ABOVE GROUND BIOMASS AND CARBON STOCK ESTIMATION FROM *PROSOPIS JULIFLORA* IN BANNI GRASSLAND USING SATELLITE AND ANCILLARY DATA

Vineet Vaibhav[a], Arun B. Inamdar[b*] and Divya N. Bajaj[a]

[a] *Student, Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, Powai, Mumbai 400076, India;*
Tel: +91-98201-12468
E-mail: vineetvaibhav@gmail.com, divya.n.bajaj@gmail.com

[b] *Professor, Centre of Studies in Resources Engineering, Indian Institute of Technology Bombay, Powai, Mumbai 400076, India;*
Tel: +91-22 -25767682
E-mail: abi@iitb.ac.in, arun.b.inamdar@gmail.com

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Abstract: Banni grassland (latitude- 23°19'N to 23°52'N and longitude-68°56'E to70°32'E) lies in the arid region located in Gujarat, India. It was once Asia's 2nd largest tropical grassland with an approximate area of 2610 Km^2. *Prosopis Juliflora* was introduced in Banni in select areas in 1960s to control salinity ingress and maintain green cover in the area. The ability of *Prosopis Juliflora* to withstand adverse arid and semi-arid conditions and produce woods of high calorific values (4200 kcal/kg) brought in proposals for biomass energy generation.

This papers aims to estimate the biomass productivity from *Prosopis Juliflora* and assess the carbon stock in its wood. Land cover analysis with an accuracy of 94.4% was done using Landsat 5 TM 2011 satellite data to map the spatial distribution of *Prosopis Juliflora* and grassland. Analysis shows that *Prosopis* has invaded around 50% of the total area while the grassland area is found to be around 25-30%.

Field studies were undertaken for tree sampling in 4 plots of size 50mx50m. Harvesting method was followed and vegetation parameters; DBH, Girth, no. of stem and tree height were measured along with sun dried weight of woody biomass. Allometric relationship was established between field data using regression analysis. Results show that biomass is linearly related (R^2= 0.92-0.97) to vegetation parameters. Biomass productivity per hectare was found and total biomass productivity in Banni was deduced using area estimates from land cover map of 2011. Biomass estimate was converted into carbon stock was estimated by using a conversion coefficient of 0.47 as suggested by Wangda in the year 2012.

INRODUCTION

Exotic species were introduced in many countries for various reasons. Some species were helpful in some areas with regard to social and economic upliftment, environment and ecological conservation and protection, etc. *Prosopis Juliflora (*hereafter *Prosopis)* was introduced in Banni grassland (hereafter Banni) in 1960-61. This has subsequently led to the decrease in open grazing land and fodder for the livestock. Its ability to grow extremely fast despite extreme drought conditions have favoured invasion in large areas. Today, whole of Banni is under the threat of invasion and this has not only affected the Maldharis (local pastoral communities) and their livelihoods but also other economic activities of the region such as Milk production (Kutchpanjovatan, 2012 and Geevan et al, 2003).

Pastoral land in Banni is shrinking and with it the opportunities for the Maldharis to make a viable living. The availability of open grazing land is the key factor supporting milk economy. Political and economic factors are uniting to replace pastoral grazing land with allegedly more beneficial biomass production for electricity generation. *Prosopis* growth is a major issue in this region due to its invasive nature. Grassland resources in Banni are the key supporting units for the livestock and in turn for the Maldharis. The dense impermeable thickets of *Prosopis* formed by its invasion have reduced grass availability and stocking density. Further invasion of *Prosopis* at the current rate would lead to *Prosopis* growth all over Banni by 2063 (at 5% *Prosopis* cutting rate). It is thus a threat to the sustained existence of the pastoral system in Banni (Sastry et al, 2003).

The most accurate and common method for forest biomass assessment is forest inventory. The estimate of forest biomass is a measure of productivity and gives information on the amount of biomass that can be extracted for different purposes. Geospatial Technology (GT) has been successfully employed for mapping the extent, geographic distribution and monitoring forest health. Supervised, unsupervised and hybrid classification methods have been used and evaluated for accuracy of the results. Biomass productivity depends on the land cover, forest density and canopy chlorophyll content, all of which influence spectral reflectance recorded by satellite sensors (Zheng et al, 2007). A number of studies using different type of remote sensing data were done to estimate and map forest and agro-based biomass. Mapping of multiple vegetation types at a large scale became possible only due to GT. Remote sensing allows synoptic coverage and high temporal resolution, which helped to monitor the changes in the land use and land cover. Aerial photography too was used for the purpose with a relative error of 14-45 % in estimates as compared to an error of 20-65% using satellite image interpretation (Ramachandra, 2010).

STUDY AREA

This research focuses on Banni located at 23°19′ to 23°52′ N; 68°56′ to 70°32′ E as shown in Figure 1.

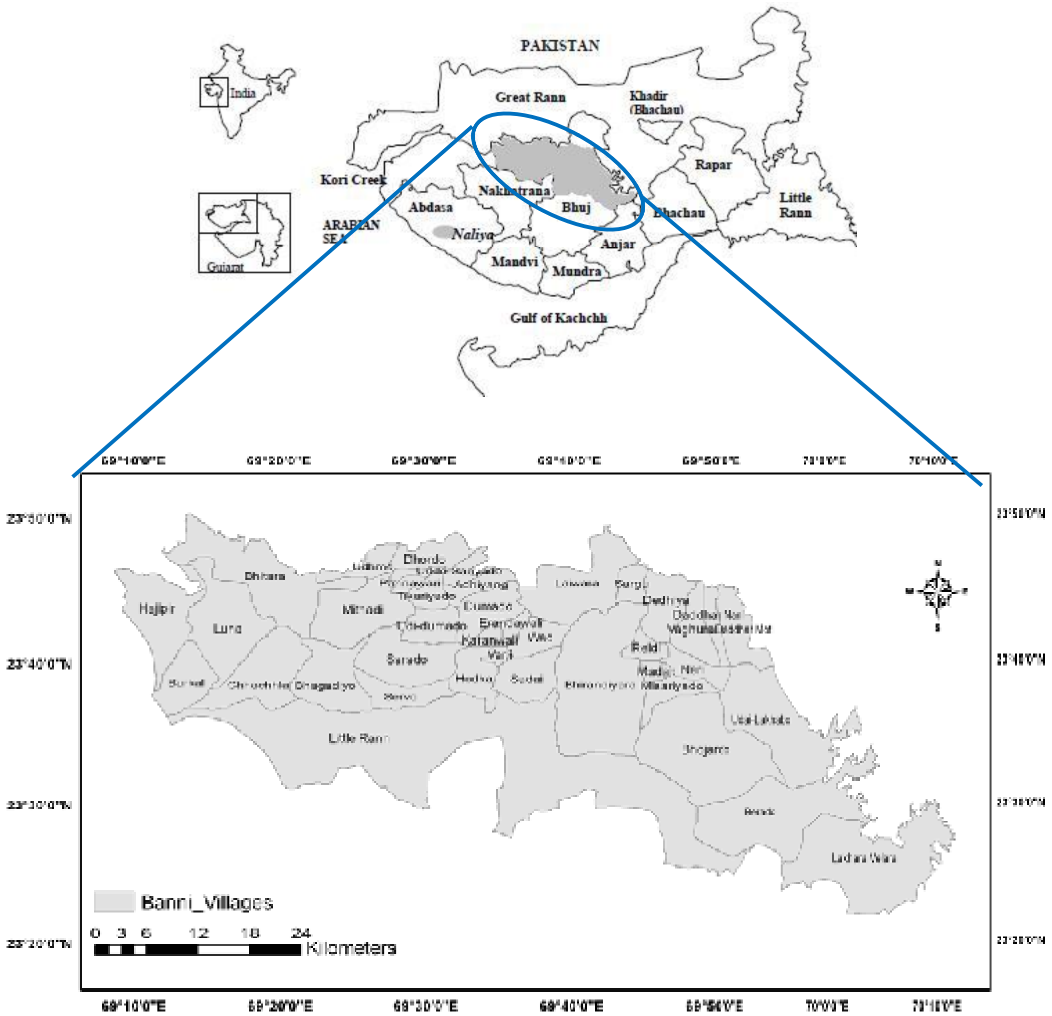

Figure 1: Map showing Study Area- Banni Grassland, India

Banni lies in the arid zone and the temperature is generally high during the entire year. It varies from 48°C–49°C in summer to 8°C -10°C in winter. Mean temperature data from 1971-2000 showed that May and June are the hottest months while December and January are the coldest months. Rainfall is extremely sparse and droughts are a recurring phenomenon in Banni. Out of the past 50 years, 33 years were classified as drought years (ISET, 2012). Records of monthly mean rainfall data for a period of 30 years showed that mean rainfall is less than 10mm in eight months a year. The total human population of Banni is approximately 20000 while livestock population is approximately 80000.

MATERIALS AND METHODS

LANDSAT 5 TM 2011 image was used to assess the spatial distribution of *Prosopis* in Banni. Extensive field work was undertaken using Trimble handheld GPS to establish control points in the field for accurate classification of image in Erdas Imagine 9.3. The work consisted of image classification using supervised techniques and field sampling of 4 plots for inventory of biophysical parameters of the *Prosopis* tree. Harvesting method was used for estimating the above ground biomass (AGB) productivity from *Prosopis*. Estimation was done to assess the total biomass that could be produced under different cutting scenarios of *Prosopis* as shown in **Error! Reference source not found.**. These scenarios were based on inputs during field visit, regeneration rate which was observed as 2-3 years and spread rate of approximately 5-10%. Additionally, AGB estimation was also aimed at assessing the total carbon sequestered by *Prosopis* wood.

Scenario	*Prosopis* Cutting	% of total area
Scenario-1	Low	5%
Scenario-2	Normal	10%
Scenario-3	High	15%
Scenario-4	Very High	30%

Table 1: *Prosopis* Cutting Scenarios

Plots for tree sampling were selected using stratified random sampling method. As the growth of *Prosopis* was bushy and thorny, plot was finalized based on relative approachability. Field inventory process was similar to the process followed by Chaturvedi in 1984. Two plots each of size 100m x 100m in dense *Prosopis* area and two plots of size each of size 100m x 100m in mixed *Prosopis* area were sampled for biophysical parameters. These plots were selected at different locations to take into considerations the changes in biomass with location within Banni. Girth (G) and diameter at breast height (D) of each tree in the plot was measured at a height of 30cm from base using measuring tape and Vernier calliper respectively. Height (H) of each tree in the plot was measured after the tree was harvested. Number of stems (n) in each tree was also observed. Dry weight was measured after the tree was chopped and sun dried. Tree with girth less than 10cm was excluded from the survey. If the stem of a tree had bifurcated into multiple stems before a height of 30 cm, each stem was considered as individual tree and readings were taken accordingly.

Multivariate regression analysis was performed to establish allometric relation between the vegetation parameters and biomass productivity. The linear relationship (**Error! Reference source not found.**) developed by Chaturvedi in 1984 for fuel-wood trees gave the best fit and highest value of coefficient of regression (R) and coefficient of determination (R^2).

$$\mathbf{W = a + b^* (nD^2h)} \qquad (1)$$

Where 'D' and 'H' are diameter at breast height and tree height; 'a' and 'b' are regression parameters; 'n' is the number of stem. 'W' is the weight of the biomass in tonne/ha. Allometric relation was developed separately for dense and mixed *Prosopis* area.

Assuming that similar conditions existed throughout Banni grassland as that of the sampled plots, biomass productivity in dense and mixed *Prosopis* cover was calculated by multiplying per hectare production and area under each type of land cover obtained from classification maps. Total biomass productivity of Banni was estimated by adding up productivity from dense and mixed *Prosopis* area. Biomass was observed to bear direct relationship with carbon present in it. Study by Wangda, 2012 and Kale et al, 2009 showed that dry biomass contained 47% carbon. Hence, the above ground biomass was converted to carbon stock by using a conversion coefficient of 0.47 in this research (Kale et al, 2009 and Wangda, 2012). Figure 2 presents the work methodology adopted for the study.

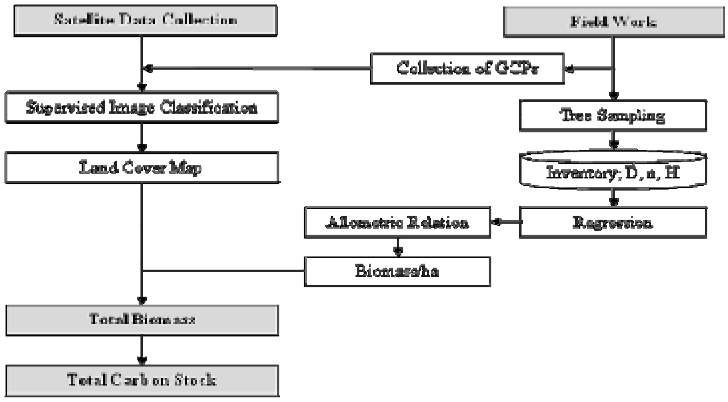

Figure 2: Work Methodology

RESULTS AND DISCUSSIONS

Land cover mapping was done using Maximum Likelihood supervised classification technique into five major land cover classes: Dense *Prosopis*, Mixed *Prosopis* and other vegetation, Highly saline land, Grassland and low lying area and Water body. An accuracy of 94.4% was achieved in the classification. Land cover analysis showed that *Prosopis* was mainly found in central Banni villages (Figure 1) such as Mithadi, Sarado, Udi-dumado, Bhagadio, Hodka, Karanwali, Dumado, and Bhirandiyara. Table 2 presents the area under different land cover classes based on the classified image of 2011 and Figure 3 shows the classified image of 2011.

Classes	**Area (Sq. Km.)**	**% of total**
Dense *Prosopis*	354.16	14%
Mixed *Prosopis* and others	936.91	36%
Grassland /Low Lying area	787.84	30%
Water body	190.56	7%
Highly Saline land	341.19	13%

Table 2: Land Cover classes and area in 2011

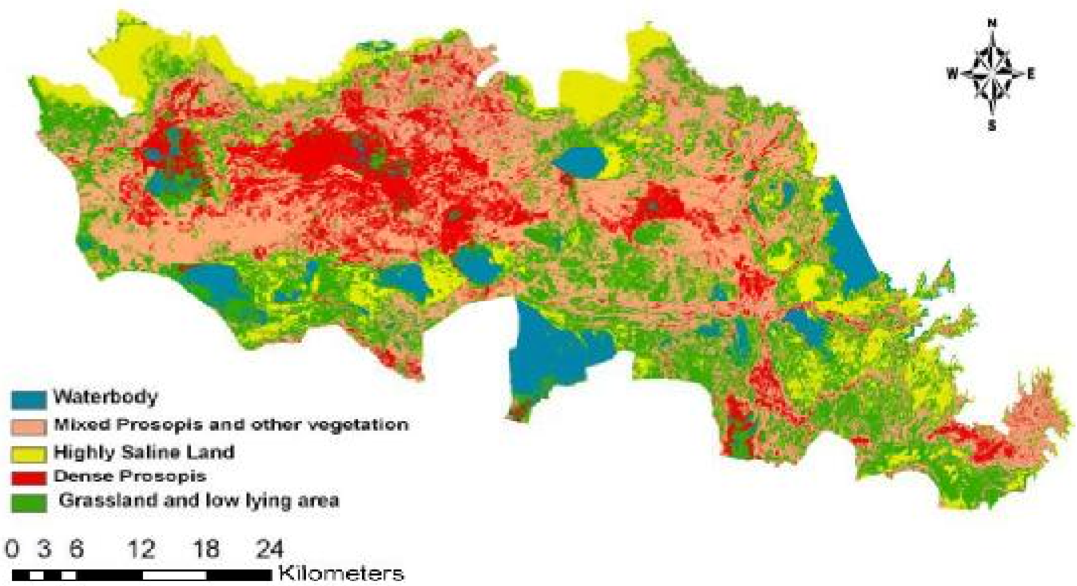

Figure 3: Land Cover Image of 2011

Biomass estimation was done combing *Prosopis* inventory data obtained from field surveys and the results of land cover analysis. Allometric relationship was developed using multivariate regression analysis between the biomass productivity and biophysical parameters. After discarding some samples, approximately 300 *Prosopis* trees were sampled in dense *Prosopis* area and 120 *Prosopis* trees were sampled in mixed *Prosopis* area. Regression analysis showed that nD^2H was well correlated with the biomass.

Coefficient of determination (R^2) in Dense *Prosopis* area was found to be 0.961 as shown in Figure 4. Biomass productivity in dense area was found to be 2204.1 kg/ha.

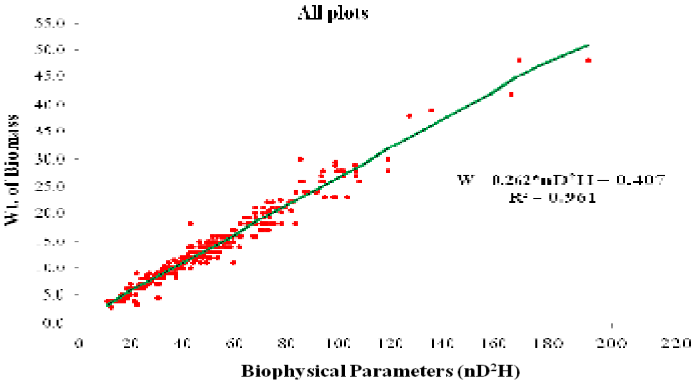

Figure 4: Allometric Relation using Regression Analysis in Dense *Prosopis* Area

In Mixed *Prosopis* area, the coefficient of determination (R^2) was found to be 0.966 and biomass productivity was 432.8 kg/ha.

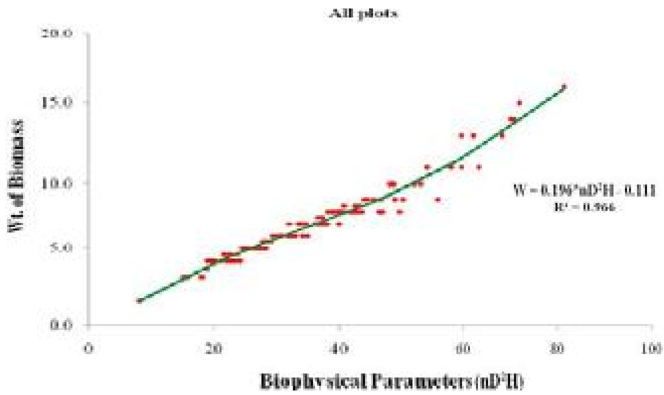

Figure 5: Allometric Relation using Regression Analysis in Mixed *Prosopis* Area

Total biomass productivity considering different cutting scenarios as explained in Table 1 was deduced from land cover classes in 2011 and biomass productivity per ha in dense *Prosopis* and mixed *Prosopis* areas. The results obtained are shown in Table 3.

Cutting Scenarios	Total Biomass Production (in Tonnes)
Low (5%)	5930.2
Normal (10%)	11860.4
High (15%)	17790.6
Very High (30%)	35581.2

Table 3: Biomass Productivity from *Prosopis* in 2011

Carbon stock in *Prosopis* wood was deduced using a conversion coefficient of 0.47 as explained in section 3. The total carbon stock in 2011 was found to be 55.7 MT.

CONCLUSIONS AND RECOMMENDATION

Biomass productivity from *Prosopis* was found to be in the range of 5930.2 T to 35581.2 T. Based on the field visits and inputs from the Maldharis, invasion of *Prosopis* is assumed to be the prime reason of degradation of Banni grassland. It is also understood that availability of nutritious grasses in Banni is the driving factor of Milk production industry in Banni.

Since this research was limited to assessing the biomass productivity and carbon stock, it is recommended to compare the economy of Milk and economy of Charcoal which is the main derivative from *Prosopis* biomass, to assess the most sustainable source of income. As lives of thousands of Maldharis are dependent on Banni grassland it is highly recommended that a holistic approach is adopted considering both the economic and environmental impacts of Banni on the Maldharis.

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