara	
16	Tamarindus indica	Chinta		Tamarind
17	Plumeria acutifolia	Deva Ganneru		
18	Bauhinia variegata	Devakanchanamu		
19	Polyalthia suberosa	Dudduga		
20	Careya arborea	Dudippa		
21	Boswelia serrata	Dumpari		
22	Thespesia populnea	Gangireni		Portia Tree
23	Erythroxylon monogynum	Gedari	Jivadali	Bastard Sandal
24	Ixora parviflora	Gorivi		Torch Tree
25	Zizyphus xylopyrus	Gotiki		
26	Polyalthia cerasoides	Guthi		
27	Madhuca indica	Ippa		
28	Madhuca latifolia	Ippa		
29	Cordia obliqua	Iriki		
30	Phoenix sylvestis	Ita		Indian Date Palm
31	Shorea talura	Jalari		
32	Psidium guajava	Jama		Guava
33	Anacardium occidentale	Jeedi Mamidi	Geru	
34	Dalbergia latifolia	Jittegi	Bidi	Rosewood
35	Ficus tomentosa	Juvvi		

Sr.no.	Species	Local Name1	Local Name2	Local Name3
36	Pongamia pinnata	Kanuga	Honge	Pongamia
37	Sterculia colorata	Karaka		
38	Terminalia chebula	Karaka		Gallnut
39	Phoenix humilis	Konda Ita		
40	Ficus anottiana	Konda Raavi		
41	Peltophorum ferruginium	Kondachinta		Rusty Shield Bearer
42	Randia candolicana	Kondamanaga		
43	Sterculia villosa	Kummara Poliki		
44	Sapindus emarginata	Kunkudu		Soapnut
45	Morinda tinctoria	Madddi		
46	Morinda tinctoria	Madddi		
47	Ficus bengalensis	Marri		Banyan Tree
48	Ficus glomerata	Medi		
49	Butea monosperma	Moduga		Flame of the Forest
50	Pandanus tectorius	Mogili		Screwpine
51	Strychnos nux-vomica	Mushti		Strychnine Tree
52	Plectronia didyma	Nalla Balasu	Therane	
53	Terminalia tomentosa	Nalla Maddi		Laurel
54	Acacia nilotica	Nalla Thumma		Babul
55	Premna tomentosa	Naruva		
56	Dolichandrone atrovirens	Neeruddi		
57	Vitex altissima	Nemali Adugu		
58	Syzigium cuminii	Neredu		
59	Eleodendron glaucum	Neridi		
60	Enterolobium saman	Nidra Ganneru		
61	Dalbergia paniculata	Pachari		
62	Wrightia tinctoria	Palavareni		
63	Bauhinia purpurea	Pedda Ari		
64	Gardenia latifolia	Pedda Bikki	Kambi	
65	Ailanthus excelsa	Pedda Manu		
66	Diospyros montana	Pedda Ullinji		
67	Gyrocarpus americanus	Poliki		
68	Flacourtia sepiaria	Pulivelaga		
69	Ficus religiosa	Raavi		Peepul
70	Zizyphus jujuba	Regu	Elachi	Desert Apple
71	Zizyphus mauritiana	Regu		
72	Cassia fistula	Rela		Indian Laburnum
73	Buchnania latifolia	Sara		

Sr.no.	Species	Local Name1	Local Name2	Local Name3
74	Acacia suma	Sarathumma	Mugali	
75	Prosopis juliflora	Sarkar Thumma		Mesquite
76	Albizzia amara	Sigara	Chigre	
77	Pithecellobium dulce	Simachinta		
78	Santalum album	Sirigandham		Sandalwood
79	Dalbergia sissoo	Sissoo		Sissoo
80	Soumida febrifuga	Somi		
81	Acacia sundra	Sundra		Sundra
82	Borassus flabellifer	Taati	Paanai	Palmyra Palm
83	Holoptelia integrifolia	Tapasi		Indian Elm
84	Tectona grandis	Teku	Thegu	
85	Albizzia procera	Thallachinta		
86	Shorea tambuggaia	Thamba		
87	Terminalia bellerica	Thandra		
88	Terminalia arjuna	Thella Maddi		Arjuna
89	Givotia rotleriformis	Thella Poliki	Bettathavare	
90	Acacia leucophloea	Thella thumma		
91	Diospyros melanoxylon	Tumiki		Indian Ebony
92	Melia azadirach	Turaka Vepa		Persian Lilac
93	Alangium salvifolium	Udaga		Sage-leaved Alangium
94	Emblica officinalis	Usiri	Nelli	Amla
95	Dendrocalamus strictus	Veduru		Bamboo
96	Feronia elephantum	Velaga		Wood Apple
97	Azadirachta indica	Vepa	Bevu	
98	Cleistanthus collinus	Vodisa		
99	Pterocarpus marsupium	Yegi	Honne	Kino Tree
100	Anogeissus latifolia	Yelama		Axlewood
101	Hardwickia binata	Yepi		
102	Sterculia urens	Yerra Poliki		
103	Gardenia turgida	Yerrabikki		
104	Pterocarpus santalilnus	Yerrachandanam		Red Sanders
105	Gardenia lucida	Yerri Bikki		
106	Mundelia suberosa	Yerribillu	Bonachigida	
107	Ficus retusa			
108	Garcinia tinctoria			
109	Syzigium jambolanum		Nerale	
110	Flacourtia montana			
111	Grewia tiliaefolia			

Sr.no.	Species	Local Name1	Local Name2	Local Name3
112	Lagerstroemia parviflora			
113	Lannea coramandelica			
114	Stereospermum spp.			
115	Zizyphus rugosa			
116	Acacia ferruginia			Kanti
117	Albizzia marginata			
118	Dillenia indica			
119	Dillenia pentagyna			
120	Dolichandrone falcata			
121	Gimnosporia emarginata	Tandesi		

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