*International Research Journal of Environment Sciences*_____ ISSN 2319–1414
Vol. **3(6),** 56-61, June **(2014)** *Int. Res. J. Environment Sci.*

Estimation of Biomass and Carbon Sequestration of Trees in Informally Protected Areas of Rajouri, J&K, India

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Available online at: www.isca.in, www.isca.me
Received 18th May 2014, revised 30th May 2014, accepted 20th June 2014

Abstract

Conservation of natural resources through traditional beliefs and practices is an ancient practice and forms an important link between biological diversity and cultural diversity. The study examines the role of informally protected areas in maintaining diversity and carbon sequestration of tree species in 40 different sites of Rajouri Tehsil. Firstly, an inventory of trees species was prepared in the study area through field survey. To assess carbon sequestration and total biomass in the tree species, the mean above and belowground organic carbon (tones/tree) and total organic carbon of each species were calculated. A total of 53 tree species comprising of 629 individuals have been recorded in the study area. Olea ferruginea species was dominant with 161 trees and sequestered 34.52 tons of carbon in its standing biomass, followed by Pinus roxburghii (20.7 tons). Zanthoxyllum armatum had the lowest carbon sequestration potential (0.1 tons).

Keywords: Biomass, carbon sequestration, diversity, conservation.

Introduction

Nature worship is an ancient Indian tradition and conservation of natural resources was considered necessary for survival and sustenance of mankind. The practice of dedicating forest patches to deities in sacred groves is an ancient custom and likewise trees are protected for their religious, traditional and economic uses in various informally protected areas such as temples, shrines, sacred groves, graveyards etc[1]. Trees are also known to be a major sink of CO_2 and cost-effective option for mitigation of global warming and climatic change, contributing to reduce atmospheric carbon which is accumulating in the atmosphere at an increasing rate. The tehsil Rajouri is one of the 8 tehsils in the district Rajouri of J&K state. Rajouri is known to be a land of ethnic diversity where people belonging to different communities and religions live together including a number of tribal communities such as *Gujjars, Bakerwals,* etc[2]. A huge number of sacred places are also found in Rajouri, in which forest patches, varying in sizes and also other planted tree species are protected on religious as well as traditional grounds. The objective of the study was to assess the diversity of trees species and to estimate the sequestrated carbon of different tree species in different sacred places in Rajouri, contributing in reducing CO2 concentration in the atmosphere.

Material and Methods

For the present study, a total of 40 sacred sites were studied located in different villages as well as wards of Rajouri tehsil. The details of these sites are given in table-1. Field studies in the different sites were conducted to prepare an inventory of tree species and the plant material were collected and identified by referring standard local flora. Most of the information was collected from the elderly people, village heads of the respective areas[3].

For the quantitative analysis of vegetation, random sampling method was used for sampling the above ground vegetation. For the collection of data plots of 10×10m size were laid randomly in the various sites taken under study. Plot method is one of the most commonly used sampling methods for all kind of vegetation sampling. Plot method is also among the methodologies approved by the Clean Development Mechanism for afforestation and reforestation projects under the Kyoto Protocol[4]. The number of quadrats laid in each site depended on the total area covered by that site, larger the area of the site; more is the number of quadrats laid in that site. From each plot data was collected for measuring following parameters:

Analysis of data for measuring carbon sequestration[5]: To assess carbon sequestration potential of the tree species in the study area, following parameters were measured:

Tree Height and Diameter at Breast Height (DBH): To estimate biomass of different trees, non-destructive method was used. The biomass of tree was estimated on the basis of DBH and tree height. DBH can be determined by measuring tree Girth at Breast Height (GBH), approximately 1.3 meter from the ground. The GBHs of trees were measured directly by measuring tape.

Above ground biomass (AGB) of trees: The above ground biomass of tree includes the whole shoot, branches, leaves, flowers, and fruits.

It is calculated using the following formula -

AGB kg = volume of tree (m3) x wood density Kg/m3, V = π r2H, V= volume of the cylindrical shaped tree in m3, r = radius of the tree in meter, H= Height of tree in meter. Radius of the tree is calculated from GBH of tree. The wood densities were obtained from the website - www.worldagroforestycentre.org/sea/products/AFDbases/WD/.

Table -1
List of Informally Protected sites selected for vegetative study in Rajouri

Name of Sacred Grove	Name of the Deity	Place	Area (ha)	Location	Community	No. of Tree species
Baba Keshav Nath Sacred Grove	Baba Keshav Nath	Talwal	0.01	Rural	Sasan	10
Baba Naar Singh Sacred Grove	Baba Naar Singh	Talwal	0.0075	Rural	Sasan	5
Baba Qutubdin Naughazia Ziarat	Baba Qutubdin Naughazia	Dhanidhar	0.4	Rural	All	14
Baba Sain Abdul Aziz Ziarat	Baba Sain Abdul Aziz	Nagrota	0.15	Rural	All	11
Banda Bahadur Gurudwara	Banda Bahadur	Thandikassi	0.0088	Rural	All	4
Boli Mata Temple	Boli Mata	Dhanidhar	0.02	Rural	All	16
Cave Shrine Sacred Grove	Lord Shiv, Lord Vishnu	Mankot	0.013	Rural	All	1
Chandershekhar Temple	Lord Shiv	Dhangri	0.015	Rural	All	10
Chugga Biradri Memorial	-	Talwal	0.0063	Rural	Chugga	4
Cremation Ground Rajouri	-	Rajouri City	0.011	Urban	All	3
Dargah Hazrat Sultan Shah	Baba Hazrat Sultan Shah	Dalogra	0.0075	Rural	All	3
Durga Temple, Dalogra	Goddess Durga	Dalogra	0.027	Rural	All	3
Durga Temple, Bathuni	Goddess Durga	Bathuni	0.017	Rural	All	9
Graveyard, Talwal	-	Talwal	0.1	Rural	All	14
Jama Masjid Dhangri	Peer Khiwe Shah	Dhangri	0.015	Rural	All	8
Jyoti Mata Temple	Jyoti Mata	Thandikassi	0.075	Rural	All	8
Kali Mata Temple	Kali Mata	Saralkote	0.02	Rural	All	11
Markazi Idgah, Bamakam Ziarat	Baba Bamakam	Dassal Gujran	0.04	Rural	All	1
Panjpeer Ziarat	Paanch Peer	Rajouri	0.011	Urban	All	7
Peer Baba Rajouri	-	Rajouri	0.0038	Urban	All	2
Peer Baba Thandikassi	-	Thandikassi	0.019	Rural	All	3
Peer Khiwe Shah Ziarat	Peer Khiwe Shah	Dhangri	0.12	Rural	All	10
Pracheen Radha Krishna Temple	Lord Krishna	Rajouri	0.022	Urban	All	9
Pracheen Shiv Temple	Lord Shiv	Rajouri city	0.019	Urban	All	12
Ram Temple, Dhangri	Lord Ram	Dhangri	0.05	Rural	All	10
Radha Krishna Temple	Lord Krishna	Thandikassi	0.0088	Rural	All	3
Sain Challa Sahib Ziarat	Sain Challa Sahib	Pullulian	0.3	Rural	All	12
Sain Gangi Sahib Ziarat	Sain Gangi Sahib	Fatehpur	0.12	Rural	All	14
Sakhi Sultan Ziarat	Sain Sakhi Sultan	Rajouri city	0.003	Urban	All	1
Santoshi Mata Temple	Goddess Durga	Palma	0.1	Rural	All	7
Sarv Dharm Sthal	All religions	Bathuni	0.002	Rural	All	4
Shiv Temple, Kheora	Lord Shiv	Kheora	0.0088	Rural	All	5
Shiv Temple, Muradpur	Lord Shiv	Muradpur	0.025	Rural	All	5
Shiv Temple, Talwal	Lord Shiv	Talwal	0.02	Rural	All	14
Shri 108 Brahmarishi Dudhadhari Barfani ji Maharaj Ashram	Lord Ram	Chachhera Wildlife Reserve	0.5	Urban	All	17
Sita Mata Temple	Sita Mata	Thandikassi	0.1	Rural	All	11
Surta Mata Mandir, Kallar	Surta Mata	Kallar	0.02	Rural	Rotra	3
Takkya Ziarat	Sain Sabat Shah	Badoon	0.02	Rural	All	7
Wali Rafiq Sahib Ziarat	Wali Rafiq Sahib	Chapprian	0.06	Rural	All	15
Ziarat Peer Makhan Shah Badshah	Peer Makhan Shah Badshah	Rajouri city	0.016	Urban	All	3

Below ground biomass (BGB) of trees: The belowground biomass (BGB) includes all biomass of live roots excluding fine roots having < 2 mm diameter. The belowground biomass has been calculated by multiplying the above ground biomass (AGB) by 0.26 factors as the root: shoot ratio.

Belowground biomass (BGB) kg/tree or ton/tree = aboveground biomass (AGB) kg/tree or ton/tree x 0.26

Qualitative Analysis: For the qualitative analysis of data, a survey based on questionnaire was also carried out to study the importance of these sites in phytodiversity conservation and to analyze their socio-economic importance.

Results and Discussion

The study was conducted in various sacred sites of Rajouri. The study was based on two types of analysis of the vegetation in the study area, the quantitative and qualitative.

Quantitative Analysis: Phyto diversity Measurement: The results of quantitative analysis of data revealed a total of 629 individuals of 53 species belonging to 30 families and 43 genera had been recorded in all the sites under study (table-2). Rosaceae family was the most dominant with 7 tree species followed by families Moraceae and Rutaceae, each with 6 tree species.Among genera, Genus *Ficus* had maximum contribution represented by 5 species, which were *Ficus benghalensis, F. carica, F. palmata, F. racemosa and F. religiosa.*

Carbon Sequestration Measurement: There are 53 species including 629 individuals have been recorded in sacred groves under study in Rajouri Tehsil of Rajouri district. Table-3 demonstrates total number of trees of each species present in the sacred groves. It also indicates the average GBH in cm and average tree height in meters. The mean above ground organic carbon (AGC) per tree (t/ tree); mean of below ground organic carbon (BGC) per tree (t/ tree); the total organic carbon of each species in tones and the total organic carbon sequestrated in 629 trees have been summarized. The organic carbon sequestrated in per species is shown for comparison purpose. *Olea ferruginea* species are dominant in sacred groves having 161 trees and sequestrated 34.52 tons of carbon in its standing biomass, followed by *Pinus roxburghii* (20.7 tons). *Zanthoxyllum armatum* has the lowest carbon sequestration potential (0.1 tons).

Qualitative Analysis: For the qualitative analysis of data, a detailed questionnaire was prepared to know the role of these sacred places in the lives of local people. It was found that most of the trees growing in these groves were used by the people for different purposes like fuel, fodder, medicinal and as edibles[6]. Although most of the trees were growing wild, but people had also planted a number of trees particularly religious, ornamental and fruit trees. Most of the people were of the view that sacred places were used by them mainly for religious purposes, which is the main reason for protection of trees growing here because of various taboos associated with the religious activities[7]. Apart from religious use, sacred groves were also used for firewood collection, grazing of animals and for recreational purposes by some people. Most of the respondents believed that sacred sites were an important storehouse of local flora in the region because of the various restrictions on the use of these trees growing in these groves[8]. But they also believe that these sacred groves are gradually shrinking in size and number due to habitation in remote areas, land requirements, improper agricultural practices, irregular rainfall and literacy brought to the tribal people which caused loss of tribal ethos.

Conclusion

These informally protected areas possess a great heritage of diverse gene pool of many forest species having socio-religious attachment and possessing various important use values for the local people. A scared grove having thick vegetation possesses high carbon sequestration potential, contributing in reducing concentration of CO_2 in the atmosphere. As they are gradually shrinking due to human activities to fulfill various human needs, the legal status and management of sacred groves in the country need to be examined. There is an urgent need to preserve and acknowledge the efforts of the people of this area in preserving the other small sacred patches of forests as local biodiversity.

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Table-2
List of tree Species recorded in the study area

S.No.	Name of the Species	Common Name	Family
1	*Acacia catechu* (L.f) Willd.	Khair	Mimosaceae
2	*Acacia nilotica* Linn.	Kikkar	Mimosaceae
3	*Aegle marmelos* L.	Bel Patra	Rutaceae
4	*Ailanthus excelsa* Roxb.	Arru	Simaroubaceae
5	*Bauhinia variegata* Linn.	Kalyadi	Caesalpiniaceae
6	*Bombax cieba* Linn.	Simbal	Bombaceae
7	*Callistemon lanceolatus* (Sm.) Sweet	Bottle brush	Myrtaceae
8	*Carica papaya* L.	Papita	Caricaceae
9	*Celtis australis* L.	khirk	Ulmaceae
10	*Cestrum nocturnum* L.	Raat ki Rani	Solanaceae
11	*Citrus aurantium* L.	Girgle	Rutaceae
12	*Citrus limon* L.	Nimbu	Rutaceae
13	*Citrus sinensis* L.	Santara	Rutaceae
14	*Cordia dichotoma* G.Forst.	Lasuda	Boraginaceae
15	*Cupressus sempervirens* L.	Saroo	Cupressaceae
16	*Dalbergia sissoo* Roxb	Taali	Paplionaceae
17	*Diospyros Montana* Roxb.	Timru	Ebenaceae
18	*Eriobotrya japonica* (Thunb.) Lindl	Lokat	Rosaceae
19	*Eucalyptus citridora* Linn.	Safeda	Myrtaceae
20	*Ficus benghalensis* L.	Bori/Bad	Moraceae
21	*Ficus carica* L.	Anjeer	Moraceae
22	*Ficus palmata* Forssk.	Fig	Moraceae
23	*Ficus racemosa* L.	Tussa	Moraceae
24	*Ficus religiosa* Linn.	Peepal	Moraceae
25	*Flacourtia indica* (Burm, f.) Merr.	-	Salicaceae
26	*Grevillea robusta* A. Cunn. Ex R. Br.	Silver oak	Proteaceae
27	*Grewia optiva* Drumm. exBurret.	Taman	Tiliaceae
28	*Juglans regia* Linn.	Akhrot	Juglandaceae
29	*Leucaena leucocephala* (Lam.) de Wit	Sreen	Mimosaceae
30	*Mallotus philippensis* (Lam.) Mull. Arg	Kameela	Euphorbiaceae
31	*Malus domestica* Borkh	Seb	Rosaceae
32	*Mangifera indica* L.	Aam	Anacardiaceae
33	*Melia azaderach* L.	Darenk	Meliaceae
34	*Morus alba* Linn.	Toot	Moraceae
35	*Murraya Koenigii* Spring	Karri patta	Rutaceae
36	*Olea ferruginea* Royle	Kau	Oleaceae
37	*Phyllanthus emblica* L.	Amla	Euphorbiaceae
38	*Pinus roxburghii* Sarg.	Chir	Pinaceae
39	*Platanus orientalis* L.	Chinar	Platanaceae
40	*Populus ciliata* Wall. Ex Royle	Safeda	Salicaceae
41	*Prunus armeniaca* L.	Charota	Rosaceae
42	*Prunus domestica* L.	Plump	Rosaceae
43	*Prunus persica* Linn.	Aru	Rosaceae

44	*Psidium guajava* L.	Amrud	Myrtaceae
45	*Punicum granatum* L.	Anardana	Lythraceae
46	*Pyrus communis* Linn.	Nashpati	Rosaceae
47	*Pyrus pashia* Buch.Ham.ex.D.Don	Botungi/ kathari	Rosaceae
48	*Quercus leucotrichophora* L.	Banj oak	Fagaceae
49	*Salix alba* L.	Binsa	Salicaceae
50	*Toona ciliata* M Roemer.	Toon	Meliaceae
51	*Ulmus wallichiana* Planch	Manu	Ulmaceae
52	*Zanthoxyllum armatum* L.	Timber	Rutaceae
53	*Ziziphus mauritiana* Lam.	Ber	Rhamnacea

Table-3
Carbon sequestration potential of trees species in the study area

S. No.	Scientific Names	Number of individuals	Average GBH (cm)	Average Height (meter)	Average organic carbon (t/individual)			Organic carbon (t/species)
					Above ground	Below ground	Total	
1	*Acacia catechu* (L.f) Willd.	4	45	7	0.09	0.02	0.11	0.44
2	*Acacia nilotica* Linn.	2	78	10	0.4	0.1	0.5	1
3	*Aegle marmelos* L.	5	31	5.5	0.03	0.007	0.03	0.19
4	*Ailanthus excelsa* Roxb.	4	68	12	0.24	0.06	0.3	1.2
5	*Bauhinia variegate* Linn.	3	54	3.3	0.046	0.01	0.05	0.17
6	*Bombax cieba* Linn.	6	157.6	12.26	0.79	0.2	0.99	5.9
7	*Callistemon lanceolatus* (Sm.) Sweet	7	62	8	0.17	0.04	0.21	1.5
8	*Carica papaya* L.	3	53	6.5	0.03	0.008	0.038	0.11
9	*Celtis australis* L.	37	76.38	7.6	0.27	0.071	0.34	12.5
10	*Cestrum nocturnum* L.	1	38	4	0.027	0.007	0.034	0.034
11	*Citrus aurantium* L.	2	27	3.6	0.011	0.003	0.014	0.028
12	*Citrus limon* L.	5	35	2.25	0.013	0.0034	0.0164	0.08
13	*Citrus sinensis* L.	3	47	3	0.031	0.008	0.039	0.117
14	*Cordia dichotoma* G.Forst.	2	183.5	17	2.412	0.627	3.039	6.0
15	*Cupressus sempervirens* L.	7	38	2.6	0.013	0.003	0.016	0.112
16	*Dalbergia sissoo* Roxb	13	53	7.2	0.119	0.031	0.15	1.95
17	*Diospyros Montana* Roxb.	9	76	12	0.38	0.1	0.48	4.32
18	*Eriobotrya japonica* (Thunb.) Lindl	6	43	5.5	0.08	0.02	0.1	0.6
19	*Eucalyptus citridora* Linn.	8	47	11	0.12	0.03	0.15	1.2
20	*Ficus benghalensis* L.	2	28	4	0.01	0.0026	0.0126	0.02
21	*Ficus carica* L.	3	80.5	8.8	0.176	0.045	0.22	0.66
22	*Ficus palmata* Forssk.	25	38.87	5.5	0.026	0.0067	0.033	0.82
23	*Ficus racemosa* L.	3	26	3.2	0.0067	0.0017	0.008	0.024
24	*Ficus religiosa* Linn.	17	223	10.7	0.165	0.043	0.219	3.7
25	*Flacourtia indica* (Burm, f.) Merr.	5	52.37	6.4	0.072	0.018	0.091	0.455
26	*Grevillea robusta* A. Cunn. Ex R. Br.	2	87	16.5	0.643	0.167	0.81	1.62
27	*Grewia optiva* Drumm.	29	56	4.56	0.077	0.02	0.097	2.8

	exBurret.							
28	*Juglans regia* Linn.	2	80	7.4	0.26	0.067	0.327	0.65
29	*Leucaena leucocephala* (Lam.) de Wit	9	53	8	0.113	0.029	0.142	1.27
30	*Mallotus philippensis* (Lam.) Mull. Arg	13	50	6	0.077	0.02	0.097	1.26
31	*Malus domestica* Borkh	7	52	3.78	0.06	0.015	0.075	0.525
32	*Melia azaderach* L.	24	69.5	7.15	0.11	0.02	0.13	3.12
33	*Morus alba* Linn.	19	63	7.5	0.2	0.052	0.252	4.78
34	*Murraya Koenigii* Spring	4	40	6	0.052	0.013	0.065	0.26
35	*Olea ferruginea* Royle	161	67.6	5.46	0.176	0.045	0.22	35.42
36	*Phyllanthus emblica* L.	10	36.5	4.6	0.038	0.01	0.048	0.48
37	*Pinus roxburghii* Sarg.	46	79.5	16	0.36	0.09	0.45	20.7
38	*Platanus orientalis* L.	4	42.5	5.5	0.05	0.013	0.063	0.25
39	*Populus ciliata* Wall. Ex Royle	3	64	17	0.27	0.07	0.34	1.02
40	*Prunus armeniaca* L.	7	83	4.25	0.186	0.05	0.234	1.638
41	*Prunus domestica* L.	4	38.33	5.2	0.06	0.015	0.07	0.28
42	*Prunus persica* Linn.	3	37.6	2	0.016	0.004	0.02	0.06
43	*Psidium guajava* L.	11	57	4.3	0.073	0.018	0.092	1
44	*Punicum granatum* L.	5	67.5	3.4	0.078	0.02	0.098	0.5
45	*Pyrus communis Linn.*	1	30	3.3	0.018	0.0046	0.023	0.023
46	*Pyrus pashia Buch.Ham.ex.D.Don*	17	59	6.4	0.133	0.034	0.167	2.84
47	*Quercus leucotrichophora L.*	1	120	16	1.28	0.33	1.61	1.61
48	*Salix alba L.*	1	82	14	0.374	0.097	0.47	0.47
49	*Tamarindus indica L.*	5	47	12	0.156	0.04	0.196	0.98
50	*Toona ciliata M Roemer.*	31	68	6.5	0.071	0.018	0.089	2.76
51	*Ulmus wallichiana* Planch	1	122	18	1.19	0.31	1.5	1.5
52	*Zanthoxyllum armatum L.*	4	43	4.1	0.02	0.0052	0.025	0.1
53	*Ziziphus mauritiana Lam.*	23	43	4.16	0.048	0.012	0.06	1.38
	Total							138.426 (t)