# BIOMASS PRODUCTION AND PREDICTION MODELS FOR *ACACIA NILOTICA* IN SALT AFFECTED VERTISOLS IN KARNATAKA

A. RAIZADA*, M.S. RAMA MOHAN RAO**, K.T.N. NAMBIAR*** AND M. PADMAIAH****

*Central Soil and Water Conservation, Research & Training Institute, Dehra Dun (Uttarakhand).*

## Introduction

In India about 5.50 million ha is reported to be saline (including coastal sandy areas), 3.88 m ha alkali and 8.53 m ha is waterlogged. Groundwater surveys indicate that poor quality water is being utilized in different states, specially Rajasthan (84% of irrigated water), Haryana (62%), Punjab (41%), Karnataka (38%), Andhra Pradesh (32%) and Gujarat (30%) (Dagar and Tomar, 2002). In such areas where water quality is poor and fresh water is not available for agriculture, the use of such poor quality water often leads to other unexpected problems and release of salts in the soil solutions.

This problem is also caused by indirect means, large areas are salt affected due to soil characteristics, land features and increase in area under irrigation. These areas are required to be reclaimed by various ameliorative methods. The use of trees as a natural aspect in reclaiming salt affected soils is well known.

Salt affected wastelands are being used to grow trees for meeting rural requirements of fodder and fuelwood and to restore the ecological balance of such sites. Plantation of trees or trees mixed with grasses in silvipastoral combinations are recommended for the restoration of such sites. Silvipastoral systems are low input agro technologies for utilization of degraded lands and in those conditions where suitable trees and grasses tolerate extreme climatic and soil conditions. In these combinations trees provide firewood and /or fodder while grasses reduce surface soil erosion due to their high soil binding capacity and also produce much needed fodder. This land use combination is highly suitable for those areas where livestock rearing is used to supplement income by small and marginal farmers (Singh, 1986; Puri, 1989; Vishwanathan *et al*., 1999).

*Acacia nilotica* spp. *indica* (Benth.). Brenan is an extremely valuable tree for fuelwood, timber, fodder, tannin etc. It is drought resistant and is an important species for conservation practices. Its wood is heavy (sp. gr. 0.67 - 0.68) and the calorific value of sapwood is 4,800 kcal per kg while that of the heartwood is 4,950 kcal per kg. The wood therefore makes good charcoal.

The forest cover in Karnataka is 36,991 km$^2$ out of which open forests constitute 10,835 km$^2$ while the per capita tree cover is only 0.08 ha. Dense forests occupy 26,156 km$^2$ and are confined only

* Senior Scientist (Forestry), ** Ex. Principal Scientist (Soils), *** Ex. Senior Scientist (Forestry), ***Senior Scientist (Agric. Extension), now at Directorate of Oilseeds Research, Hyderabad (Andhra Pradesh).

to the western coast. The dry parts of the State covering Raichur, Koppal, Bellary, Bijapur, Gulbarga and Bidar have very poor tree cover (FSI, 2001) and the potential to raise drought tolerant species is high. Further many areas are salt affected either due to inherent soil properties or due to increase in irrigation area and subsequent release of salts.

This paper reports on the biomass production from *A. nilotica* raised in salt affected soils in District Bellary. Prediction models have been prepared to estimate biomass production in existing and future plantations.

**Study site**

The plantation was raised in the Research Farm of the CSWCRTI, Research Centre, 12 kms away from Bellary (15°9' N lat. and 76°15' E long., alst. 445m amsl). The area receives an average rainfall of about 500 mm which is spread over 35 rainy days. Soils of the area come under vertisols with the clay content varying between 32-51%. The clay minerals belong to the montmorillonite and beidellite group, which give these soils the characteristic feature of swell-shrink, resulting in the development of cracks and increased moisture loss.

*A. nilotica* was planted at a spacing of 8 x 8m, with three grass species – *Cenchrus ciliaris, Dicanthium annulatum* and *Chloris bourneii* as an understorey crop for fodder production. The average green yield of these grasses were 2.6, 1.5 and 0.8 t/ha/yr over a period of 10 years.

**Methodology**

Fifteen trees, seventeen years old, were harvested by random selection. Tree diameters were recorded at the point, just above which the stem begins to branch out. *A. nilotica* has a tendency to branch out at a height which is usually less than 1.3 m. It was assumed that taking the diameter just at the point where the stem begins to branch, would bring in a considerable amount of uniformity in preparing the prediction model. Height of each tree was measured using a calibrated bamboo staff (Table 1). Number and diameter of branches occurring at 1.30m height were measured and diameter at breast height (dbh in cm) computed using the formula suggested by MacDicken *et al*. (1991).

**Tree biomass estimation**

Trees were harvested at the ground level and the individual bole section, branches more than 2 cm in diameter, branches less than 2 cm in diameter, twigs and leaves were separated immediately in the field and their fresh weight recorded. Representative samples of these were collected, dried at 80°C till constant weight and dry weight calculated. Allometric relationships to predict biomass (Pandya *et al*., 1972; Singh and Sharma, 1977; Raizada and Srivastava, 1989) were computed using tree diameter (cm) as an independent variable and linear, logarithmic and power equations. Equations with the highest $r^2$ values were selected as prediction model.

Soil samples were collected from four depths 0-7.5cm, 7.5-15, 15-30 and 30-45 cm. Samples were air dried, 2 mm sieved material was used for determination of pH (1:2.5), electrical conductivity and organic carbon, using standard laboratory techniques (Jackson, 1967, Piper, 1966).

**Table 1**

*Sample dimensions of Acacia nilotica tree utilized for the study.*

| Sl. No. | Diameter at point where branching occurred (cm) | Tree height (m) | No. of branches from main stem | Multiple stem diameters at 1.3 m | Computed dbh * | Tree canopy ($m^2$) |
|---|---|---|---|---|---|---|
| 1 | 9.5 (85) | 3.7 | 3 | 3, 6, 4 | 7.81 | 4.20 |
| 2 | 16 (80) | 4.7 | 3 | 6, 8, 4 | 10.77 | 6.52 |
| 3 | 10.4 (60) | 3.5 | 2 | 8.3, 3.4 | 8.97 | 4.50 |
| 4 | 10 (46) | 3.9 | 2 | 6, 3 | 6.70 | 4.12 |
| 5 | 15.4 (74) | 4.8 | 2 | 7.4, 6.2 | 9.65 | 4.45 |
| 6 | 10.1 (132) | 4.5 | - | - | - | 4.30 |
| 7 | 11.6 (130) | 4.2 | - | - | - | 4.32 |
| 8 | 13.1 (120) | 5.1 | 3 | 7, 4, 5.1 | 9.54 | 4.55 |
| 9 | 9.3 (126) | 4.4 | 4 | 4, 3.2, 3.1, 3.6 | 6.98 | 4.02 |
| 10 | 11.6 (90) | 4.1 | 2 | 6.4, 4.7 | 7.94 | 4.10 |
| 11 | 12.5 (130) | 4.5 | - | - | - | 4.55 |
| 12 | 9.6 (90) | 4.1 | 2 | 5.6,3.2 | 6.45 | 3.50 |
| 13 | 11.2 (96) | 4.3 | 3 | 4.2,5.1,1.2 | 6.71 | 4.28 |
| 14 | 10.6 (115) | 4.4 | 2 | 5.3, 4.8 | 7.15 | 4.26 |
| 15 | 11.4 (120) | 4.4 | 3 | 6.2, 3.2,4.6 | 8.35 | 4.40 |

* as per MacDicken *et. al.* (1991).
Figures in paranthesis are the height from ground level where branching occurred.

## Results and Discussions

*Soil features* : The entire area of study has been relegated to salt affected soils. This could be attributed to the topographic situation, since it is situated on the lower half of the slope and the salts have migrated from the upper reaches where the land is irrigated. The groundwater table too occurs at a depth of 1 m and its analysis revealed it to be highly brackish (21 d S/m; pH 7.3). Soil pH varied from 7.8 to 8.1 from 0-7.5 cm depth to 30-45 cm depth. Electrical conductivity varied from 1.14 at 0-7.5 cm depth going up to 3.35 at 30-45 cm depth and varying between 3.35 to 4.16 at this depth in different points in the plot. Organic carbon % was 0.80, 0.64, 0.46 and 0.38 at 0-7.5, 7.5-15, 15-30 and 30-45 cm depths in the plot. Despite these adverse situations, the tree species has survived and continues to flower and fruit every year.

*Tree biomass production* : Although the plantation is even aged, there are wide variations in diameter (3.1 to 16 cm) in the entire block, and 9.3 to 15.4 cm in the sampled trees (Table 2). Tree height also varies from 3.5 to 5.1 m, which in turn has influenced above ground biomass. Tree diameters (measured at the point of branching) vary from 9.3 to 15.4 cm. On an average most of the trees had 2.3

**Table 2**

*Over dry biomass (kg) of various components from harvested A. nilotica trees.*

| Sl. No. | Diameter (cm) | Leaf (kg) | Twigs (kg) | Small branches (kg) | Big branches (kg) | Bole biomass (kg) | Utilisable biomass* (kg) | Total above-ground biomass (kg) |
|---|---|---|---|---|---|---|---|---|
| 1 | 9.5 (85) | 1.2 | 7 | 2.48 | 3.81 | 12 | 18.29 | 26.49 |
| 2 | 16(80) | 3.1 | 25 | 10.21 | 24.13 | 38.3 | 72.64 | 100.74 |
| 3 | 10.4 (60) | 0.8 | 10 | 3.03 | 7.62 | 18.9 | 29.55 | 40.35 |
| 4 | 10 (46) | 1.2 | 9.5 | 3.31 | 6.03 | 14 | 23.34 | 34.04 |
| 5 | 15.4 (74) | 1.5 | 15.5 | 11.04 | 16.83 | 34.2 | 62.07 | 79.07 |
| 6 | 10.1 (132) | 0.5 | 7.3 | 2.76 | 10.5 | 14 | 27.26 | 35.06 |
| 7 | 11.6 (130) | 1.6 | 15.7 | 3.31 | 14 | 18.9 | 36.21 | 53.51 |
| 8 | 13.1 (120) | 2.3 | 17.5 | 6.07 | 18.42 | 22.7 | 47.19 | 66.99 |
| 9 | 9.3 (126) | 0.7 | 8.8 | 2.48 | 7.62 | 19.4 | 29.5 | 39 |
| 10 | 11.6 (90) | 0.4 | 2.6 | 5.8 | 10.16 | 18.6 | 34.56 | 37.56 |
| 11 | 12.5 (130) | 2.4 | 17.2 | 8.3 | 15.27 | 18.9 | 42.47 | 62.07 |
| 12 | 9.6 (90) | 0.9 | 9.1 | 3.86 | 10.16 | 15.5 | 29.52 | 39.52 |
| 13 | 11.2 (96) | 1.2 | 6.2 | 3.65 | 9.66 | 14.68 | 27.99 | 35.39 |
| 14 | 10.6 (115) | 1.6 | 5.1 | 4.2 | 9.32 | 15.2 | 28.72 | 35.42 |
| 15 | 11.4 (120) | 1.1 | 6.25 | 3.2 | 9.28 | 16.6 | 29.08 | 36.43 |

*Utilisable biomass = small and big branch biomass + bole biomass

branches at 1.30 m (standard height for measurement of dbh) and the computed dbh ranged from 6.45 to 10.77 cm (Table 1). Oven dry weights of sampled trees (kg/tree) are given in Table 2. As expected, trees with larger diameter had a higher above ground biomass with the maximum contribution by bole and least by leaves. Contribution by big branches (>2 cm dia.) varied from 3.81 to 24.13 kg/tree, leaf biomass from 0.5 to 3.1 kg/tree and bole biomass from 12 to 38.8 kg/tree. Utilizable biomass (bole + bark + branches) for firewood ranged from 18.3 to 72.64 kg/tree and total above ground biomass ranged from 26.50 to 100.74 kg/tree.

In a biomass study carried out on *A. nilotica* in Haryana (Tandon *et al.*, 1988), it was concluded that biomass yields increased sharply from the age of 13 years. Estimated yields from this 17 year old plantation were comparably lower than those obtained on five year old trees in Haryana. These significant reductions can be attributed to the poor site condition and high salt concentrations. In spite of the stressed conditions, the trees on an average produced 45.75 kg of dry biomass each, which is equal to 7.13 t/ha @ 156 trees/ha and reflects on the resilience characteristics of the species.

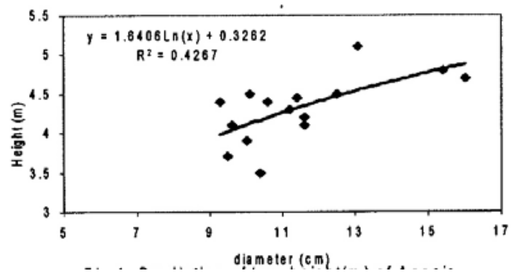
There are reports that *Acacia* is a tolerant tree species for alkali soils and they posses a genetic potential of avoiding sodium at the root surface. Grewal and Abrol (1986) reported that potassium content was more in *Acacia* and *Parkinsonia* roots, than in *Eucalyptus* and *Acacia* accumulated higher calcium in all plant parts as compared to *Eucalyptus* and *Parkinsonia* . It has been reported earlier (Khan and Yadav, 1962) that plants which survive highly alkaline conditions take up large amounts of sodium. While plant growth is determined by oxygen supply and bicarbonate levels at high pH levels (Becock, 1965), these factors combine to give reduced plant yields and also show abnormal root activity (Pearson and Bernstein, 1958).

**Biomass Prediction models**

Three predictions models (linear, power and exponential) were evaluated to predict tree biomass and the equation with the best fit were selected. Predictions were computed for tree height, bole biomass, utilizable biomass (bole + bark + branches) and total above ground biomass. The best fit obtained using all the three forms for predicting height, produced $r^2$ value of only 0.4267 (Fig. 1) which may be attributed to the large variations in the point at which diameter was measured (Table 1). However, the best fit for predicting bole, utilizable and total above ground biomass was in the linear form and produced $r^2$ values of 0.8281, 0.9162 and 0.8665 (Figs. 2, 3, 4) respectively. The equations are :

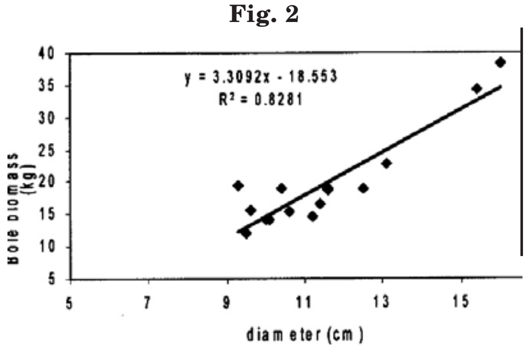
Bole Biomass y = 3.3092 x -18.553
$r^2 = 0.8281$
Utilizable biomass y = 6.9319 x -43.731
$r^2 = 0.9162$

**Fig. 1**



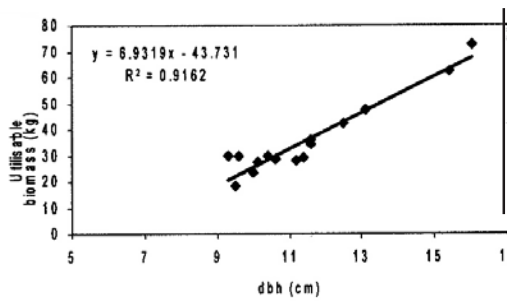

Prediction of tree height (m) of *Acacia nilotica* using diameter as an independent variable

**Fig. 2**



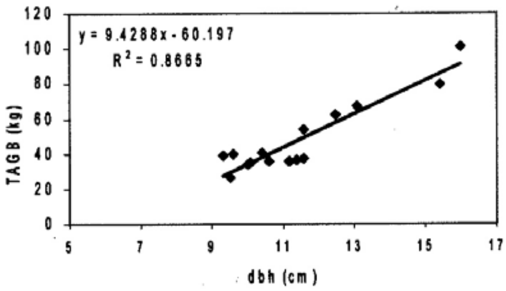

Prediction of bole biomass (kg) of *Acacia nilotica* using diameter as an independent variable

**Fig. 3**




Prediction of utilsable biomass (kg) from *Acacia nilotica* using diameter as an independent variable

**Fig. 4**




Prediction of total above-ground biomass (kg) from *Acacia nilotica* using diameter as an independent variable

Total above ground biomass :
$y = 9.4288\,x - 60.197$
$r^2 = 0.8165$

Computations were carried out to observe % difference in the actual and estimated values, the results of which are given in Table 3. Perusal of the table reveals that % differences were not very significant. In general most of the predicted values were slightly lower than the observed values. High variations were observed in sample tree no 9, where the stem branching occurred at a height of 126 cm (Table 1) but the diameter was less (9.3 cm). Thus the method suggested in this paper can also be used to predict biomass of various components, specially in those trees where multiple branching is of frequent occurrence.

**Table 3**

*Actual and computed biomass values of A. nilotica and % variation based on prediction models*

| Sl. No. | Diameter (cm) | Bole biomass (kg) | | | Utilisable biomass (kg) | | | Total above ground biomass (kg) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Actual | Computed | % diff. | Actual | Computed | % diff. | Actual | Computed | % diff. |
| 1 | 9.5 | 12 | 12.88 | +7.33 | 18.29 | 22.12 | +20.94 | 26.47 | 29.37 | +10.87 |
| 2 | 16 | 38.3 | 34.4 | -11.38 | 72.64 | 67.16 | -8.15 | 100.74 | 90.66 | -11.11 |
| 3 | 10.4 | 18.9 | 15.88 | -19 | 29.55 | 28.36 | -4.02 | 40.35 | 37.86 | -6.17 |
| 4 | 10 | 14 | 14.54 | +3.85 | 23.34 | 25.58 | +9.63 | 34.04 | 34.09 | +0.14 |
| 5 | 15.4 | 34.2 | 32.4 | -5.55 | 62.07 | 63.02 | +1.53 | 79.07 | 85.00 | +7.5 |
| 6 | 10.1 | 14 | 14.87 | +6.21 | 27.26 | 26.28 | -3.6 | 35.06 | 35.03 | -0.08 |
| 7 | 11.6 | 18.9 | 19.83 | +4.92 | 36.21 | 36.67 | +1.27 | 53.57 | 49.17 | -8.11 |
| 8 | 13.1 | 22.7 | 24.80 | +9.25 | 47.19 | 47.07 | -0.25 | 66.99 | 63.32 | -5.47 |
| 9 | 9.3 | 19.4 | 12.22 | -37 | 29.50 | 20.73 | -29.72 | 39 | 27.50 | -29.5 |
| 10 | 11.6 | 18.6 | 19.83 | +6.61 | 34.56 | 36.68 | +6.13 | 37.56 | 49.17 | +31 |
| 11 | 12.5 | 18.9 | 22.81 | +20.7 | 42.47 | 42.91 | +1.03 | 62.07 | 57.66 | -7.1 |
| 12 | 9.6 | 15.5 | 13.21 | +14.77 | 29.52 | 22.81 | -22.73 | 39.52 | 30.32 | -23.28 |
| 13 | 11.2 | 14.68 | 18.51 | +26.08 | 27.99 | 33.90 | +21.11 | 35.39 | 45.40 | +28.24 |
| 14 | 10.6 | 15.2 | 16.52 | +8.7 | 28.72 | 29.74 | +3.55 | 35.42 | 39.74 | +12.19 |
| 15 | 11.4 | 16.6 | 19.17 | +15.5 | 29.08 | 35.30 | +21.4 | 36.43 | 47.30 | +29.83 |

+ and – denote variations above or below the actual values obtained

## Conclusions

Silvi-pastoral systems using various tree grass combinations are being recommended for the rehabilitation of wastelands including salt affected lands. *Acacia nilotica* is a suitable tree species for these problem sites and can be safely incorporated with fodder grasses like *Cenchrus ciliaris* and *Dicanthium annulatum* in the black soil region of Karnataka and produce much needed fodder and firewood for the resource poor regions of the semi-arid tropics. Biomass prediction using the method suggested can be used to calculate availability from plantations of this species which can be raised in salt affected vertisols.

## SUMMARY

**Biomass prediction models were prepared for 17 year old *Acacia nilotica* trees raised on salt affected vertisols of the semi arid tropics in Karnataka. *A. nilotica* was raised at 8x8 m spacing with an under storey of three grass species – *Cenchrus ciliaris*, *Dicanthium annulatum* and *Chloris bourneii* for the production of fodder. Wide variations occurred in the trees sampled by random selection in the plantation, with respect to diameter (3.1 to 16 cm) and tree height (3.5 to 5.1 m). Leaf biomass varied from 0.5 to 3.1 kg/tree, contribution by big branches (> 2 cm dia.) varied from 3.81 to 24.13 kg/tree. Total above ground biomass ranged from 26.5 to 100.74 kg/tree. Prediction models with the best fit were in the linear form with $r^2$ values of 0.8261, 0.9162 and 0.8665 for predicting bole, utilizable and total above ground biomass.**

### कर्णाटक की लवण से कुप्रभावित वर्टिसोल मृदाओं में *अकेसिया नीलोटिका* का जैवपुंज उत्पादन और पूर्वकथन प्रतिरूप

ए० रायजादा, एम०एस० राममोहन राव, के०टी०एन० नम्बियार व एम० पद्मैय्या

### सारांश

कर्णाटक के अर्द्ध–शुष्क उष्ण प्रदेशों की लवण कुप्रभावित वर्टिसोल मृदाओं में उगाए हुए 17 वर्षीय *अ० नीलोटिका* वृक्षों के जैवपुंज पूर्वकथन मॉडल (प्रतिरूप) तैयार किए गए। *अ० नीलोटिका* को 8 x 8 मी० अन्तराल देकर उगाया गया जिसके नीचे भूस्तर पर तीन घास जातियां – *सेंचरस सिलियारिस, डायकैंथियम एन्युलेटम* और *क्लोरिस बोर्निआई* चारा उत्पादित करने को उगाई हुई थी। रोपवन लगाने में यादृच्छिक चुनाव से वृक्षों का न्यादर्शन करने से उनमें व्यास (3.1 से 16 सेमी० तक) और वृक्ष की ऊंचाई (3.5 से 5.1 मी० तक) की दृष्टि से काफी अन्तर आ गया। पत्तियों का जैवपुंज 0.5 से 3.1 किग्रा/वृक्ष तक, उसमें बड़ी शाखाओं (> 2 सेमी व्यास की) का योगदान 3.81 से 24.13 किग्रा/वृक्ष तक रहता पाया गया। भूमि से ऊपर का कुल जैवपुंज 26.5 से 100.74 किग्रा/वृक्ष तक रहा। सबसे अधिक ठीक बैठने वाले पूर्वकथन प्रतिरूप रेखीय रहते पाए गए जिनमें तने, समुपयोज्य और भूमि से ऊपर कुल जैवपुंज बताने के लिए त्रिज्या² ($r^2$) मान क्रमशः 0.8261, 0.9162 और 0.8665 रहे।

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