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Community Managed Forests a Potential Sources of Carbon Sink: A Case Study from Kumaun Central Himalaya

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ABSTRACT

Participatory approaches to forest management have gained wide acceptance worldwide and have also become the primary guiding principle in the management of natural resources. The state Uttarakhand is ecologically and socially diverse owing to distinct climatic, physiographic factors and demographic setup. Community management of the forests in the state as Van Panchayat (V P) started from the year 1932 and close to 7211 km2 area (19 % of the total forest area) presently managed by the V Ps. Present study was carryout in a seventy years old V P of Kumaun Himalaya to investigate community perception, change in vegetation dynamics, C stock and C sequestration rate. The selected V P was monitored for ten years to collect the data and change in community perception over the time. The results indicated that dependency of the people for fuel wood for forest is decreasing due to availability of LPG connections but scarcity of green fodder still prevailed. Demographic variable indicated that both human and cattle population decreased over the study period. The possible reason for this the migration in search of jobs. Total tree density, basal area, biomass, carbon (C) content in all the selected species except Pinus roxburighii increased. Quercus leucotrichophora showed maximum density thus also have maximum C sequestration rate while Rhododendron arboreum showed the least. On an average the V P sequestrated 13.1 t C ha-1yr-1. It can be concluded that there is a shift in energy consumption pattern and awareness for conservation increasing in the community. The community can trade forest C, which is now emerging, to raise funds for functioning but careful choices in this regard will become especially critical to link community forests as C trade centres.

KEYWORDS Participatory management, Van Panchayats, demography, carbon sequestration, carbon trade

Introduction

The United Nation's Program for Reduction in Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+) aims to enhance the livelihoods of subsistence economies by facilitating the development of voluntary markets and international agreements to credit communities for afforestation and conservation of carbon activities (Eggleston et al. 2006, Asner et al. 2011, Ribeiro et al. 2013). Decentralization of forest management begins in the mid 1980, especially for commercially low-value forests that nonetheless play an important role in the livelihoods of hundreds of millions of rural households in developing countries, is the biggest revolutionary steps in the 21st century (Agarwal et al. 2008). Participatory approaches to forest management have gained wide acceptance and have also become the primary guiding principle in the management of natural resources worldwide (Mandoza and Prabhu 2005). Humans have shaped and used their environments in sustainable ways for thousands of years and it may be possible to establish partnerships that accomplish the same results today (Agarwal and Gibson 1999). About 90% of the global biomass of carbon (C) resides in forest trees and hence their C allocation dynamics are central to global biogeochemistry as well as to their organismal eco-physiology, directly affecting survival and growth (Koorner 2003, Klein and Hoch 2015). Changes in tree C allocation patterns have shown to exert large effects on constituents of the terrestrial C cycle (Luyssaert et al. 2007, Bonan 2008, Canadell and Raupach 2008, Reichstein et al., 2013). The REDD+ policy proposes to deliver multiple outcomes including emissions reduction, livelihood support and sustainable forest management and thus appears largely compatible with Community Forestry (C F). However, the addition of a new value (carbon sequestration) to traditional values of local livelihoods and ecological resilience may have implications for community management approaches at local level (Poudel et al. 2014). Decentralization reforms in the past two decades have often promoted local, more democratic participation in governance. Overall, local communities and organizations have come to govern close to an additional 200 million hectares of forests compared to the 1980s (White and Martin 2002, Molnar et al. 2004).

The state Uttarakhand is ecologically and socially diverse owing to distinct climatic, physiographic factors and demographic setup. Various classes of forest occupies 37999.532 km^2 area (71 %) of the total geographic area (53483 km^2), of which 24418.67 km^2 area (64.26 %) was managed by the state Forest Department and 7211.204 km^2 area (18.977 %) by the communities as *Van Panchayats* (Annon. 2013). The state can be divided into three distinct climatic regimes i.e. tropical, subtropical and temperate. The lower hills (below1200 m) are dominated by tropical dry and moist deciduous forests chiefly comprised of *Shorea robusta* Garten F. followed by almost pure stands of *Pinus roxburghii* Sarg. Between 1200 m and 2,000 m. *Quercus* spp. make their appearance above 1400 m and *Cedrus deodara* D. Don. above 1,800 m, and *Q. semecarpifolia* Sm. dominate above 2400 m. Population of the state was 10.1 million (2011 census). Agriculture is the main occupation around which all activities are centred (Ram et al. 2004) and managed at the cost of surrounding forests. The community management of forests as *Van Panchayat* (V P) of in the state was very old traced back to 1932 when first V P was established in the Almora district, way before the beginning of decentralization of forest management in the mid 1980s. V Ps came into existence through *Van Panchayat Act* (Forest Councils Act) passed in 1931 to resolve a long, violet protest against prohibition of forest right of local residence (Agarwal and Yadama 1997). Despite empirical and historical formulation of V Ps, the role of community and local participation in conservation forest has become limited in the central Himalayan forests. Effective forest governance is central to improve the stocking and change outcomes in the context of global climate change. The proposition that natural resources need protection from the destructive actions of people is widely accepted (Pretty 2003). Given the importance of the C F/ V Ps as a reservoir of above- and below- ground C, it presents potential for implementation of REDD+ policies towards environmental sustainability and socio-economic development. However, research on long tern monitoring of C dynamics of C Fs of Kumaun is still incipient and it needs to be evaluated more systematically. In this study C F was monitored for 10 years and the data were collected after an interval of 5 years to observe the changes. The purpose of this study was to in-

vestigate change in vegetation dynamics, C stock and its sequestration rate in a seventy years community managed forest in Kumaun Himalaya.

Materials and methods

The study V P was located 29^{0}47/ N Lat and 79^{0}36/ E Long at 1400 m asl altitude. Monsoon climate is prevalent in the study area. Wide variation was observed in temperature, in summers it raises up to 40 ^{0}C and in the winters may fall below 0 ^{0}C. Annual precipitation varied from 900 mm to 1800 mm and shows highly seasonal distribution. Precipitation is mainly concentrated to the rainy season (mid-June to mid-September) which counts 80 % and the rest is sporadic mainly between January–April. The rocks of the study area are metamorphosed and soils are sandy loam in nature.

The selected V P was constituted in year 1943 (source, Uttarakhand Forest Department) and was managed by the community since then. The selected V P forest is a naturally regenerated without giving irrigation or any other treatment. This study explores local perceptions as a preliminary step of V P management. Three meetings were held from 2005 to 2015, at an interval of five years, each consists of 50 users. Venue of meeting was the community centre or school and conducted in the month of third week of June at every time. As the number of women in the village was higher compared to men and considering that they were largely involved in the collection of forest resources. Therefore, during focal group discussion and questionnaire survey 60 % representation was given to women to voice their opinion. The focal group discussion and questionnaire survey was conducted for five classes of causal influences viz., biophysical, demographic, economic, institutional and socio-political. Existing studies have recognized each of these as being instrumental in influencing resource governance outcomes (Mandoza and Prabhu 2005). The questions asked were about the size of household, male, female members in a family, educational status, availability of LPG connection, cattle number, forest health, most preferred tree species, fuel wood supply, fodder supply, litter collection, fire incidence, present management system and its improvement, if any for future.

Field sampling was conducted in 3 periods (2005, 2010, and 2015) according to the methods prescribed by Sexana and Singh (1982) and Ram et al. (2004). To understand complete tree layer vegetation composition and distribution Importance Value Index (IVI) was used and calculated by adding relative frequency, density relative dominance. Tree density was calculated following Curtis and McIntosh (1950). Individual species were identified and a tree was defined by characteristic circumference at breast height (cbh at 1.37 m) of 30 cm and height of 10 m, respectively. Tree height was measured by Ravi Multimeter (Bhatt and Ram 2007) and cbh by a meter tape. Tree basal area, calculated as .

Tree C pools and fluxes (sequestration rate) were calculated from pool-specific measurements performed between 2005 and 2015. After sampling five important, evergreen tree species were indentified in the community forest (Table 2). 18 plots, 3 species^{-1} of 30 × 20 m^2 size were established in July 2005. The distance between the two plots was about 100 m. All plots are assumed to have homogenous topography, parent material and soil type, anthropogenic disturbances and grazing. Each plot was geographically referenced using a Geographic Positioning System (GPS, Garmin made, Garmin Inc.). In each plot ten trees species^{-1} were labelled and measured in July 2005, July 2010 and July 2015. Measurement period was kept 5 year, because of slow growth of the selected species and reduce errors involve in the measurement of cbh in a single year. Components wise annual woody biomass was estimated at each measurement using an allometric equation developed by Rawat (1983), Tewari et al. 1985, Rana et al. (1989a). Mortality and biomass removal was also estimated in each plot during the study period, as the number of individuals found dead/ missing during the study period. Biomass of trees that died during the study period was also calculated and net biomass change for each species was calculated as, Net biomass change , where B_i is the initial biomass, B_n biomass after n years, DB is the dead biomass.

The biomass of tree components (bole, branches, twigs and leaf, above ground and below ground) was converted to C using the 0.475 conversion factor and dead biomass was deducted in totalling and C is converted to CO_2 by multiplying factor 3.67 (44/12). Annual CO_2 sequestration rate was determined as

Where C_n Carbon n years after measurement, C_i is the initial Carbon and T is the measurement intervals

Results and discussion

Community perception

Participatory approaches of forest management have gained wide acceptance and have also become the primary guiding principle in the management of natural resources worldwide (Mandoza and Prabhu 2005). Traditional participatory approaches have often been criticized as lacking in rigor, and hence were in need of improvement. However, traditional participatory techniques have also fallen short of the type of analytical support required to meet the challenges of true participatory planning and management of community-based forest resources. The present study is an attempt to estimate the biomass, total C stock and C sequestration rate in a broad leaved-pine mixed community managed forest of Amlora district of Uttarakhand. The demographic variable (total population, family size, number of females and males family^{-1}) and cattle population decreased while the number of LPG connections increased over the years (Table 1). Female to male ratio was 1.8 in 2005 and it decreased to 1.4 in year 2015 and maximum decrease was observed between 2005 and 2010. This may be due to the migration of males in search of jobs to other cities. This migration also leads in the reduction of cattle number family^{-1}. Tiffen et al. (1994) point out as long as this number is not excesses can improve forest condition by increasing aggregate household contributions for conservation and strengthening the institutions that facilitate conservation.

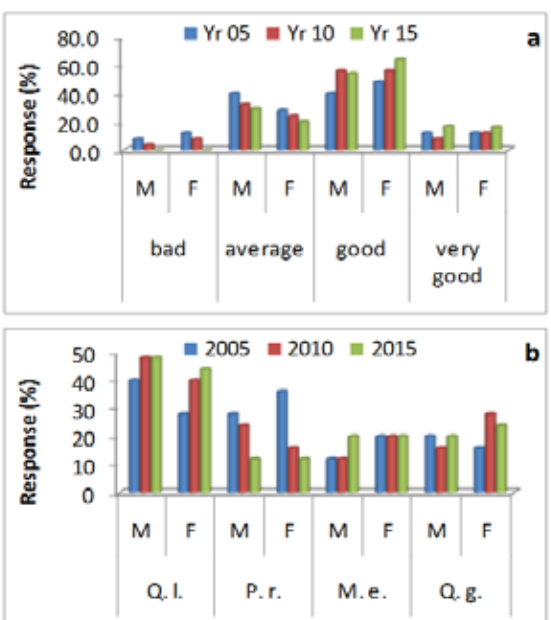
Table 1. Demographic status of the village during the course of study

Parameters	Year		
	2005	2010	2015
Population	405	336	298
Family size	4.5	4	3.3
Female	2.5	2.7	2.3
Male	2	1.3	1
number of cattle	4	3.3	3
LGP connection (%)	20	40	85

More than 50 % of male and females have the perception that the forest managed by the community is in good condition (Fig. 1 a). Similar findings have been reported in a number of other recent studies (Gautam et al. 2004, Rudel et al. 2002). My observation is that villagers are given more emphasis in the conservation of VP forest and use surrounding reserve forest, managed by government, to full fill their daily needs. Bowler et al. (2014) synthesized published literature on community forests and concluded that total tree basal area and tree density were greater in forests under CFM than in comparator sites. Presence of locally appointed and paid guards, especially at the life of lean green fodder scarcity period (December to March) is also associated with good condition of V P forest.

Among the different demographic variables, the one that affects outcomes most is population change rather than the absolute number of user households (Agarwal and Chharte 2006). Involvement of women in institutionalized decision

making improves the prospects for better resource conservation (Sarin 1995, Agarwal 1998,). Women are typically charged with collection of forest products such as fodder and firewood in hill areas. If they are in leadership positions, they can create regulatory mechanisms that are more suited to the local context as well as their needs for forest products (Agarwal and Chharte 2006). *Q. leucotrichophora* and *P. roxburghii* were the most valuable species in year 2005. But in the year 2015 *Q. leucotrichophora* followed by *Q. glauca* were the most valuable species and both males and females have change their thought for *P. roxburghii,* as categorising it as the least valuable species and (Fig, 1 b). This is mainly due the biased perception of the peoples of the state which is also reflected in the community. In the year 2005 all the females and 88 % of males responded that there is shortage of green fodder and hey. This situation remains the same in the response of the year 2015, though the number of females marginally reduced to 92 % and males 88 % (Fig. 1 c). Thus, provision of alternative green fodder is still needed to full fill the green fodder requirement. Fire incidence in the V P indicates declining trends over the study years (Fig. 1 d). This could be due to effective protective measures taken by the V P management council because within communities to implement the agreed upon rules resulting from their negotiations are easy. Because of continuing interactions among members over time, territorially circumscribed communities might also be able to develop specific ways of managing the resources near which they are located (Agarwal 1998). This is also associated with the initiatives taken by the state government like financial support to VP for fire protection and increase in the general awareness of the peoples.



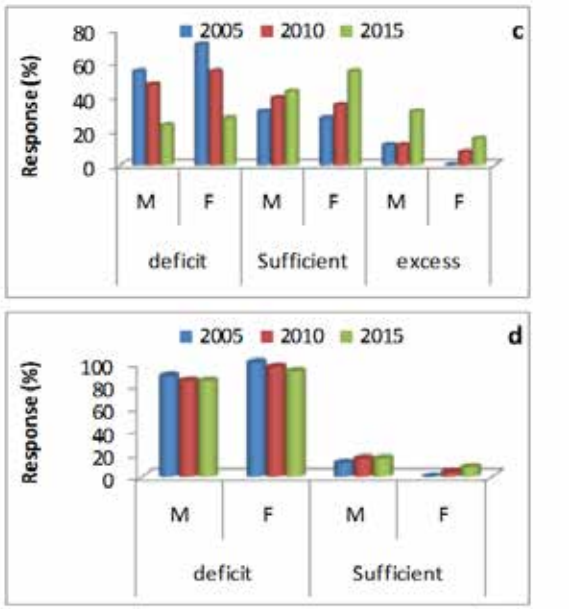


Figure 1. Community response on (a) forest condition (b) most preferred species (c) fuel wood availability and (d) status of green fodder. M indicated males and F indicated females. Q. l. denotes *Q. leucotrichophora,* P. r. *P. roxburghii*, M. e. *M. esculenta* and Q. g. *Q. glauca*

Vegetation characteristics

Total tree density showed increasing pattern and it was increased from 846.7 ha^{-1} in the year 2005 to 966.7 ha^{-1} in the year 2015. With respect to individual species, the density was maximum for *Q. leucotrichophora* and minimum for *Cornus capitata*. The density of *Q. glauca, M. esculenta* increased over the years and *Q. leucotrichophora, R. arboreum* remain constant while *P. roxburghii* decreased in the V P from 2005 to 2015 period. The decrease could be due to selective felling permission in *P. roxburghii* by the V P committee and conservation preference to other broadleaf species. Mean cbh increased from 79.7± 7.0 cm (2005) to 90.2 ±6.4 cm (2015) and mean height from 17.1± 1.9 m (2005) to 19.2 ±19.2 m (2015) across the species over the study period. Similarly, basal area and IVI increased over the study period for all species except *P. roxburighii* (Table 2). The values of total tree density (ha^{-1}) between 320 and 1560 individual ha^{-1} and basal area values between 12 and 74 m^2ha^{-1} in the community forest were within the earlier reported ranges (Singh et al., 1984; Singh and Singh 1986, Rawal and Pangtey 1994, Dhar et al. 1997, Ram et al. 2004) reported for Kumaun Himalayan forests.

Table 2. Tree and vegetation characteristics of the selected species in different measurement periods in the *Van Panchayat.*

Species	Year	Mean Height (m)	Mean cbh (cm)	Density (ha^{-1})	Frequency (%)	Basal area (m^2ha^{-1})	IVI
Q. glauca	2005	12.8	42.5	93.3	46.7	1.374	29.24
	2010	14.02	48.7	113	53.3	2.193	32
	2015	15.55	56.2	147	66.7	3.789	39.97
Q. leucotrichophora	2005	15.63	66.5	347	86.7	13.09	100.3
	2010	16.97	73.3	353	86.7	15.96	95.45
	2015	18.17	77.8	360	93.3	18.16	94.41
M. esculenta	2005	13.17	78.3	93.3	40	4.617	34.97
	2010	14.27	81.3	127	53.3	6.758	42.75

	2015	15.5	85.4	147	53.3	8.625	44.78
R. arboreum	2005	12.77	106	33.3	26.7	3.068	19.88
	2010	13.5	108	40	33.3	3.859	21.78
	2015	14.43	111	46.7	40	4.723	23.98
P. roxburghii	2005	30.77	107	127	46.7	11.71	58.2
	2010	31.17	109	93.3	53.3	8.917	43.59
	2015	31.53	113	66.7	40	6.853	29.77
Others	2005	17.33	77.7	153	66.7	7.44	57.41
	2010	18.77	82.5	207	66.7	11.29	64.43
	2015	20.27	97.1	200	73.3	15.11	67.07

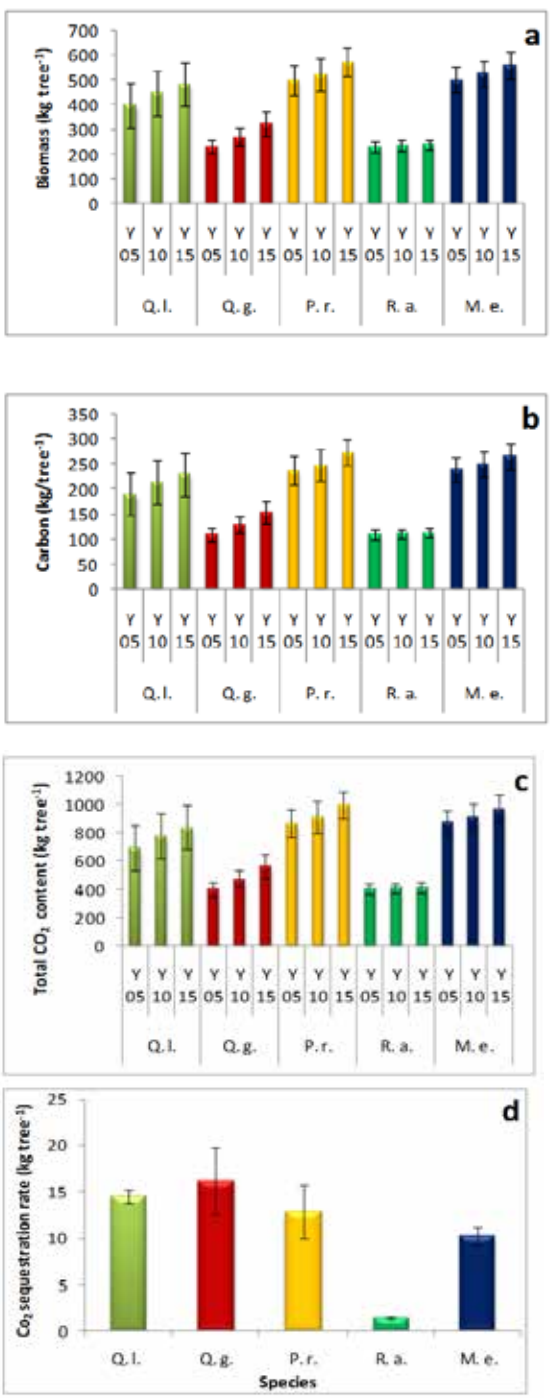


Figure 2. Individual tree (a) Biomass, (b) accumulated C, (c) CO_2 content and (d) C sequestration rate of the selected species in the *Van Panchayat*. R. a. denotes for *R. arboreum* other explanations are same as Fig. 1. Error bars indicated SE

Biomass and carbon

Mean tree biomass (kg tree^{-1}), C (kg tree^{-1}) and CO_2 content (kg tree^{-1}) for all the selected species increased over the study period except for *R. arboreum* it remains the same because of its very slow growth rate (Fig 2 a-c). C sequestration rate varied from 1.4 ± 0.1 to 16.1± 3.6 kg tree $^{-1}$ (Fig 2 d) over the study period. *Q. leucotrichophora* showed maximum biomass and stored carbon followed by *M. esculenta.*Total biomass and stored carbon (t ha^{-1}) of *P. roxburighii* declined over the study period (Fig 3 a-d). 67.8 % (*R. arboreum*) to 89.9 (*Q. leucotrichophora)* % carbon was stored by the above ground parts while 9.7 % (*Q. leucotrichophora*) to 33.2 (*R. arboreum)* % carbon was stored in the below ground parts. This could be due to more spread of root system of *R. arboureum.* The biomass values are within the range of the reported values for central Himalayan forests (Rana et al. 1989b). The component allocation (data are not given) of biomass indicated that branches, twigs and foliage contributed more biomass and carbon in all the studied evergreen broad leaved species compared to *P. roxburghii*, a needle shaped coniferous evergreen tree species in which it contain in the bole. Forest management may play in mitigating climate change, the accurate carbon assessment of activities is paramount to forecasting potential mitigation benefits (Ryan et al. 2010 and Malmsheimer 2011). On an average *Q. leucotrichophora* sequester 6.16 t ha^{-1}yr^{-1}, *Q. glauca* 4.51 t ha^{-1}yr^{-1}, *M, esculenta* 6.15 t ha^{-1}yr^{-1} and *R. arboreum* 0.6 t ha^{-1}yr^{-1} CO_2 whereas *P. roxburghii* showed decline trend in the community managed forest. The decline CO_2 sequestration rate may be attributed to the selected felling of the tree to meet fuel-wood requirement. The lowest rate of CO_2 sequestration of *R. arboreum* could be attributed to its slow growth. The results indicated that C values increasing over the study period and V P besides full filling fuel wood requirement sequestering 13.1 t C ha^{-1}yr^{-1}.

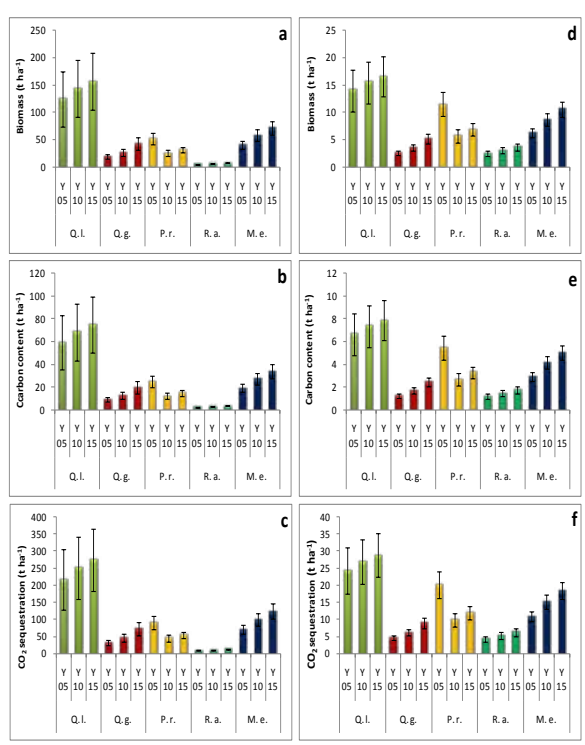


Figure 3. Total above ground (a-c) and below ground (d-f) biomass, C content and C Sequestration rate of the selected species over the study periods in the *Van Panchayat.*

Conclusion

After analyzing community-based forest management system of the V P it may be concluded that there is a shift in energy consumption pattern and awareness for conservation increasing. Effective community based conservation requires adequate funds for implementing the rules they create. The community can trade forest C, which is now emerging, to raise funds for functioning but careful choices in this regard will become especially critical linking community forest as a C trade activities keeping its effect on government owned forests. Because community based forest conservation would be more profitably on principles of sound checks and balances.

REFERENCES

Agarwal, A., Chhatre, A., and Hardin, R. (2008), "Changing Governance of the World's." Forests Science, 320, 1460-1462. Agarwal, A., and Chharte, A. (2006), "Explaining Success on the Commons: Community Forest Governance in the Indian Himalaya." World Development 34, 149–166. Agarwal, A., and Gibson, C. C. (1999), "Enchantment and Disenchantment: The Role of Community in Natural Resource Conservation" World Development, 27, 629-649. Agarwal A., and Yadama G. N. (1997), "How do Local Institutions Mediate Market and Population Pressures on Resources? Forest Panchayats in Kumaon, India". Development and Change, 28, 435-465. Agarwal, B. (1998), "Environmental management, equity and ecofeminism: Debating India's experience". Journal of Peasant Studies, 25, 55–95. Annon. (2013), "Uttarakhand Forest Statistics 2012-13". Uttarakhand Forest Department, Dehradun. Asner, G. P., Martin, R. E., Knapp, D, E,, Tupayachi. R., Anderson, C., Carranza, L., Martinez, P., Houcheime. M., Sinca, F., and Weiss, P. (2011), "Spectroscopy of canopy chemicals in humid tropical forests". Remote Sensing Environment, 115, 3587–3598. Bhatt, J., and Ram, J. (2007), "Seed and seedling characteristics of the Himalayan Hornbeam (Carpinus viminea Wall.) India". Ecological Research, 22, 156-159. Bowler, D. E. , Buyung-Ali, L. M ., Healey, J. R., Jones, J. P. G., Knight, T. M., and Pullin A. S. (2014), "Does community forest management provide global environmental benefits and improve local welfare"? Frontier of Ecology Environment 2012, 10, 29–36 Bonan, G. B. (2008), "Forests and climate change: forcings, feedbacks, and the climate benefits of forests". Science, 320, 1444–1449. Canadell, J. G., and Raupach, M. R. (2008), "Managing forests for climate change mitigation". Science, 320, 1456–1457. Curtis, J. T., and McIntosh, R. P. (1950), "The interrelationship of certain analytic and synthetic characters". Ecology, 31, 438-455. Dhar, U., Rawal, R. S., and Samant, S.S. (1997), "Structural diversity and representativeness of forest vegetation in a protected area of Kumaun Himalaya, India: implications for conservation". Biodiversity and Conservation, 6, 1045-1062. Eggleston, S., Buendia, L., Miwa, K., Ngara, T., and Tanabe, K. (2006), "IPCC guidelines for National Greenhouse Gas Inventories". Hayama, Japan: IPCC-IGES Gautam, A., Shivakoti, G., and Webb, E. (2004), "Forest cover change, physiography, local economy, and institutions in a mountain watershed in Nepal". Environmental Management, 33, 48–61. Klein, T., and Hoch G. (2015), "Tree carbon allocation dynamics determined using a carbon mass balance approach". New Phytologist, 205, 147–159 Korner, C. (2003), "Carbon limitation in trees". Journal of Ecology, 91, 4–17. Luyssaert, S., Inglima, I., Jung, M., Richardson, D., Reichstein, M., Papale, D., Piao, S. L., Schulze, E. D., Wingate, L, Matteucci, G. (2007), "CO2 balance of a boreal, temperate, and tropical forests derived from a global database". Global Change Biology, 13, 2509–2537. Malmsheimer, R. W., Bowyer, J. L., Fried, J. S., Gee, E., Izlar, R., Reid, R. A., Munn, I. A., Oneil, E., and Stewart, W. C. (2011), "Managing forests because carbon matters: integrating energy, products, and land management policy". Journal of Forestry, 109, S7–S50. Mendoza, G. A. and prabhu, R. (2005), "Combining participatory modeling and multi-criteria analysis for community-based forest management". Forest Ecology and Management, 207, 145-156. Molnar, A., Scherr, S. J., and Khare A. (2004), Who Conserves the World's Forests"? Forest Trends, Washington DC,USA. Poudel, M., Thwaites, R., Race, D. and Dahal, G. R. (2014), "REDD+ and Community Forestry: Implications for Local Communities and Forest Management- a Case Study from Nepal". International Forestry Review, 16, 39-54. Pretty J. (2003), "Social Capital and the Collective Management of Resources". Science, 302, 1912-1914. Ram, J., Kumar, A., and Bhatt J. (2004), "Plant diversity in six forest types of Uttaranchal Himalaya, India". Current Science, 87, 975-978 Rana, B. S. Singh, S. P. and Singh, R. P. (1989a), "Biomass and net primary productivity in central Himalayan forests along an altitudinal gradient". Forest Ecology and Management, 27, 199-218. Rana, B. S., Singh, S. P., and Singh, R. P. (1989b), "Carbon and energy dynamic of seven Central Himalayan forests". Tropical Ecology, 30, 253-264. Rawal, R. S., and Pangtey, Y. P. S. (1994), "High altitude forests in a part of Kumaun, Central Himalaya". Proceeding of Indian National Science Academy, 60, 557- 564 Rawat, Y. S. (1983), "Plant biomass, net primary production and nutrient cycling in Oak forests". Ph. D. thesis, Kumaun University Nainital. Reichstein, M., Bahn, M., Ciais, P., Frank, D., Mahecha, M. D., Senevirante, S.I., Zscheischlwe, J., Beer, C., Buchmann, N., Frank, D. C. (2013), "Climate extremes and the carbon cycle". Nature, 500, 287–295. Ribeiro, N. S., Matos, C. N., Moura, I. R., Washington-Allen R. A., and Ribeiro, A. I. (2013), "Monitoring vegetation dynamics and carbon stock density in miombo woodlands". Carbon Balance and Management, 8, 11 Rudel, T. K., Bates, D., and Machinguiashi, R. (2002), "A tropical forest transition: Agricultural change, outmigration, and secondary forests in the Ecuadorian Amazon". Annals of the Association of American Geographers, 92, 87–102. Ryan, M. G., Harmon, M. E., Birdsey, R. A., Giardina, C. P., Heath, L. S., Houghton, R. A., Jackson, R. B., McKinley, D.C., Morrison, J. F., Murray, B. C., Pataki, D. E., and Skog, K. E. (2010), "A synthesis of the science on forests and carbon for US forests". Issues in Ecology, 13, 1–16. Sarin, M. (1995). "Regenerating India's forests: Reconciling gender equity with joint forest management". IDS Bulletin: Institute of Development Studies, 26, 83–91. Sexena, A. K., and Singh J.S. (1982), "A phytosociological analysis of of woody species in forest communities in a part of Kumaun Himalaya". Vegetatio, 49, 111-119. Singh, J. S., Rawat, Y. S. and Chaturvedi, O. P. (1984), "Replacement of oak forest with pine in the Himalaya affects the nitrogen cycle". Nature, 311, 54- 16 Singh, S. P., and Singh, J.S. (1986), "Structure and function of the central Himalayan oak forests". Proceeding of Indian National Science Academy, 96, 159- 189 Tewari A. K., Sexena A. K., and Singh J. S. (1985), "Inventory of forest biomass for Indian central Himalayan region". In Sigh J.S. (ed.), Environmental regeneration in the Himalaya.: concept and strategies. Central Himalayan Environemntal Association and Gyanodaya Prakashan, Nainital. Tiffen, M., Mortimore, M., and Gichuki, F. (1994), "More people–less erosion: Environmental recovery in Kenya". John Wiley and Sons, London. White, A., and Martin A.(2002), "Who Owns the World's Forests"? Forest Trends, Washington DC, USA.