Financial analysis of Chir pine plantations for carbon offsets, timber and resin in Nepal

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A financial analysis was done for Chir pine (*Pinus roxburghii*) plantations that produce carbon offset payments, timber and resin in a community forest context in Nepal. Results indicate that the inclusion of carbon offset payments increases rotation age and land expectation value. The optimal rotation age is approximately 35 years without including carbon offset payments, while the rotation age can increase beyond 75 years with the inclusion of carbon offset payments. The substantial change in optimal rotation age also suggests that carbon offset payments will likely change the product mix produced from Chir pine plantations. Likewise, land expectation value increases significantly with carbon offset payments indicating that local communities could benefit from such payments. The results also indicate that different assumptions about the quantity of long term carbon storage (i.e. pickling rate) have a significant impact on rotation age and land expectation value.

Key words: *Pinus roxbughii*, land expectation value, carbon offset payment, resin

In recent years, policy makers have been searching for different ways to mitigate the effects of rising Green House Gases (GHGs) concentration. Particular interest has been directed towards carbon stocks in forests which are the main terrestrial sinks for carbon (Balboa-Murias *et al*., 2006; Deng *et al*., 2011). Each cubic meter of wood stores approximately 200 kg of carbon in forests, and for every ton of carbon sequestered in forest biomass, 3.667 tons of CO_2 are removed from the atmosphere (Krcmar *et al*., 2001). Globally, the quantity of carbon stored in terrestrial ecosystem is 2477 billion tons, where soil and vegetation accounts for approximately 81%, and 19%, respectively (Ravindranath and Ostwald, 2008). Previous studies suggest that costs of carbon sequestration in forests are comparable to, and in some cases lower than, the costs of alternative mitigation and abatement approaches (Matthews *et al*., 2002). Their role in cost effective mitigation of atmospheric carbon dioxide has been widely recognized (Richards and Stokes, 2004; Sohngen and Brown, 2008; Nepal *et al*., 2012).

With the growth of community forests throughout the developing world, there is potential for them to play a significant role in sequestering and storing atmospheric carbon. There is growing interests among policymakers and others in receiving carbon offset payments through carbon trading mechanisms as a means of generating income for local communities. Preliminary research findings from carbon monitoring surveys of selected community forests in Nepal suggest that carbon stocks are increasing at the rate of 2 to 5 tons per hectare per year (Dahal and Banskota, 2009). Thus, carbon offset payments could be another potential source of income to community forest users in addition to benefits from timber and resin. In this paper we have done a financial analysis of the management of Chir pine *(Pinus roxburghii)* forest plantations considering carbon offset payments, resin and timber using a Hartman model to estimate the optimal rotation age and land expectation value (LEV) at a range of carbon offset prices (in addition to timber and resin benefits). We have also estimated the impact of different assumptions of carbon emissions from the harvesting of wood products (or pickling rate) on the optimal rotation age and LEV. Finally, the impact that carbon offset payments would have on the optimal mix of forest products (timber and resin) from the plantation stand have also been estimated. The specific aim of this study is to estimate the magnitude of the impacts of carbon offset payments on Chir pine plantations grown in a community forest context in Nepal.

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Chir pine is a common coniferous species of the mid-hills regions (900–1950 m) of Nepal, and growing up to 2700 m (Jackson, 1994). It is found ranging from longitudes of 70^0 E to 93^0 E and latitudes of 26^0 N to 36^0 N (Ghildiyal *et al*., 2009). Naturally, it is distributed from Bhutan (only in drier areas), Northern India, Nepal (south of Tibet), Pakistan, and Afghanistan (Dogra, 1985; Yi and Raven, 1999; Gauli *et al*., 2009). It has standing volume of 6.3% of the total forest in Nepal (DFRS, 1999); proportionally the fourth highest total tree volume in the country. Establishing Chir pine on heavily degraded forest sites and grazing lands is an integral component of community forestry activities in the hill regions. Due to its high survival rate, it has proved to be a successful pioneer of most degraded sites (Mohns *et al*., 1988). In Nepal, Chir pine is the only species tapped for resin, and currently resin tapping is being done in around 35 out of 75 districts of Nepal. On average, one person can earn up to NRs. 30,000 ($400) in the eight months tapping period (Upadhyay, 2008). According to Resin Tapping Guideline of Ministry of Forests and Soil Conservation (2007), resin tapping could be done when the diameter at breast height (DBH) reaches 30 cm. Resin is used for manufacturing of rosin and turpentine. Rosin is used in manufacturing of adhesives, paper sizing agents, printing inks, detergents etc., while turpentine is used in disinfectants, cleaning agents, pharmaceutical preparations, perfumery industry and others (Coppen and Hone, 1995; Wang *et al*., 2006; Thakur, 2003).

Materials and methods

In this section we discuss how timber volume and the quantity of sequestered carbon were calculated. We also discuss how we used the Hartman (1976) model to estimate the optimal rotation age and economic returns from timber, resin and carbon offsets. This analysis makes use of thinning regime for a Chir pine plantation (Table 1).

Timber and resin yield

The portion of the tree greater than 20 cm in

Table 1: Chir pine plantation thinning regime used in the analysis

Plantation Age (year)	Stems/ha	Stems/ha after thinning	Stems thinned/ha
5	1600	1600	0
10	1600	1600	0
15	1600	1400	200
20	1400	1050	350
25	1050	900	150
30	900	800	100
35	800	625	175
40	625	500	125
45	500	400	100
50	400	300	100
55	300	225	75
60	225	190	35
65	190	145	45
70	145	145	0
75 (last cut)	145	0	145
		Total	**1600**

Source: DFRS, 2007

diameter is considered big timber that is used in construction and similar purposes. Timber of this size class usually gets a higher price than smaller timber. Small timber was assumed to consist of the portion of the tree greater than 10 cm in diameter but less than 20 cm in diameter. The remainder of the tree volume was considered slash (not sold). To calculate the various timber product classes, first the whole tree volume was calculated followed by the volume up to 10 cm in diameter, and then subtracted from the whole tree volume. This gives the portion of tree stem that is considered slash. Next the volume of the stem up to 20 cm in diameter was calculated and subtracted from the volume up to 10 cm. This gives the volumes of big and small timber. The volume of bark was subtracted from the volume of big and small timber and included as slash. All equations for volume calculations are based on the work of Sharma and Pukkala (1990) and are given in table 2. Height and DBH were taken from growth and yield data from 219 trees in Himachal Pradesh, India (Tewari, 1994)[3]. Because the DBH and height data were only given in 10 year increments, total tree, big timber, and small timber volumes were fitted to the following functional form, using nonlinear regression to obtain continuous yield functions:

$$v(t) = at^{b}e^{-ct} \qquad (1)$$

Where v (t) is the volume of timber per hectare for a particular stand age, t is the stand age in years and a, b, and c are parameters to be estimated. Resin yield was assumed to be 4.25 kg per tree per year and begin when DBH equals 30 cm (MFSC, 2007).

Carbon offsets

In general, carbon content is assumed to be 50% of dry matter (Negi *et al.*, 2003; Lamlom and Savidge, 2003; Sharma and Singh, 2010). However, a Chir pine specific carbon content of 46.32%, based on the work of Negi *et al.* (2003), was used in this analysis. The dry density of Chir pine is 0.497 metric tons per cubic meter (Chaturvedi and Khanna, 1982). Thus the carbon per cubic meter of Chir pine can be estimated by multiplying the volume (in cubic meters) by 0.2302 (0.497 x 0.4632). Since, CO_2 equivalents are traded in the market, not carbon, we converted the amount of carbon into CO_2 equivalents by multiplying by 3.67. Hence, all the carbon benefits are presented as CO_2 equivalents.

Land expectation value (LEV) calculation

The present value of carbon was calculated using equation 2.

Table 2: Equations used for timber calculations (Sharma and Pukkala, 1990)

S.No	Equations	Parameter definition
1. Volume	$\text{In}(v)=a(-2.9770)+b(1.9235)*\text{In}(d)+c*1.0019)*\text{In}(h)$	V= total stem vol. with bark (dm^3) d= diameter (cm) h= height (m)
2. Proportion of tree top (beyond 10cm)	$\text{In}(V_1/V)=a(6.2696)+b(-2.8252)*\text{In}(d)$	V_1= over bark vol.of tree top V = total over bark stem vol.
3. Proportion of timber beyond 20 cm dia.but > 10 cm in dia.	$\text{In}(V_2/V_t)=a(8.5662)+b(-3.0486)*\text{In}(d)$	V_2=over bark vol. of the portion of timber beyond 20 cm in dia. but>10cm in dia. V_t = total over bark vol. up to 10 cm in dia.
4. Proportion of bark in timber >10 cm in dia.	$\text{In}(P_b)=a(1.1763)+b(-0.6997)*\text{In}(d)$	P_b = bark proportion
5. Proportion of bark in timber >20 cm in dia.	$\text{In}(P_b)=a(1.2535)+b(-0.7194)*\text{In}(d)$	P_b = bark proportion

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[3] The growth and yield data used in this analysis do not allow for variation in plant density or site quality. Some publications on *Pinus roxburghii* by Applegate *et al.* (1988) and Gilmour *et al.* (1990) provide some data in this regard. Likewise, a working paper by Rautiainen (1991) also provides some information regarding stocking, diameter and height for specific ages of plantations of Pinus roxburghii in the Nepalese context. However, they do not provide sufficient information to estimate yields. Therefore, data from Tewari (1994) was used in this study.

$$PV_C = \sum_{0}^{t} P_C\alpha\{v(t) - v(t-1)\}e^{-rt} - P_C\alpha(1-\beta)v(t)\, e^{-rt} \quad ......(2)$$

Where, PVC is the present value of carbon over one rotation or harvest cycle in \$/hectare, PC is the price of carbon (\$/CO_2 equivalent), α represents the metric tons of carbon per cubic meter of tree biomass, v (t) is the volume of timber calculated at a particular stand age, β is the pickling rate or the amount of carbon sequestered long-term after harvest, and r is the discount rate. We did a sensitivity analysis of different carbon prices of \$0, \$2, \$5, \$10, \$25 and \$50. The discount rate is assumed to be 10%. This discount rate is based on a literature review as well as personal contacts with Forest Officers at Department of Forest, Kathmandu, Nepal. The analysis was done with different values of the pickling rate β (0, ½, and 1) for big timber. A pickling rate of 0 indicates that all the carbon sequestered during tree growth will be emitted back into the atmosphere through decay or burning soon after harvest. Likewise, a pickling rate of 0.5 indicates that 50% of the sequestered carbon will be emitted back into the atmosphere soon after harvest and 50% will remain sequestered. A pickling rate of one indicates that all sequestered carbon remains sequestered after harvest. For small timber and slash the pickling rate was assumed to be 0.

The present value of timber was calculated by using equation 3:

$$PV_t = Prv(t)e^{-rt} \quad ......(3)$$

Where, PVT is the present value of timber in \$/hectare, PT is the price of timber in \$/cubic meter, r is the discount rate, and t equals the stand age in years. We use a timber price of 50 (approximately \$0.625) Nepalese Rupees per cubic foot for big timber and 50% of this price for small timber (GoN, 2005). Likewise, the present value of resin was calculated by using equation 4:

$$PV_R = \sum_{0}^{t} P_R Vr(t)e^{-rt} \quad ......(4)$$

Where PV_R is the present value of resin in \$/hectare, P_R is price of resin in \$/ton, vr(t) is the volume of resin calculated at a particular age (t), r is discount rate, and t is the stand age in years. We are using resin price of 6 (approximately \$0.075) Nepalese Rupees per kg for this analysis (GoN, 2005). The cost of resin tapping is assumed to be borne by resin traders so are not included in the financial analysis.

Establishment cost (EC) is a cost associated with plantation in the plantation year which is assumed to be NRs. 3200/ha (approximately \$43) based on personal communication with Forest Officers at Department of Forest. We assume forest management and thinning costs to be zero because it will be carried out with community labor or community participation. All of the harvesting costs are assumed to be paid by the timber buyer or timber harvesting company and therefore considered to be external to the community.

Finally, LEV was calculated using present value of carbon, timber and resin along with establishment cost using equation 5:

$$LEV = (PV_C + PV_T + PV_R - EC)/(1 - e^{-rt}) \quad ......(5)$$

Where, LEV is the land expectation value in \$/hectare assuming the forest stand is management in perpetuity for timber, carbon and resin. PVc equals the present value of carbon in \$/hectare over one harvest cycle, PV_T equals the present value of timber in \$/hectare over one harvest cycle, PV_R is the present value of resin in \$/hectare over one harvest cycle, r is the discount rate and t equals the stand age in years. LEV results are presented in US dollars based on the exchange rate of \$1 = NRs. 75.

Results and discussion

Land expectation value (LEV)

Figure 1 shows the relationship between carbon prices and LEV. The LEV increases significantly with an increase in carbon price. With a carbon price of 0 (i.e. only with timber and resin benefit), LEV is \$35.25 per hectare. As soon as carbon price increases from \$2 to \$ 50, LEV increases from \$51.18, \$52.84, and \$54.49 to \$503.63, \$538.19, and \$572.75 at different pickling rates (β) of 0, 0.5, and 1, respectively. Therefore, there would be a substantial increase in LEV with the increase in carbon prices regardless of the assumption made about carbon emissions at harvest. Similar results were observed (i.e. increased LEV with inclusion of carbon benefit) by Andrew Stainback and Alavalapati (2002) and Dwivedi *et al.* (2009). LEV is higher at larger pickling rates due to emission costs (i.e. higher emission cost when pickling rate of 0, lower emission cost with pickling rate of 0.5, and no emission cost when pickling rate of 1) at the time of harvest.

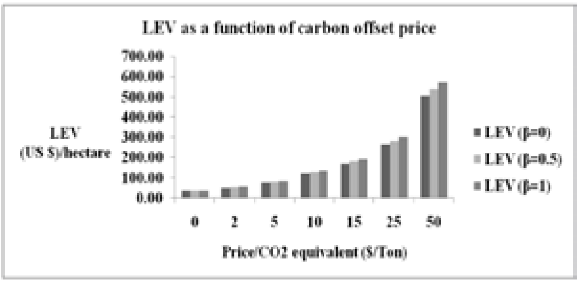

Fig. 1: LEV (US $) at different prices of carbon and emission assumptions (β) at harvest

Optimal rotation age

Figure 2 shows the overall results for optimal rotation as a function of carbon offset price at three different pickling rates. Due to the uncertainty of carbon markets and future carbon offset prices, we considered a wide range of carbon prices from $2 to $50. All the results assume a discount rate of 10%. The optimal rotation age is 35 years when there is no income from carbon. When the price of carbon is $2 per ton and above, the optimal rotation age increases. Therefore the price of carbon has significant effect on the optimal rotation age as well as LEV. Several other studies also concluded that optimal rotation age increases with the inclusion of carbon offset payments (Romero *et al.*, 1998; Andrew Stainback and Alavalapati, 2002; Kooten *et al.*, 1995; Price and Willis, 2011). At a pickling rate of 0, rotation age will be higher than when pickling rate is 0.5 or 1. This result is more pronounced at higher carbon prices.[4] A pickling rate of 0 means that all the carbon sequestered will be emitted back into the atmosphere when harvested. With this pickling rate, there would be higher emission costs at the time of harvest, which creates an incentive to delay harvest.

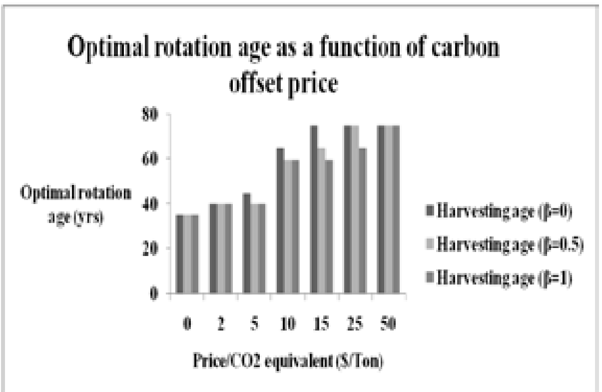

Fig. 2: Optimal rotation age at different prices of carbon and emission assumptions (β) at harvest

In addition, carbon payments increase big timber supply and resin production due to extending the rotation age. However as the carbon price increases the supply of small timber declines. When the rotation age is increased due to carbon payments, then there are two effects on timber supply. As the trees age due to a longer rotation age, more timber is produced. However the stand is also harvested less frequently due to the longer rotation age. To account for both of these impacts, timber supply is calculated assuming a regulated forest by dividing the volume of timber produced at the end of the rotation by the length (years) of the rotation. Figure 3 shows the amount of big timber and small timber volume produced at different carbon prices and pickling rates. Only trees with a diameter of 30 cm DBH are considered capable of producing resin. Thus, as the rotation age is lengthened resin production increases.

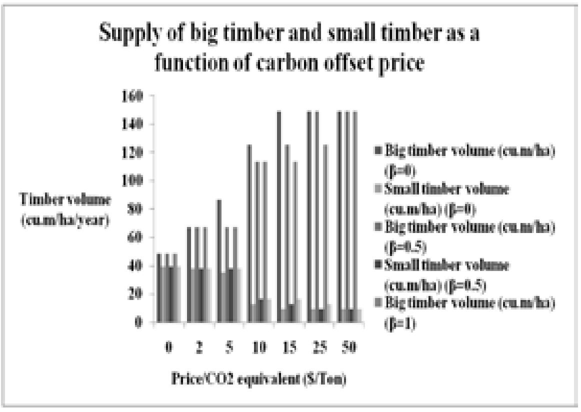

Fig. 3: Big timber volume and small timber volume at different prices of carbon and emission assumptions (β) at harvest

Conclusion

Chir pine is a common forest type found in the mid-hills region of Nepal managed both by communities and private enterprises. In this study we modeled how carbon offset payments would impact the optimal rotation age and LEV of Chir pine. In the community forestry context, where forests are managed for big timber, small timber and resin, carbon offset payments substantially increase the optimal rotation age and the LEV.

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[4] When the carbon price is $25 per ton then the rotation age is at or above the model maximum of 75 years at all pickling rates.

The increase in LEV could bring much needed cash income to local communities in the region. The increase in the rotation age would increase the amount of big timber and resin and decrease the amount of small timber produced from each harvest. Since timber and resin is a primary source of income from Chir pine plantation, carbon offset payment additionally could substantially increase economic benefit to the community. The increase in cash income due to carbon offset payment could also allow local communities to engage in more intensive forest management which would potentially bring additional benefits.

Future studies could investigate the impact that carbon offset payments would have on forest management variables other than rotation age (e.g. spacing and alternative thinning regimes). This study only considered forest management at the stand level. However, the substantial increase in LEV due to carbon offset payments could induce local communities to plant and manage forest on more marginal land. Thus, economic studies that included impacts on the extensive margin could be useful. Finally, due to limited data, the growth and yield information utilized in this study comes from regions in India that have similar growing conditions to those in the mid-hills region of Nepal. Growth and yield information specific to the mid-hills region of Nepal could improve future studies.

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References

Andrew Stainback, G., and Alavalapati, J. R. R. 2002. Economic analysis of slash pine forest carbon sequestration in the southern U. S. *Journal of Forest Economics* **8 (2):** 105–117.

Applegate, G. B., Gilmour, D. A., and Mohns, B. 1988. Biomass and productivity estimations for community forest management: a case study from the hills of Nepal – I. Biomass and productivity of Chir pine (*Pinus roxburghii* Sargent) plantations. *Biomass* **17 (2):** 115–136.

Balboa-Murias, M. Á., Rodríguez-Soalleiro, R., Merino, A., and Álvarez-González, J. G. 2006. Temporal variations and distribution of carbon stocks in aboveground biomass of radiata pine and maritime pine pure stands under different silvicultural alternatives. *Forest Ecology and Management* **237 (1–3)**: 29–38.

Chaturvedi, A. N., and Khanna, L. S. 1982. **Forest Mensuration**. International Book Distributors, Dehradun, India.

Coppen, J. J. W., and Hone, G. A. 1995**. Gum Naval Stores: Turpentine and Rosin from Pine Resin.** Natural Resources Institute, FAO, Rome, Italy.

Dahal, N., and Banskota, K. 2009. Cultivating REDD in Nepal's community forestry: A discourse for capitalizing on potential? *Journal of Forest and Livelihood* **8 (1):** 41–50.

Deng, S., Shi, Y., Jin, Y., and Wang, L. 2011. A GIS-based approach for quantifying and mapping carbon sink and stock values of forest ecosystem: A case study. *Energy Procedia,* **5 (0)**: 1535–1545.

DFRS.1999. **Forest Resources of Nepal (1987–1998).** Publication no.47, .Department of Forest Research and Survey, Kathmandu, Nepal.

DFRS. 2007. **The Thinning Guidelines for Plantation Forest of *Pinus patula* and *Pinus roxburghii* in Nepal**. Minsitry of Forests and Soil Conservation, Department of Forest Research and Survey, Kathmandu, Nepal.

Dogra, P. D. 1985. Conifers of India and their wild gene resources in relation to tree breeding. *Indian Forester* **111 (11):** 935–955.

Dwivedi, P., Alavalapati, J. R. R., Susaeta, A., and Stainback, A. 2009. Impact of carbon value on the profitability of slash pine plantations in the southern United States: an integrated life cycle and Faustmann analysis. *Canadian Journal of Forest Research* **39 (5):** 990–1000.

Gauli, A., Gailing, O., Stefenon, V., and Finkeldey, R. 2009. Genetic similarity of natural populations and plantations of *Pinus patula* and *Pinus roxburghii* Sarg. in Nepal. *Annals of Forest Science* **66 (7):** 703–703.

Ghildiyal, S. K., Sharma, C. M., and Gairola, S. 2009. Additive genetic variation in seedling growth and biomass of fourteen *Pinus roxburghii* provenances from Garhwal Himalaya. *Indian Journal of Science and Technology* **2 (1):** 37–45.

Gilmour, D. A., King, G. C., Applegate, G. B., andMohns, B. 1990. Silviculture of plantation forest in central Nepal to maximise community benefits. *Forest Ecology and Management* **32 (2–4):** 173–186.

GoN. 2005. **Forest Regulation 1995 (3rd amendment**). Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Hartman, R. (1976). The harvesting decision when a standing forest has value. *Economic Inquiry* **14 (1):** 52–58.

Jackson, J. K.(1994. **Manual of Afforestation in Nepal**. Forest Research and Survey Centre, Babarmahal, Kathmandu, Nepal.

Kooten, G. C. v., Binkley, C. S., and Delcourt, G. 1995. Effect of carbon taxes and subsidies on baoptimal forest rotation age and supply of carbon services. *American Journal of Agricultural Economics* **77 (2):** 365–374.

Krcmar, E., Stennes, B., Cornelis van Kooten, G., and Vertinsky, I. 2001. Carbon sequestration and land management under uncertainty. *European Journal of Operational Research* **135(3)**: 616–629.

Lamlom, S. H., and Savidge, R. A. 2003. A reassessment of carbon content in wood: variation within and between 41 North American species. *Biomass and Bioenerg,* **25 (4):** 381–88.

Matthews, S., O Connor, R., and Plantinga, A. J. 2002. Quantifying the impacts on biodiversity of policies for carbon sequestration in forests. *Ecological Economics* **40 (1)**: 71–87.

MFSC. 2007. **Resin Tapping Guideline**. Ministry of Forests and Soil Conservation, Kathmandu, Nepal.

Mohns, B., Applegate, G. B., and Gilmour, D. A. 1988. Biomass and productivity estimations for community forest management: A case study from the hills of Nepal – II. Dry matter production in mixed young stands of chir pine (*Pinus roxburghii*) and broad-leaved species. *Biomass* **17 (3)**: 165–184.

Negi, J. D. S., Manhas, R. K., and Chauhan, P. S. 2003. Carbon allocation in different components of some tree species of India: A new approach for carbon estimation. *Current Science* **85 (11):** 1528–1531.

Nepal, P., Grala, R. K., and Grebner, D. L. 2012. Financial feasibility of increasing carbon sequestration in harvested wood products in Mississippi. *Forest Policy and Economics* **14 (1)**: 99–106.

Price, C., and Willis, R. 2011. The multiple effects of carbon values on optimal rotation. *Journal of Forest Economics* **17 (3):** 298–306.

Rautiainen, O. 1991. **Management of Young Chir pine Stands: A Case Study in Lele village, Lalitpur District.** Forest Management and Utilization Division/FMUDP Project, Kathmandu, Nepal.

Ravindranath, N. H. and Ostwald, M. 2008. **Carbon Inventory Methods: Handbook for Greenhouse Gas Inventory.** Carbon Mitigation and Roundwood Production Projects: Springer London, Limited.

Richards, K. R., and Stokes, C. 2004. A review of forest carbon sequestration cost studies: A dozen years of research. *Climatic Change* **63:**1–48.

Romero, C., Ros, V., Rios, V., Daz-Balteiro, L., and Diaz-Balteiro, L. 1998. Optimal forest rotation age when carbon captured is considered: Theory and Applications. *The Journal of the Operational Research Society* **49 (2):** 121–131.

Sharma, D., and Singh, M. 2010. Assessing the carbon sequestration potential of subtropical pine forest in north-western Himalayas – A GIS approach. *Journal of the Indian Society of Remote Sensing* **38 (2):** 247–253.

Sharma, E. R., and Pukkala, T. 1990. **Volume Equations and Biomass Prediction of Forest Trees of Nepal.** Publication No. 47, Ministry of Forests and Soil Conservation, Forest Survey and Statistics Division, Babar Mahal, Kathmandu, Nepal.

Sohngen, B., and Brown, S. 2008. Extending timber rotations: carbon and cost implications. *Climate Policy* **8 (5):** 435–451.

Tewari, D. N. 1994. **A Monograph on Chir pine (*Pinus roxburghii* Sarg.)**. International Book Distributors, Rajpur Road, Dehradun, India.

Thakur, R. B. 2003. **A Compendium of Tree Species of Nepal**. Sarvottam Offset Printing Press (P.) Ltd. Putalisadak, Kathmandu, Nepal.

Upadhyay, M. 2008. A Term Paper on Economic Analysis of Resin Tapping (Unpublished). Institute of Forestry, Pokhara, Nepal.

Wang, Z., Calderon, M. M., and Carandang, M. G. 2006. Effects of resin tapping on optimal rotation age of pine plantation. *Journal of Forest Economics,* **11(4)**: 245–260.

Yi, W. Z., and Raven, P. H. 1999. **Flora of China**, **Vol. 4**. Science Press, St. Louis, Missouri Botanical Garden, Beijing, China.