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Forest Plantations for Climate Change Mitigation –Reviewing Estimates of Net Primary Productivity in Forest Plantations

Vithal R. Karoshi and B.S. Nadagoudar*

INTRODUCTION

Net primary productivity (NPP) is an important driver of the carbon balance. It is defined as the balance between carbon gain through photosynthesis (gross primary productivity, GPP) and losses through autotrophic respiration (Ra).

It represents the net carbon uptake from the atmosphere into vegetation. In contrast with carbon losses through respiration, disturbance, and harvest, it greatly influences the strength of the terrestrial carbon sink. Forest management can exploit NPP for carbon sequestration in forests and biomass production for bio energy for climate change mitigation. NPP is an important parameter in many forestry models that are used to assess the future mitigation potential of the sector.

Carbon sink performance depends on various factors. It differs in man-made plantations and natural forests. Similarly, the carbon sink is affected by plant species/clones/hybrids as well as by management factors like fertilisation, irrigation, and intermittent thinning, etc.

The trees assimilate CO_2 by photosynthesis and store carbon in biomass and in the soil. The tropical forests make up 80 per cent of the total world forests and are recognised as having the greatest long term potential to sequester atmospheric carbon. The forests have many other vital functions to carry on for sustainable earth systems besides carbon sequestration. In order to cease any more increase of CO_2 in the atmosphere by means of additional plantation areas could be an important means. Therefore, it is worth an idea to plant trees for mitigating the increase of CO2 in the atmosphere. Therefore, this paper has proposed to investigate and to estimate regional potential NPP from plantations.

The existing forest may not be sufficient to maintain ecological balance. Therefore, additional areas presently which are either unutilised or unfit for agriculture could be converted into biomass production purpose so that extra amount of carbon is sequestrated in order to mitigate climate change through establishment of plantations. The investigator was confronted with the following questions during the study: (1) What are the important tropical species which have higher NPP?, (2) What are the factors which affects NPP variability?, (3) How much area could be brought

*Presently, General Manager-Plantations, Emami Biotech Ltd., and Director of Research (Retired), University of Agricultural Sciences, Dharwad, respectively.

under potential plantations based on land availability? and (4) What could be the regional potential NPP from plantations?

MATERIAL AND METHODS

The present investigation was carried out in the Forestry Research Programme at International Institute for Applied System Analysis (IIASA), Austria in 2007 during the Young Scientists Summer Program.

Extensive survey and review of literature on forest biomass, NPP and trees growth in various geographical locations was made. The appropriate studies were recorded with major focus on high NPP values in any given situation. Internet search was the main tool used in getting the required data.

Eighty four studies on various species were found very useful and hence, data were extracted from those studies. The major data extraction was done on type of species, type of soil, average temperature and precipitation, altitude, latitude and longitude, study site/location, age of trees, and density of wood besides vital data on yield/biomass. The data collected were thoroughly checked for their consistency. The units were converted from cubic metre and tonne of biomass to required unit of NPP (net primary productivity) for easier comparison. While arriving at NPP data from other units the wood carbon content was considered as 50 per cent as per reports of IPCC and Australian Greenhouse Commission. The data on wood density were collected from various published literatures.

Data were collected from 84 studies with 252 data sets and also from various sources like FAO documents/reports, scientific research papers from indexed journals, review papers from journals and few reports from international conferences.

The collected data were grouped according to the following criteria, viz., species group, soil, precipitation, temperature, latitude and longitude besides altitude. In most cases above ground biomass (AGB) was recorded. Finally, mapping was carried out according to latitude and longitude by using GIS software, i.e., ARC View. The study sites were located in tropical and sub-tropical countries.

RESULTS AND DISCUSSION

There were 252 data sets in the study of which 190 were used for final data analysis. There were as many as 67 studies on *Eucalyptus* which indicates that Eucalyptus is widely researched and planted species in the tropics followed by *Pinus* and *Acacia* (Table 1). From the following table it can be observed that highest average NPP is recorded in case of *bamboo*(17.523) followed by rubber (15.970), oil palm (14.500) (*Samanea* and *Erythrina* (13.350), coconut (12.150), *cassia* (10.350), *eucalyptus* (10.009), *alnus* (10.000), *sesbania* (9.433), *prunus* (9.000), *leucaena* (8.739), *acacia* (9.000) and *casuarinas* (7.550) etc.

TABLE 1. SPECI ES AND THEIR NPP VALUES

Genera/Species (1)	No.of datasets (2)	Avg.NPP (3)	Max.NPP (4)	Min.NPP (5)
Castanea	1	1.500	1.500	1.500
Gliricidia	1	1.690	1.690	1.690
Terminalia	2	2.121	3.400	0.841
Cunninhamia	1	2.215	2.215	2.215
Cordia	2	3.613	4.125	3.100
Sissoo	6	3.640	11.922	1.232
Pinus	25	3.965	7.750	0.560
Salix	2	4.100	4.583	3.617
Prosopis	7	5.247	11.000	0.835
Gmelina	4	5.359	6.714	3.895
Poplar	11	5.694	14.125	1.554
Tectona	10	5.877	17.550	0.528
Albizia	2	6.875	7.000	6.750
Mixed	3	7.475	8.700	6.788
Casuarina	6	7.550	20.930	2.775
Leucaena	7	8.739	18.400	4.200
Acacia	27	9.000	18.5	5.500
Prunus	1	9.000	9.000	9.000
Sesbania	5	9.433	15.585	6.494
Alnus	1	10.000	10.000	10.000
Eucalyptus	67	10.009	38.250	0.391
Cassia	1	10.350	10.350	10.350
Coconut	1	12.150	12.300	12.000
Erythrina	1	13.350	13.350	13.350
Samanea	1	13.350	13.350	13.350
Oil palm	1	14.500	20.000	9.000
Rubber	1	15.970	22.457	9.484
Bamboo	5	17.523	37.813	6.628

It is clear from Table 1 that there is tremendous variation of NPP values both between and within species/genera. The variation in NPP values between species is due to nature of plant growth, e.g., bamboo is the fastest growing woody plant on this planet which can grow up to 1 meter in 24 hours when suitable conditions are provided. The variation in NPP within species is due to the factors like soil, climate and treatment. It clearly indicates that NPP values could be improved by way of species selection followed by exercising appropriate treatment like cloning, fertilisation, soil working, manipulation of stocking levels (thinning), coppicing, pollarding, weeding and irrigation, etc.

The variation in NPP values within the species is due to factors like altitudinal range, rainfall amount and pattern, and soil factors, e.g., minimum NPP was recorded in bamboo (6.628) when cultivated under higher altitude (2560m), lower annual rainfall (800mm) and poor soils (forest degraded soils) whereas, maximum NPP (37.813) was recorded under most ideal conditions like mid-altitude (800m), annual rainfall of 1450mm and forest soils that are rich in organic carbons. Most species recorded higher NPP under altitudinal range of 250m-2500m, annual rainfall range of 800-1500mm and forest rich soils.

The tropical plants grow in wide range of ecological conditions. It is also true that optimal growth is found in particular ecological settings. However, from this study it is found that most tropical tree species perform better in the optimal altitudinal range of 250m to 2500m. Hence, plantations for carbon sequestration projects should focus on the land areas which are falling in this altitudinal range.

The major climatic factor which influences plants growth is precipitation. The amount and distribution of precipitation is always an important factor in tropical forestry due to excessive evapo-transpiration rates in hot summers. In the present study it is found that precipitation range of 800mm to 1500mm is most suitable for tropical species. Eucalyptus is the dominant hardwood planted species in tropics. Its performance depends on principal factor of precipitation besides other climatic and soil factors.

India has a geographical area of 328.7 mha and 2.3 per cent of the world's forest stock. Woody biomass can be obtained from different sources like clear felling of natural forests, collection of residues from timber processing industries and more importantly from plantations. The biomass extraction from forest may not be a wise idea as primary forests are to be conserved for various reasons. Hence, the potential option for biomass supply is plantation forestry. The land categories which are available for biomass production are cultivable waste, permanent pasture, barren uncultivable land and fallow land. There are different estimates suggesting different areas available for biomass production. As per the Planning Commission of India (1992) the area available for biomass production is 130 mha whereas according to another study by Sudha and Ravindranath (1999) it is just 42.6 mha.

Based on these estimates of land availability for biomass production in India and range of NPP values different scenarios have been worked out. As per the scenarios it is found that in India the highest annual NPP (2392 million tonnes of carbon) is possible when the available land of 130 mha is afforested with high NPP species like *Bamboo, Samanea, Erythrina, Cassia and Eucalyptus.*

SUMMARY AND CONCLUSIONS

(i) Large number of species available for plantations to sequester carbon: From the study it is clear that there are large numbers of tropical species with relatively higher NPP values. Therefore, there is wide choice for forestry projects and plantation crops (coconut, oil palm and rubber) that aim at climate change programme through carbon sequestration.

(ii) Ecological differences need to be considered (species and site conditions): It is clear that there is tremendous variation in NPP values both within the species and between the species. Therefore, for optimum NPP it needs to be looked at ecological suitability of species.

(iii) Management matters: The NPP value varies with in the species due to management practices as seen in the case of eucalyptus. Therefore, management aspect like weeding, fertilisation, application of insecticides, etc., is equally important in carbon sequestration through forestry projects.

(iv) Plenty of land is available for plantations in tropical and sub-tropical regions: During the study it is found that there is no dearth of land availability for forestry projects for biomass production.

(v) Annual potential NPP in India ranges from 34 to 2392 M t C: The area needs to be stratified based on ecology and species suitability: Based on ecology and species requirement the geographical areas should be stratified so that management of plantations will be easier and optimum NPP can be expected.

(vi) The Potential NPP estimated from top down approaches (satellite/climate based) is not directly comparable to bottom up approaches: When we compare the actual plantation NPP maps with global NPP maps it is found that there is large variation. The global NPP maps have extremely higher values and in most cases they are unrealistic because the values are derived by downscaling technique. Therefore, the potential NPP maps should not be compared with the existing global NPP maps.

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