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Assessment of Above Ground Carbon Stock in Trees of Ponda Watershed, Rajouri (J&K)

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Abstract

Forest sequesters large terrestrial carbon which is stored in the biomass of tree and plays a key role in reducing atmospheric carbon. Thus, the objectives of the present study were to assess the growing stock, above ground biomass and carbon in trees of Ponda watershed of Rajouri district (J&K). IRS-P6 LISS-III satellite data of October 2010 was used for preparation of land use/land cover map and forest density map of the study area by visual interpretation. The growing stock estimation was done for the study area as well as for the sample plots laid in forest and agriculture fields. The growing stock and biomass of trees were estimated using species specific volume equations and using specific gravity of wood, respectively. The total growing stock in the study area was estimated to be 0.25 million m^3 which varied between 85.94 m^3/ha in open pine to 11.58 m^3/ha in degraded pine forest. However in agriculture area, growing stock volume density of 14.85 m^3/ha was recorded. Similarly, out of the total biomass (0.012 million tons) and carbon (0.056 million tons) in the study area, open pine forest accounted for the highest values of 43.74 t/ha and 19.68 t/ha and lowest values of 5.68 t/ha and 2.55 t/ha, respectively for the degraded pine forest. The biomass and carbon density in agriculture area obtained was 5.49 t/ha and 2.47 t/ha, respectively. In all the three forest classes *Pinus roxburghii* showed highest average values of growing stock volume density, biomass and carbon.

Key Words: growing stock, biomass, above ground carbon, remote sensing and GIS

Introduction

Forest plays an important role in maintaining environmental balance and economic sustainability. They provide numerous services and maintain life support systems essential for life on earth (Khosla 1992; Jaiswal et al. 2002). In terrestrial ecosystems, forests are the most productive among their biotic components and these productive characteristics of forests make them attractive for mitigation of climate change (Nabuurs et al. 2007; Ramachandran et al. 2007; Kishwan et al. 2009). The significance of forest in global carbon cycle and their potential to hold and sequester carbon is also well recognized as they are natural storehouses of biomass and carbon (Sheikh et al. 2012). Forests influence climate and the climate change processes by changing the concentration of atmospheric carbon (Pandey et. al. 2011; Brown and Gaston 1996). They present an important sink of carbon dioxide and are estimated to store more than one trillion tones of carbon worldwide (FAO 2008). Therefore this global importance of forest ecosystems emphasizes the need to accurately determine the amount of biomass and carbon stored in different forest ecosystems (Kale et al. 2001).

Growing stock based estimation of biomass and carbon stocks is the reliable and valuable source (Brown and Lugo 1984; Haripriya 2000; Chhabara et al. 2002). However,

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application of remote sensing technology is suitable for verifying land use land cover change monitoring, growing stock, biomass and carbon pool estimation in forest ecosystems (IPCC 2003; Sharma 2005; Torres 2009). Biomass cannot be directly measured from space, but remotely sensed reflectance can be related to biomass estimates based on field measurement (Kaur 2007). Considerable work has already been done using both aerial and satellite remote sensing data in Himalaya and other parts of India (Rana et al. 1989; Singh and Roy 1990; Sundriyal et al. 1994; Nigam 2000; Sharma 2005; Singh et al. 2004; Sharma and Singh 2010; Kaul et al. 2011; Devagiri et al. 2013; Guleria et al. 2013). However, studies related to growing stock based biomass and carbon especially using geospatial techniques, in subtropical pine forests of Rajouri, Northwestern Himalaya have not been carried out. Thus, an effort has been made to map the forest cover type of the area in order to estimate growing stock, biomass and carbon stocks using remote sensing and geographical information system.

Materials and Methods

Study Area

Ponda Watershed selected for present study lies in Rajouri Forest Range, Rajouri, Jammu and Kashmir, India (Fig. 1). It is located between 33° 16′ to 33° 24′ N latitude and 74° 11′ to 74° 19′E longitudes and spread over an area of 8070.9 hectare with altitude range of 800 m asl to 1,000 m asl. Physiographically it consists of numerous hills and small valleys of meandering brooks in foot hills of Pir Panjaal range. The climate of study area is subtropical with the average temperature varying from 7.42°C to 37.4°C. The average annual rainfall received is 1150 mm and maximum rainfall in the area is received through southwest monsoon during July-September.

Data Collection and Analysis

In the present study, we have used survey of India topo maps (43K3 and 43K7), existing forest maps, remotely sensed satellite data (IRS-P6 LISS-III of October, 2010 for the field survey during the period June 2011 to May 2012. A total of 40 sample plots of 20x20 m size in forest class and 20 sample plots of 50x50 m size were laid in agriculture fields to enumerate the number of trees, their species and Circumference at Breast Height (CBH) in order to assess the species wise, plot wise and overall tree growing stock of the watershed. The information pertaining to forest types, tree species, girth and height of trees along with

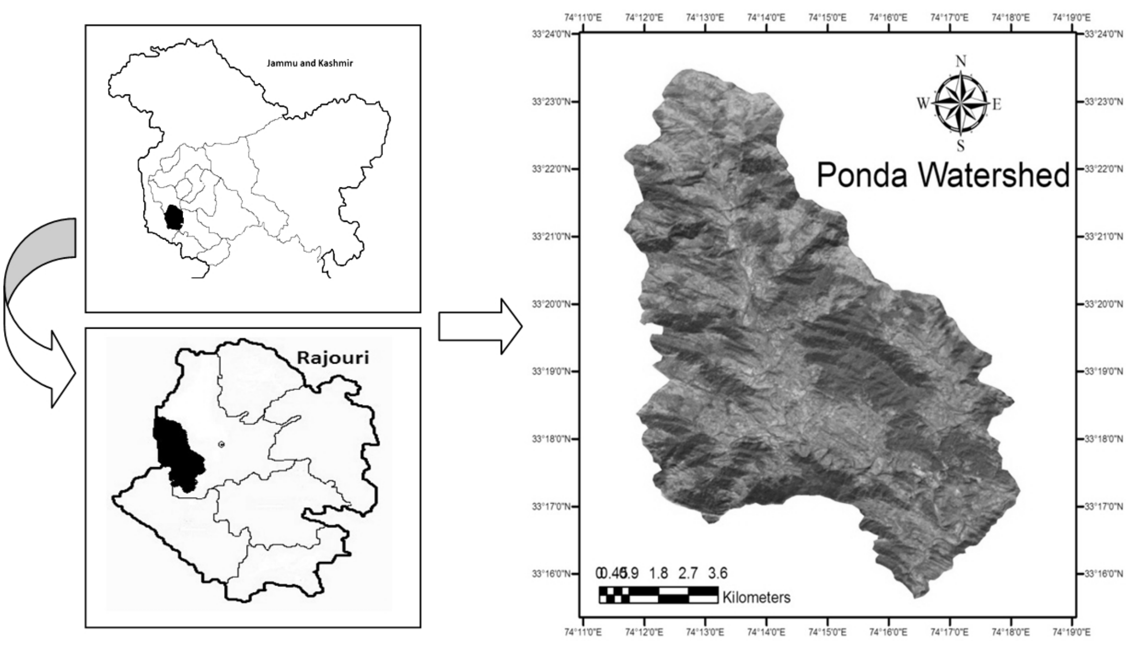

Fig. 1. Location map of study area.

ground truth was also collected. On the basis of reconnaissance survey, an interpretation key was developed for the visual image interpretation and the study area was classified mainly in two classes i.e. agriculture and forest using ILWIS Ver. 3.0 GIS software.

The forest area was further classified into three density classes i.e. dense (density cover ＞40%), open (10%～40 %) and degraded (＜10%). The estimation of growing stock was undertaken by sorting out the data collected according to plot wise and species wise. The plot wise volume of individual tree species was calculated from the field data collected using specific volume equation (FSI 1996) and in turn tree volume was multiplied by specific gravity to obtain biomass (FRI 1996; Torres 2009). Finally, carbon pool from biomass was obtained by multiplying the biomass by universal coefficient factor of 0.45 (Rao 2007; Torres 2009).

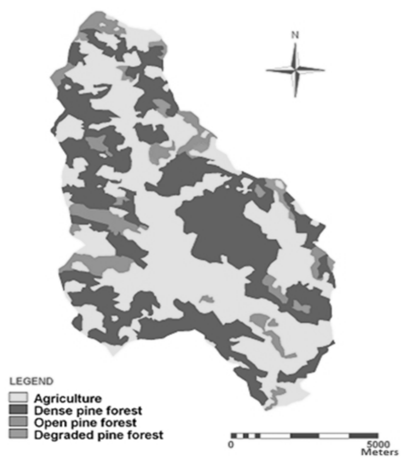

Fig. 2. Landuse/landcover map of the Ponda watershed.

Results and Discussion

Land use/land cover

The land use/land cover map of Ponda watershed (Fig. 2) obtained showed that majority of the area of the watershed was under forest class (52.46 %) whereas rest of the area was under agriculture (47.54%). In the forest category which was further divided into three classes' viz. dense pine, open pine and degraded pine comprised of 42.24%, 8.04% and 2.18%, respectively.

Growing stock

Since the growing stock is an estimate of total volume of wood available at any particular time (Singh et al. 2004).The total growing stock in the study area was estimated to be 0.25 million m^3 (Table 1). Growing stock volume density was found to be 153.85 m^3 ha^{-1} which is quite low as compared to the range of values reported from Himalayan subtropical chir pine forests (Singh et al. 2004; Sharma et al. 2010; Sheikh and Kumar 2010; Devi et al. 2013). In the present study, growing stock volume was in the range of 67.76 m^3 ha^{-1} to 156.27 m^3 ha^{-1} as reported by Sharma and Baduni (2000) from different aspects of Siwalik chir pine forests of Pauri district of Garhwal Himalaya. According to Indian State of Forest Report (2013), the total growing stock volume in the state of Jammu and Kashmir was found to be 377.24 million m^3. However, the average growing stock volume density of Indian forests is 54 m^3 ha^{-1}. The growing stock per hectare in various forest classes and agriculture area was also estimated (Fig. 3). The average growing stock per hectare was found highest in open pine forest (85.94 m^3h^{-1}) followed by dense (41.48 m^3ha^{-1}) and degraded pine forest (11.58

Table 1. Total growing stock, biomass and carbon estimation

Land use/ Land cover	No. of plots	Total			Total Area (ha)	Total		
		Growing stock (m^3/plot)	Biomass (tons/plot)	Carbon (tons/plot)		Growing stock (m^3)	Biomass (tons)	Carbon (tons)
Agriculture	20	2.80	1.37	0.62	3,836.95	056,978.70	28,009.73	12,585.20
Dense pine	14	1.66	0.81	0.37	3,409.36	141,420.25	69,414.57	31,229.74
Open pine	24	2.24	1.09	0.49	0649.12	055,785.37	27,386.37	12,320.30
Degraded pine	02	0.46	0.22	0.10	0175.56	002,032.98	00,997.18	00447.68
Total	60	7.16	3.49	1.58	8,070.99	256,217.30	12,5807.9	56,582.91

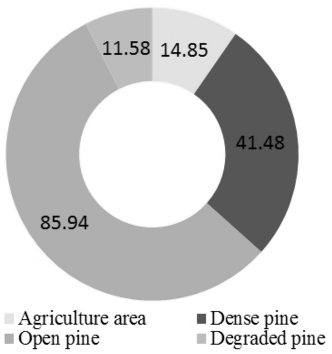

Fig. 3. Growing stock volume density (m^3 ha^{-1}) in different LULC of the study area.

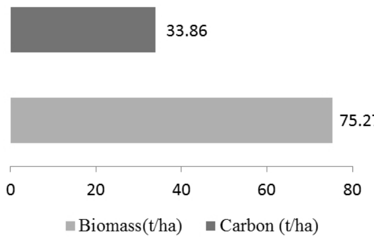

Fig. 4. Total biomass and carbon density in the study area.

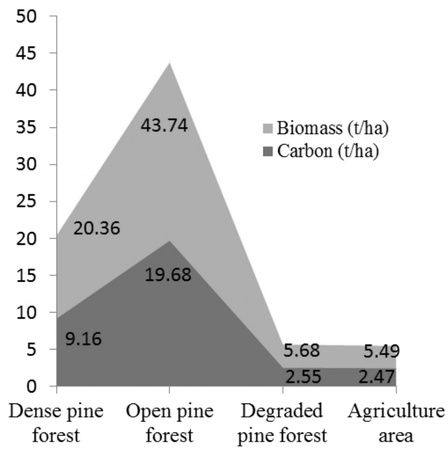

Fig. 5. Distribution of biomass and carbon in different LULC of the study area.

m^3ha^{-1}), whereas in agriculture area, the total growing stock was 14.85 m^3ha^{-1} which can be attributed due to less popularity of agro-forestry systems in the area.

Biomass and carbon

The total biomass of 125,807.9 tons and carbon of 56,582.91 tons was estimated in study area (Table 1) with biomass and carbon density of 75.27 t/ha and 33.86 t/ha, respectively (Fig. 4), which is considerably closer to the biomass value of 73.30 t/ha as reported by Sharma et al. (2010) for chir pine forests of the Garhwal Himalaya. Kaur (2007) reported high biomass (246.12 t/ha) and carbon (116.91 t/ha) in pine forests and low biomass (64.41 t/ha) and carbon (30.59 t/ha) in mixed pine forests of Govind Wildlife Sanctuary and National park, Uttarakhand. Joshi et al. (2013) reported a much low biomass and carbon stock, in comparison to present study, falling in the range of 9.47 t/ha to 38.54 t/ha and 4.73 t/ha to 19.27 t/ha, respectively, in mixed pine forests of Kumaun Central Himalaya affected by various types of biotic pressure. However, these values are lower than the reported values for other chir pine forests of Himalayas (Sheikh and Kumar 2010; Sheikh et al. 2012; Pant and Tewari 2013; Shah et al. 2014). Out of total biomass and carbon stock in the study area, open forest accounted for the highest values for biomass (43.74 t/ha) and carbon (19.68 t/ha) followed by dense pine forest with biomass of 20.36 t/ha and carbon of 9.16 t/ha (Fig. 5). The high biomass in open forests of the study area was due to maximum number old growth or mature pine trees and other associated broad leaved tree species such as *Mallotus philippensis, Cassia fistula Grewia optiva*. The low biomass in dense pine forest was due to higher number of young age trees and sporadic distribution of other tree species (Sharma 2009; Ranot and Sharma 2013; Pant and Tewari 2013). The low values of biomass (5.68 t/ha) and carbon (2.55 t/ha) was observed in the degraded pine forest (Rao 2007). The biomass and carbon from agriculture area was found to be 5.49 t/ha and 2.47 t/ha, respectively (Fig. 5). The low biomass in agriculture areas was because of low biomass yielding fruit tree species and less prevalence of trees in the fields (Sharma 2009).

The carbon stock recorded in the present study is in consonance with the results of Jina et al. (2008) who reported a carbon density of 81.31-115.40 t/ha in non-degraded chir pine forest while 17.59-33.42 t/ha in degraded Pine forest of Kumaun, Central Himalaya. The results are also in conformity with the results obtained by Sharma (2009), in chir pine forests of Solan Forest Division who recorded a carbon density of 44.71 t/ha. The trend for carbon stock was similar to that of biomass, because carbon is directly related to biomass, i.e., higher the biomass the greater the carbon

(Manhas et al. 2006; Sheikh et al. 2012).

Values for growing stock volume density, biomass and carbon varied between various tree species across the study area. In all the three forest classes *Pinus roxburghii* showed highest average values of growing stock volume, biomass and carbon which is in conformity with the results reported by other authors such as Sharma and Baduni (2000), Negi et al. (2003) and Sheikh et al. (2012), whereas, the lowest value for the parameters of growing stock volume, biomass and carbon were recorded for *Phyllanthus emblica*, *Leucaena leucocephala* and *Mallotus philippensis* in dense, open (Table 2) and degraded pine forests, respectively (Table 3). Similarly in agriculture class, *Melia azedarach* showed highest value of average growing stock volume (0.278±0.208 m^3ha^{-1}), biomass (0.136±0.102 t/ha) and carbon (0.061±0.046 t/ha) followed by *Ficus religiosa Pyrus communis*, etc (Table 3). However, Kour (2014) reported total growing stock volume density of 6.13 m^3/ha in agriculture fields of Vijaypur, Samba, Jammu and Kashmir which varied from 2.48 m^3/ha for *Mangifera indica* to 0.003 m^3/ha for *Eucalyptus citridora*.

The reason for variation in growing stock, biomass and carbon across different areas may be attributed to different approach of study, conservation practices, disturbance levels and pressure of communities on forests (Shah et al. 2014). In the present study the reasons for the low biomass and carbon stock are due to the increasing biotic pressure on forests as forests present around the agricultural fields of the study area are highly degraded due to continuous anthropogenic disturbances such as frequent forest fires, encroachment, extraction of wood for timber and fuel *etc* (Sharma and Rai 2007; Sheikh and Kumar 2010; Sharma and Ahmed 2014). The encroachment of forests to agriculture land use in the study area is also a possible reason resulting a decline in the carbon densities (Sharma and Rai 2007). Deforestation and other changes in land use cause significant exchanges of carbon between the land and the atmosphere. Thus, support the hypothesis that land use transformation from forest to agriculture and other usage causes tremendous losses of biomass and release of carbon to atmosphere (Haripriya and Atkinson 2006; Kaul et al. 2011). Therefore some management practices need to be implemented to save these forests against various threats, so as the carbon pools of these forests can be saved. Forests of-

Table 2. Species wise average growing stock volume density, biomass and carbon in dense and open pine forest

Genera and Species	Dense Pine				Open Pine			
	BA (m^2ha^{-1})	GSVD (m^3ha^{-1})	Biomass (t/ha)	Carbon (t/ha)	BA (m^2ha^{-1})	GSVD (m^3ha^{-1})	Biomass (t/ha)	Carbon (t/ha)
Pinus roxburghii Sarg.	0.059±0.048	0.234±0.263	0.115±0.130	0.051±0.058	0.062±0.075	0.474±0.809	0.232±0.397	0.105±0.178
Mallotus philippensis (Lam.) Muell.Arg	0.122±0.031	0.130±0.014	0.056±0.007	0.025±0.003	0.013±0.006	0.070±0.038	0.034±0.019	0.015±0.008
Phyllanthus emblica Geartn	0.012	0.057	0.028	0.012	0.015±0.013	0.075±0.086	0.037±0.042	0.016±0.019
Bauhinia variegata Linn.	-	-	-	-	0.017±0.019	0.088±0.150	0.043±0.074	0.019±0.033
Grewia optiva Drumm.exBurret.	-	-	-	-	0.013±0.006	0.070±0.055	0.069±0.027	0.046±0.012
Olea ferruginea Royle	-	-	-	-	0.012±0.006	0.075±0.037	0.036±0.018	0.016±0.008
Ficus palmata Forssk.	-	-	-	-	0.012±0.005	0.076±0.034	0.037±0.017	0.016±0.007
Ficus racemosa Linn.	-	-	-	-	0.014±0.004	0.088±0.027	0.043±0.013	0.019±0.006
Phoenix acaulis Rosb.ex Buch. Ham	0.015	0.066	0.032	0.014	0.024±0.015	0.155±0.097	0.076±0.048	0.034±0.021
Pyrus pashia Buch.Ham.ex.D.Don	0.031±0.005	0.139±0.025	0.068±0.012	0.030±0.005	0.012±0.006	0.080±0.038	0.039±0.018	0.017±0.008
Woodfordia fruitcosa (L.) Kurz.	-	-	-	-	0.011±0.006	0.072±0.035	0.035±0.017	0.016±0.007
Leucaena leucocephala (Lam.) de Wit.	-	-	-	-	0.010±0.002	0.069±0.015	0.034±0.007	0.015±0.003
Butea monosperma (Lam.) Taub.	-	-	-	-	0.031±0.028	0.200±0.176	0.098±0.086	0.044±0.038
Callistemon lanceolatus (Sm.)	-	-	-	-	0.055	0.352	0.173	0.077
Cassia fistula Linn	0.020	0.089	0.043	0.019	0.011±0.004	0.072±0.024	0.035±0.011	0.016±0.005
Syzgium cumini (L.) Skeels.	-	-	-	-	0.017±0.019	0.108±0.119	0.053±0.058	0.024±0.026

Table 3. Species wise average growing stock volume density, biomass and carbon in degrade pine forest and agriculture fields

Genera and Species	Degraded Pine				Agriculture Fields			
	BA (m^2ha^{-1})	GSVD (m^3ha^{-1})	Biomass (t/ha)	Carbon (t/ha)	BA (m^2ha^{-1})	GSVD (m^3ha^{-1})	Biomass (t/ha)	Carbon (t/ha)
Acacia catechu Wild.	-	-	-	-	0.004±0.002	0.017±0.008	0.008±0.004	0.003±0.001
Albizia chinensis (Osbeck) Merr	-	-	-	-	0.002±.0001	0.012±.0008	0.005±.0004	0.002±.0002
Bauhinia variegata Linn.	-	-	-	-	0.004±0.002	0.023±0.017	0.011±0.008	0.005±0.003
Bombax ceiba Linn.	-	-	-	-	0.007±0.005	0.048±0.036	0.023±0.018	0.010±0.008
Callistemon lanceolatus (Sm.)	-	-	-	-	0.005±0.003	0.035±0.017	0.017±0.008	0.007±0.004
Cassia fistula Linn.	-	-	-	-	0.001±.0005	0.011±0.003	0.005±0.001	0.002±.0007
Celtis australis Linn.	-	-	-	-	0.002±.0006	0.015±0.003	0.007±0.002	0.003±.0008
Citrus limon Burm.f	-	-	-	-	0.002±.0005	0.011±0.003	0.005±0.001	0.002±.0007
Citrus medica Linn	-	-	-	-	0.001±.0001	0.001±.0007	0.005±.0003	0.002±.0001
Citrus sinensis Linn.	-	-	-	-	0.001±.0002	0.010±0.001	0.005±.0007	0.002±.0003
Dalbergia sisoo Roxb.	-	-	-	-	0.008±0.003	0.041±0.018	0.020±0.009	0.009±0.004
Eriobotrya japonica (Thumb.) Lindl	-	-	-	-	0.003±0.002	0.020±0.010	0.010±0.005	0.004±0.002
Eucalyptus citriodora Linn	-	-	-	-	0.012±0.004	0.059±0.020	0.029±0.010	0.013±0.004
Ficus carica Linn.	-	-	-	-	0.002±0.001	0.013±0.007	0.006±0.003	0.003±0.001
Ficus palmata Forssk.	-	-	-	-	0.001±.0002	0.010±0.001	0.005±.0007	0.002±.0003
Ficus racemosa Linn.	-	-	-	-	0.012±0.004	0.002±.0007	0.006±0.002	0.002±0.001
Ficus religiosa Linn.	-	-	-	-	0.023±0.035	0.225±0.363	0.110±0.178	0.049±0.080
Grevillea robusta A. Cunn.ex R.Br.	-	-	-	-	0.009	0.059	0.029	0.013
Grewia optiva Drumm.exBurret.	-	-	-	-	0.005±0.003	0.027±0.024	0.013±0.012	0.006±0.005
Juglans regia Linn.	-	-	-	-	0.022±0.003	.0015±.0001	0.011±0.001	0.005±.0006
Leucaena leucocephala (Lam.) de Wit.	-	-	-	-	0.001±.0001	0.009±.0009	0.005±.0004	0.002±.0002
Mallotus philippensis (Lam.) Muell.Arg.	0.266±0.178	1.657±1.313	0.813±0.644	0.366±0.290	0.002±.0005	0.013±0.001	0.006±.0007	0.003±.0003
Malus domestica Borch.	-	-	-	-	0.011±0.002	0.073±0.019	0.036±0.009	0.016±0.004
Mangifera indica Linn.	-	-	-	-	0.009±0.006	0.059±0.042	0.029±0.020	0.013±0.009
Melia azedarach Linn.	-	-	-	-	0.004±0.003	0.278±0.208	0.136±0.102	0.061±0.046
Morus alba Linn.	-	-	-	-	0.002	0.016	0.008	0.003
Morus nigra Linn.	-	-	-	-	0.003±0.001	0.019±0.011	0.009±0.005	0.004±0.002
Olea ferruginea Royle	-	-	-	-	0.003±0.002	0.020±0.012	0.010±0.006	0.004±0.002
Phoenix acaulis Rosb.ex Buch. Ham.	-	-	-	-	0.002±0.001	0.015±0.007	0.007±0.003	0.003±0.001
Phyllanthus emblica Geartn.	-	-	-	-	0.004±0.002	0.027±0.014	0.013±0.007	0.006±0.003
Pinus roxburghii Sarg.	0.436±0.092	2.388±0.665	1.172±0.231	0.527±0.147	0.012±0.004	0.085±0.035	0.041±0.017	0.018±0.008
Populus ciliate Wall.Ex Royle	-	-	-	-	0.013±0.004	0.087±0.028	0.043±0.013	0.019±0.006
Prunu armeniaca Linn.	-	-	-	-	0.005±0.002	0.032±0.013	0.015±0.006	0.007±0.003
Prunus domestica Linn.	-	-	-	-	0.004±0.002	0.030±0.013	0.015±0.006	0.006±0.003
Prunus persica Linn.	-	-	-	-	0.005±0.003	0.033±0.019	0.016±0.009	0.007±0.004
Psidium guajava Linn.	-	-	-	-	0.002±.0005	0.013±0.003	0.006±.0014	0.003±.0006
Pyrus communis Linn.	-	-	-	-	0.0024	0.0154	0.0075	0.0034
Pyrus pashia Buch.Ham.ex.D.Don	-	-	-	-	0.0059	0.036	0.0178	0.008
Salix alba Linn.	-	-	-	-	0.002±.0003	0.011±0.002	0.006±.0009	0.002±.0004
Thevetia peruviana (Pers.) K.Schum	-	-	-	-	0.001±.0002	0.010±.0017	0.005±.0008	0.002±.0004
Toona ciliata M Roemer.	-	-	-	-	0.005±0.003	0.029±0.018	0.014±0.009	0.006±0.004
Ulmus wallichiana Planch.	-	-	-	-	0.004±0.005	0.027±0.035	0.013±0.017	0.006±0.008
Woodfordia fruitcosa (L.) Kurz.	-	-	-	-	0.001±.0002	0.011±.0013	0.005±.0006	0.002±.0003
Ziziphus mauritiana Lam.	-	-	-	-	0.003±0.002	0.021±0.011	0.010±0.005	0.004±0.002

BA, Basal Area; GSVD, Growing Stock Volume Density.

ten store carbon at rates well below their potential and thus could be responsive to management for enhanced carbon sequestration (Sheikh et al. 2012). Thus, more amount of carbon can sink into these potential forests by afforestation and reforestation of degraded areas with site specific indigenous species which have soil binding characteristics (Kaur 2007). At the same time creation of new plantation on degraded lands is a better option for carbon storage when these are planted and harvested periodically and used as a long term source of timber (Baishya et al. 2009). Thus, local people should be involved in plantation and these types of community conserved forests will play a major role in long term mitigation of carbon dioxide emissions (Godinhor et al. 2003; Pala et al. 2013).

Conclusions

In the present study a considerable variation in the growing stock, biomass and carbon storage with respect to forest types and trees species was obtained. Open pine forest showed high growing stock biomass and carbon because of diversity of tree species along with the maximum number of high girth and mature pine trees. However, carbon sequestration potential of dense pine forest is more due to higher proportion of low girth and young age trees thus would enhance the future carbon stock. In degraded pine forest and agriculture fields growing stock, biomass and carbon storage was very low due to various anthropogenic disturbances. Thus mixed type of species stands may be promoted in the lands, forest or community, as these stands tend to have higher carbon uptake potential and storage. It can also be concluded from the present study that Remote Sensing and GIS are the useful techniques to handle, update and retrieve large amount of forest related spatial information which includes tree density, forest type mapping, mapping of trees outside forests, etc. necessary for growing stock, biomass and carbon estimation.

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