Carbon Stock in 18-year old *Acacia auriculiformis* Cunn., *Anthocephalus chinensis* Lamk. and *Tectona grandis* L. of Tankawati Forest Area in Chittagong, Bangladesh

Mohammad Rahmat Ullah[1], Mohammed Al-Amin[2] and S. M. Zahirul Islam[3]

[1] College of Forestry, Beijing Forestry University, Beijing-100083, P. R. China.
[2] Institute of Forestry & Environmental Sciences, University of Chittagong, Bangladesh.
[3] Bangladesh Forest Research Institute, P.O. Box. 273, Chittagong-4000, Bangladesh.
E-mail: r_ullah101@yahoo.com

Abstract

The aim of the study was to estimate carbon stock of 18-year old three plantations species namely *Acacia auriculiformis* Cunn., *Anthocephalus chinensis* Lamk. and *Tectona grandis* L. Systematic sampling method was used to identify each sampling point through the Global Positioning System (GPS). Tree biomass estimated by Loss on Ignition method and soil carbon stock was dertermined by Walkley-Black oxidation method. Results showed that the total carbon stock was highest 211.09 ton·ha^{-1} in *Acacia auriculiformis* plantation. The maximum litter carbon was 2.46 ton·ha^{-1} in *Tectona grandis* plantation followed by 1.89 ton-ha-1 in *Anthocephalus chinensis*. Selection of plantation tree species according to highest carbon stock capacity may help the developing countries to earn more carbon credits, and in the long run, to tackle the climate change.

সারসংক্ষেপ

বাংলাদেশে বনায়নকৃত ১৮-বছর বয়সী, আকাশমনি, কদম এবং সেগুন প্রজাতি বৃক্ষে কার্বনের পরিমাপ করা হয়েছে। নিয়মতান্ত্রিক পদ্ধতির মাধ্যমে গোবাল পজিশনিং সিস্টেমের (GPS) সাহায্যে প্রত্যেক নমুনা বিন্দু সনাক্ত করা হয়েছে। গাছের জৈববস্তুপুঞ্জ এবং মাটির কার্বন নির্ণয়ে যথাক্রমে ইগনিশন (Ignition) এবং ওয়াল্কি-ব্লেক (Walky-Black) জারণ পদ্ধতি ব্যবহার করে করা হয়। ফলাফলে দেখা যায় মোট কার্বনের সর্বোচ্চ ছিল আগত আকাশমনি আবাদে (২১১.০৯ টন/হেক্টর)। এছাড়াও গাছের পাতায় সর্বোচ্চ কার্বন পাওয়া যায় সেগুন আবাদে (২.৪৬ টন/হেক্টর) এর পরে রয়েছে দেশীয় কদম আবাদে (১.৮৯ টন/হেক্টর)। কার্বন মজুদের ক্ষমতানুসারে আবাদযোগ্য প্রজাতি সনাক্ত করা গেলে উন্নয়নশীল দেশগুলো অনেক বেশী মুনাফা অর্জন এবং অদূর ভবিষ্যতে জলবায়ু মোকাবেলায় সক্ষম হবে।

Keywords : Carbon stock, plantations, loss on ignition, Walkley-Black method

Introduction

The response of forests to rise atmospheric CO_2 concentrations is crucial for the global carbon cycle since forest ecosystems contain from 62% to 78% of the total terrestrial carbon (Hagedorn *et al.* 2002). Moreover, creation and maintenance of carbon stocks in the tropical forests is an important response option for global warming in tropical developing countries such as Bangladesh (Moura-Costa 1996, Myers 1996). Under the greenhouse gas reduction regime through the CDM concept, carbon credits can be gained from natural and plantation forests in developing countries (UNFCCC 2004), so forests play an important role in the sequestration of carbon globally (Rawat *et al.* 2003). Plantations have high annual carbon sequestration rates (Bass *et al.* 2000) and establishing plantations on degraded land has been proposed as an effective carbon management approach (Montagnini and Porras 1998). Through the Clean Development Mechanism (CDM), carbon management approach can be achieved by plantation programme in developing countries such as Bangladesh (UNFCCC 2004). Developing countries are mostly affected by the consequences of the global warming (Anon. 1998). The large portions of natural forests in Bangladesh have already been significantly degraded and fragmented (Mollah and Kundu 2004), leaving the country with only a small percentage of forest cover (Alamgir and Al-Amin 2007). The total plantation area of Bangladesh under reforestation activities are 0.257 million ha, among which hill forest, bamboo forest, long rotation, short rotation and mangrove plantations are 0.023, 0.004, 0.131, 0.054 and 0.045 million ha, respectively (FAO 2007).

A realistic estimate of the carbon stock is crucial for two reasons: the first one indicates the potentiality of vegetation to release or absorb carbon and the second one indicates that a time series of the carbon stock in vegetation may be used to strain methods, i.e., inverse modeling, in estimating the net carbon flux to or from the global soils (Goodale *et al.* 2002). Poverty and lack of appropriate technology are two major barriers in Bangladesh for estimating the carbon sinks in the forests through plantation programmes under the CDM. Bangladesh can effectively participate in the carbon trading, but the country is lacking research on the quantification of carbon credits by reforestation and afforestation.

Quantification of net carbon sequestration by plantation species is a primary research in deducting the carbon credit of reforested plantations. Bangladesh has a very long history of plantation forestry starting from 1871 with *Tectona grandis* in Chittagong hill forest, along with indigenous species. Many plantations were established successfully and the area is now viewed as an important example for carbon sequestration in Bangladesh. Hence, determination of carbon stocks at different geo-positions of 18-year old plantations of *Acacia auriculiformis, Anthocephalus chinensis* and *Tectona grandis* is the prime objective.

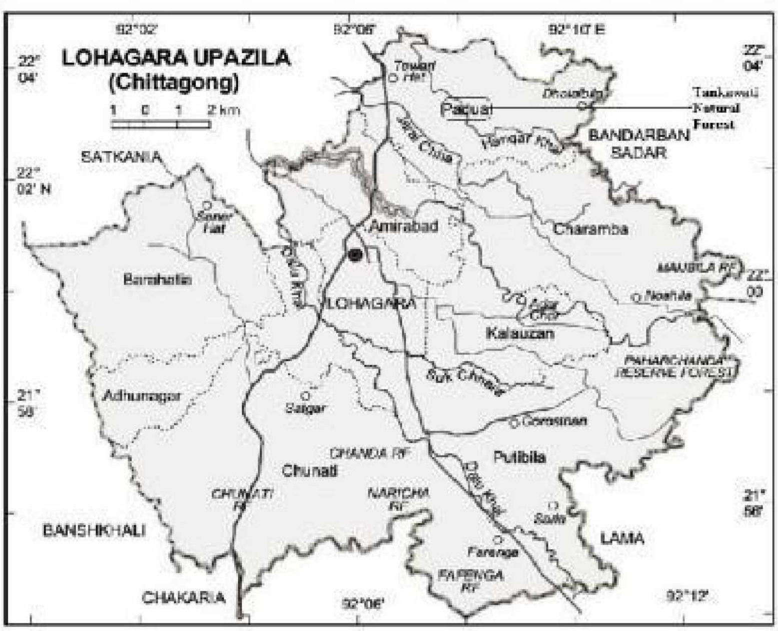
Materials and Methods

The study was conducted in the mono plantation area of Tankawati forest (21°56'–21°59'N and 92°06'–92°13'E) of Chittagong South Forest Division, Bangladesh. The study area was situated on the western aspect of mid hill. The plantation area was 28.4 ha for Teak (*Tectona grandis*), 6.3 ha for Akashmoni (*Acacia auriculiformis*) and 6.3 ha for Kadam (*Anthocephalus chinensis*). The elevation of the study area ranged between 14 m and 87 m above mean sea level (Islam *et al.* 1999). The study area has a moist tropical maritime climate, with high rainfall concentrated during monsoon period from June to September, high temperature (only small seasonal differences) and high humidity (70% to 85%) (Motaleb and Hossain 2007). The mean monthly temperature in the study area ranges from 21.20°C in November to 28.44°C in April with a mean annual temperature of 26.44°C. The mean monthly maximum temperature ranges from 26.37°C in November to 32.72°C in April and the mean monthly minimum temperature from 16.03°C in November to 25°C in April. The mean minimum and maximum temperatures are 21.97°C and 30.51°C respectively. The mean annual fluctuation in temperature is about 6.4°C during the rainy season of May to September and 10.08°C during the dry season. The highest concentration of precipitation is found from May to September, pre- and post-monsoon periods of rain during April, May and October, November to March constitute the dry season. The mean monthly relative humidity of the study area is high throughout the year, which is very high (87%) in July and low (69%) in February (Motaleb and Hossain 2007). Soils are brown sandy loams, somewhat excessively drained, Barkal soil series and classified according to the USDA Taxonomy by Alam *et al.* (1993) as Udic Ustochrept.

Sampling procedure

The study was conducted from January to December in 2009. Data on diameter and tree height were collected from standing trees; soil samples were collected from the field and were analyzed in laboratory. The three mono plantations of *Acacia auriculiformis*, *Anthocephalus chinensis* and *Tectona grandis* were raised in 1991 in the deforested areas of Tankawati forest. Each intersection point was determined using systematic sampling method. The geo-position of the plantation area was determined by using GPS at first, after that one-minute interval was inserted in the map from 21°56'–21°59'N latitude and 92°08'–92°12'E longitude of the study area (Map 1). A total of 27 sample plots were selected for three species of 18 years old plantation and sample plots size were 10 m x 10 m.

Primarily, the land use of each intersection point was identified in the field. In the fixed grid lines, number of stems was counted, a Spiegel Relascope was used to measure height and a diameter tape was used to measure diameter. Samples were collected from all trees of the plot for laboratory analysis to estimate carbon stock and increment cores were collected by wood borer at breast height (1.3 m). We established



Map 1. Map showing the Tankawati Forest area in Chittagong

27 sample plots, each of 2 m x 2 m in size and nine plots from each plantation, in the crown-covered area to estimate the biomass of fallen litter in the plantations. Fallen litter was collected after six months and the average litter fall for six months was converted to annual litter fall per ha.

To estimate soil carbon stock in the selected geo-position, nine soil plots from each plantation were sampled at three depths, i.e., top (1 to 14 cm), middle (14 to 30 cm) and bottom (30 to 100 cm). The size of the sample plot was 2 m x 2 m. Each sample was a composite of three sub-samples. Thus for the three plantations, a total of 27 soil samples were studied. Soil samples were collected using an earth augur. The samples were carefully taken to the laboratory for chemical analysis through the Walkey-Black oxidation method.

Biomass estimation

Scientists developed different models for determining above ground biomass (Negi *et al*. 1988, Brown *et al*. 1989 and Luckman *et al*. 1997). We used models of Brown *et al*. (1989) to determine the above ground biomass as it is reported one of the most suitable methods for tropical forest (Alves *et al*. 1997, Brown 1997, Schroeder *et al*. 1997). The model is as follows:

$$Y = \text{Exp.}\{-2.4090 + 0.9522 \ln (D^2HS)\}$$

where, Y the above ground biomass (kg)

H the height of the trees (m),

D the diameter at breast height (cm)

S the wood density (ton·m^{-3}), for specific species Satter *et al*.(1999).

Below ground, biomass was calculated as 15% of the above ground biomass (MacDicken 1997). The above- and below-ground biomasses were added to get the total biomass of the plantation.

Carbon stock estimation

Loss on ignition method was used to estimate carbon stock of the tree species. The fresh weight of tree samples were taken using an electronic balance, then dried at 65°C in an oven for 48 h to measure dry weight. Oven dried grind samples were taken (1 g) in pre-weighted crucibles, after that they were put in the furnace and followed by ignition for 1 h. After cooling, the crucibles with ash were weighted to calculate the percentage of biomass carbon as Allen *et al*. (1986):

$$\text{Ash } (\%) = (W_3 - W_1)/(W_2 - W_1) \times 100$$

$$C\ (\%) = (100 - \text{Ash } \%) \times 0.58$$

where,

C the biomass carbon stock (%)

W_1 the weight of crucibles (g)

W_2 the weight of oven dried grind samples and crucible (g)

W_3 the weight of ash and crucibles (g). 58% carbon was considered in ash free litter material.

During field work, soil from each depth was collected to determine organic carbon, and soil core was used to calculate bulk density for different depths. Field's moist soil cores were dried in an oven at 105°C for 8 h, and re-weighted to determine moisture content and dry bulk density. To estimate the percentage of organic carbon in the soil, samples were analyzed by the wet oxidation method (Huq and Alam 2005).

Results and Discussion

Among the three mono plantations established at the mid-hill positions, the highest tree biomass carbon and soil organic carbon were found in *Acacia auriculiformis* plantation, followed by *Tectona grandis* and *Anthocephalus chinensis* plantations (Fig. 1). The total (above- and

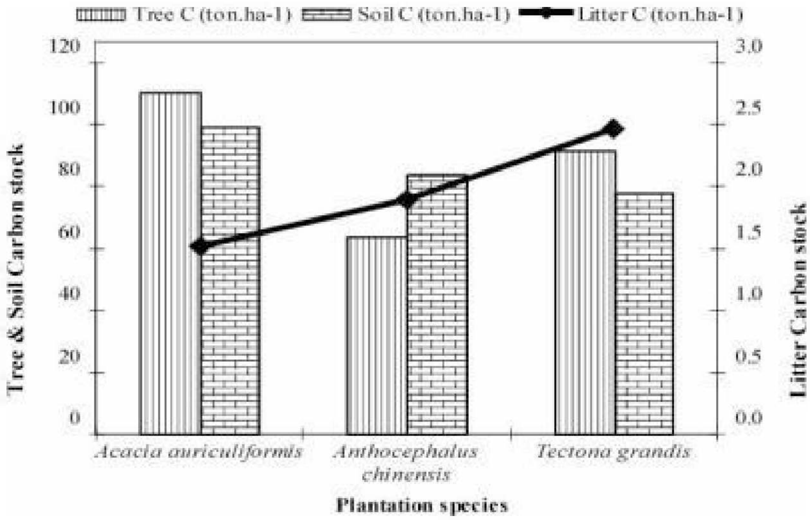


Figure 1. Carbon stocks (ton·ha^{-1}) of 18-year old plantations

below-ground) carbon stocks were found highest in *A. auriculiformis* (110.25 and 100.84 ton·ha^{-1} respectively), followed by *T. grandis* (91.28 and 80.33 ton·ha-1) and *A. chinensis* (63.70 and 85.26 ton·ha^{-1}) plantations. Highest litter carbon stock (2.46 ton·ha^{-1}) was found in the plantation of deciduous trees of *T. grandis* rather than other two plantations. Soil organic carbon was found highest in *A. auriculiformis* (99.32 ton·ha-1) and the lowest in *T. grandis* (77.87 ton·ha^{-1}).

A. auriculiformis is a fast growing species compare to *T. grandis* and *A. chinensis*. Moura-Costa (1996) found that fast growing species accumulate higher amounts of biomass than slow growers during the same time period. During the growth of trees, carbon was accumulated in their biomass, and thereby the amount of carbon stored in the tree plantation areas increase. Hossain (2003) found that *A. auriculiformis* plantation showed better survival and growth in different areas of Bangladesh with the yield of 15–20 m^3·ha^{-1}·yr^{-1} after rotation of 10–12 years, but it is less than 7–8 m^3·ha^{-1}·yr^{-1} in a *A. chinensis*. Sá *et al.* (1998) found that plantation of leguminous tree, *A. auriculiformis*, had 2–3 fold higher above-ground carbon stock capacity than a plantation of other species of the same age. Therefore, from Sá *et al.* (1998) and our studies, it was found that in similar hill position(s) and also from same-age plantations of different species, *A. auriculiformis* plantation might stock higher carbon than other stated species.

In this study, it was found that *T. grandis* plantation had the highest litter carbon because of large broad-leafed and deciduous tree (*A. auriculiformis* and *A. chinensis* both are evergreen) that shades its leaves during the dry season as litter fall including branches, twigs and bark resulting in larger amount of litter which generates higher carbon stock than other species. Consequently, it is evident that variation of litter carbon stock per ha was mainly affected by litter delivery and their total amount, which may different with species.

The distribution of soil carbon stock also varied among the three species. Osman *et al.*

(2001) concluded that soil organic matter increases with the age of the plantation until canopy closure, but is dependent on the ability of the species to produce litter. Among the three species *A. auriculiformis* produce more litter than the other two species and in turn, the decomposition of litter enrich the carbon stock in soil. Singh *et al.* (2004a) mentioned that the deposition and release of carbon through litter fall and its decomposition was highest in legume species, i.e., *A. auriculiformis*, *Albizia procera* and *A. lebbeck* plantations. *T. grandis* (non-legume) contributes poor carbon stock in the soil due to its deposition of less organic matter (Singh *et al.* 2004b).

Hossian (2005) mentioned that fast growing exotic species are mostly dominated in the natural hill forest ecosystems, crop fields, fallow and marginal lands. Moreover, their luxuriant growth suppressed the growth of other native species. However, carbon densities of tree plantation vary with age, species and site (Lasco and Pulhin 2009). The difference of carbon stocking was found among the three species of same-age group and same location (Fig. 1). It is may be due to differences in wood density. As a result the carbon stock of exotic species is higher than that of native species. *T. grandis* and *A. auriculiformis* are exotic species in Bangladesh but at present these two species become common species due to their higher growth and productivity compare to the native one *A. chinensis*.

Conclusion

The results clearly show the capacity of three 18-year old plantations of *Acacia auriculiformis, Anthocephalus chinensis* and *Tectona grandis* to sequester atmospheric carbon and that reforestation makes a significant contribution to carbon sequestration in Bangladesh. Both *A. auriculiformis* and *T. grandis* are exotic tree species in Bangladesh, but now become common species due to the most of the land coverage through plantation and their economic values. Hence, it is essential to conduct the study for estimating carbon stock. A continued increase in carbon stock and their accumulation rates for all plantation species along with plantation age indicated a progressive development of soil.

To overcome the problem of global warming and climate change, sustainable forest management is the best way to achieve optimum carbon sequestration; and more easy, applicable and fast scientific methods are required to estimate the carbon stock in plantation forest. In the present study, the estimation of carbon stock can be directed to researchers and administrators to analyze global carbon credit, which can be helpful to develop the forestry and environmental sectors, such as Bangladesh and other tropical countries with similar environments.

References

Alam, M.L.; Saheed, M. S.; Shinagawa, A. and Miyauchi, N. 1993. Chemical properties of general soil types of Bangladesh, *Memoirs of the Faculty of Agriculture, Kagoshima University* 29: 75-87.

Alamgir, M. and Al-Amin, M. 2007. Regeneration status in a proposed biodiversity conservation area of Bangladesh. *Pakistan Academy of Sciences* 44 (3): 165-172.

Allen, S.E.; Grimshaw, H.M. and Rowland, A.P. 1986. Chemical analysis. In: Moore, P.D. and Chapman, S.B. (ed.). Methods in Plant Ecology, Blackwell Scientific Publications, Boston, PP. 285-344.

Alves, D.S.; Soares, J.V.; Amaral, S.; Mello, E.M.K.; Almeida, S.A.S.; da Silva, O.F. and Silveira, A. M. 1997. Biomass of primary and secondary vegetation in Rondonia, Western Brazilian Amazon. *Global Change Biology* 3: 451-461.

Anonymous 1998. *Greenhouse Gas Assessment Handbook: A Practical Guidance Document for the Assessment of Project-level Greenhouse Gas Emissions.* Environment Department, World Bank, Washington DC. 64: 168 pp.

Bass, S.; Dubosis, O.; Moura, Costa P.; Pinard, M.; Tipper, R. and Wilson, C. 2000. *Rural Livelihood and Carbon Management.* International Institute for Environment and Development Eco-Securities Ltd. University of Aberdeen, London, 1: 94 pp.

Brown, S.; Gillespie, A.J.R. and Lugo, A.E. 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. *Forest Science* 35 (4): 881-902.

Brown, S. 1997. *Estimating Biomass and Biomass Change of Tropical Forests: A Primer.* FAO Forestry Paper, Rome, Italy, 134: 165 pp.

FAO. 2007. National Forest and Tree Resources Assessment 2005-2007-Bangladesh. Nipun Printing Industries Ltd. 280 pp.

Goodale, C.L.; Apps, M.J.; Birdsey, R.A.; Field, C.; Heath, L.S.; Houghton, R.A.; Jenkins, J.C.; Kohlmaier, G.H.; Kurz W.; Liu, S.R.; Nabuurs, G.J.; Nilsson, S. and Shvidenko, A.Z. 2002. Forest carbon sinks in the Northern Hemisphere. *Ecological Application* 12 (3): 891-899.

Hagedorn, F.; Landolt, W. and Tarjan, D. 2002. Elevated CO_2 influences nutrient availability in young beech-spruce communities on two soil types. *Oecologia* 132: 109-117.

Hossain, M.K. 2003. *Growth performance and critics of exotics in the plantation forestry of Bangladesh.* The XII World Forestry Congress, Canada. < www.fao.org/ DOCREP/ARTICLE/ WFC/XII/0113-B1.HTM >. Retrieved on 12 November, 2012.

Hossain, M.K. 2005. *Conversion of dipterocarp-dominat natural forests to short rotation plantations-an unrecoverable threat to the native dipterocarps in Bangladesh.* APAFRI, Malaysia. < www.docin.com/p-70676086.html >. Retrieved on 12 May, 2013.

Huq, S.M.I. and Alam, M.D. 2005. *A handbook on Analyses of Soil, Plant and Water.* BACER-DU, University of Dhaka, Bangladesh xxii: 246 pp.

Islam, K.,R.; Kamaluddin, M.; Bhuiyan, M.K. and Badruddin, A. 1999. Comparative performance of exotic and indigenous forest species for tropical semi evergreen degraded forest land reforestation in Chittagong, Bangladesh. *Land Degradation Development* 10: 241-249.

Lasco, R.D. and Pulhin, F.B. 2009. Carbon budgets of forest ecosystems in the Philippines. *Journal of Environmental Science Management* 12 (1): 1-13.

Luckman, A.; Baker, J.; Kuplich, T.M.; Yanasse, C.C.F. and Frery, A.C.A. 1997. A study of the relationship between radar backscatter and regenerating tropical forest biomass for spaceborne SAR instruments. *Remote Sensing Environment* 60: 1-13.

MacDicken, K.G. 1997. A guide to monitoring carbon storage in forestry and agroforestry projects. *Specialist* 3: 1-87.

Motaleb, M.A. and Hossain, M.K. 2007. Studies on natural regeneration of a semi-evergreen forest of Chittagong (South) Forest Division, Bangladesh. *Journal of Forestry and Environment* 5: 95-101.

Mollah, A.R. and Kundu, D.K. 2004. Site-Level Field Appraisal for Protected Area Co-Management: Lawachara National Park, Nature Conservation and Management, Dhaka.

Montagnini, F. and Porras, C. 1998. Evaluating the role of plantations as carbon sinks: An example of integrative approach from the humid tropics. *Environment Management* 22: 459-470.

Moura-Costa, P. 1996. *Tropical forestry practices for carbon sequestration*. In: Schulte A. and Schöne D. (ed.). Dipterocarp Forest Ecosystem: Towards Sustainable Management. Singapore: World Scientific Publishing Co. Ltd., PP. 308-334.

Myers, N. 1996. The world's forests: problems and potentials. *Environment Conservation* 23: 156-168.

Negi, J.D.S.; Sharma, S.C. and Sharma, D.C. 1988. Comparative assessment of methods for estimating biomass in forest ecosystem. *Indian Forester* 114 (3): 136-143.

Osman, K.T.; Rahman, M.M. and Barua, P. 2001. Effects of some forest tree species on soil properties in Chittagong University Campus, Bangladesh. *Indian Forester* 127 (4): 431-442.

Rawat, V.; Singh, D. and Kumar, P. 2003. Climate change and its impact on forest community. *Indian Forester* 1289 (6): 787-789.

Sá, T.D. de A.; Vielhauer, K.; Kanashiro, M.; Denich, M. and Vlek, P.L.G. 1998. *Towards improving natural resources use in Eastern Amazonia through a modified sequential agroforestry system*. Apresentado como painel no II Congresso Brasileiro em Sistemas Agroflorestais, Belém, Brasil, 7 pp.

Sattar, M.A.; Bhattacharjee, D.K. and Kabir, M.F. 1999. *Physical and Mechanical Properties and Uses of Timbers of Bangladesh*. Seasoning and Timber Physics Division, Chittagong, Bangladesh Forest Research Institute: 57 pp.

Schroeder, P.; Brown, S.; Mo, J.M.; Birdsey, R. and Cieszewski, C. 1997. Biomass estimation for temperate broadleaf forests of the United States using inventory data. *Forest Science* 43: 424-434.

Singh, A.N.; Raghubanshi, A.S. and Singh, J.S. 2004a. Comparative performance and restoration potential of two *Albizia* species planted on mine spoil in a dry tropical region, India. *Ecological Engineering* 22: 123-140.

Singh, A.N.; Raghubanshi, A.S. and Singh, J.S. 2004b. Impact of native tree plantations on mine spoil in a dry tropical environment. *Forest Ecology and Management* 187: 49-60.

UNFCCC. 2004. Report of the conference of the parties on its ninth session held at Milan from 1 to 12th December; art 2: action taken by the conference of the parties at its 9th session. < www.unfccc.int/. > Retrieved on 7 September 2012.