A NEXUS BETWEEN FOREST RESTORATION PROGRAMME AND CLIMATE CHANGE

RASHID MEHMOOD[1], ZAWAR HAIDER[2], IHSAN NADIR[3], IFTIKHAR AHMED[3], HAFEEZ NASIR[3]

[1]Department of Botany, MAO College Lahore, Punjab Higher Education Department Lahore, Pakistan.

[2]Government High School No.2 Pasrur (Sialkot), Punjab School Education Department Lahore, Pakistan.

[3]Pak Green Enviro Engineering (Pvt.) Ltd. Lahore, Pakistan.

**Corresponding author's Email: rashidmehmood1510@gmail.com*

Abstract

Reforestation programs have potential to mitigate the climate change caused by global carbon emissions. Restoration of historical, bella and protected site forests were programmed and executed by the government of Punjab, Pakistan. These forest areas at different locations (Changa manga, Daphar, Chichawatni, Lal Suhanra National Park, Ladam Sir-II, Abbasia plantations, Machu and Inayat) in Punjab were monitored and the growth of the plantations of these forest areas was assessed. It was monitored that 90% of the target plantations were there with a standard of 726 plants per acre. Among different plant species (*Eucalyptus camaldulensis, Acacia nilotica, Moris alba, Abizzia labbek, Ehretia laevis, Tamarix aphylla, Bombax ceiba, Ficus religiosa, Gmelina arborea, Cordia myxa, Azadirachta indica, Populus deltoides, Cedrela toona, Syzygium cumini* and *Dilbergia cisso*) at these forest sites *Eucalyptus camaldulensis* showed fast growth and adaptive ability at different sites. Mono-culture of eucalyptus also showed better growth as compared to mixed cultures. Plant biomass carbon per acre which was calculated by dry weight method indicated more values in mono-cultures (132.3 lb./acre at Inayat site) as compared to mixed cultures (39.83 lb./acre at Chichawatni site). Average plant biomass carbon per acre was 54.5 lb with total 61080.4 lb. of 1120 acres. Restoration forests will reduce atmospheric CO_2 levels and help to mitigate climate change.

Keywords: Climate Change, Eucalyptus, Mono-culture, Plant biomass carbon, Restoration.

Introduction

Forests are massive sinks of carbon, which mitigates atmospheric CO_2 concentrations (Rajeev and Hukum, 2020). Global forests have the capacity to store $2.4\pm0.4\ 10^9$ Mg of CO_2 emissions per year (Pan *et al*., 2011). Climate change mitigation has been carried out by forest and land management practices. Forest conservation to get carbon credits are already being used by many countries (Akita and Ohe, 2021). Restoring forests sequester carbon and reduces atmospheric carbon dioxide. Photosynthetic carbon sequestration by trees is more efficient to counter the rise of CO_2 concentrations across the globe as compared to the artificial CO_2 capturing systems (Lewis *et al*.,

2019; IPCC, 2018; Griscom *et al*., 2017). In response, a number of international programs, such as, New York Declaration on Forests (Summit, 2014) and Bonn Challenge (Challenge, 2011) have devised ambitious challenges for forest restoration, rehabilitation and conservation at global scale (Bastin *et al*., 2019). The special report of the IPCC suggested an increase in 1-billion-hectare forest area would be imperative to halt rising temperature to 1.5 ˚C by 2050 (IPCC, 2018).

Natural solutions of carbon dioxide reductions have more advantages than direct air capturing; engineering approaches requires resources, like, energy, water, land, limiting scale and location of their application. These activities will also generate competition between them and other production activities (Seddon *et al*., 2020) and all engineering approaches do not provide any other benefit to ecosystem as compared to sustainable natural programs (Smith *et al*., 2019). Climate Change and Land Report of IPCC stresses the mitigation potential of terrestrial ecosystems by restoration of forests and halting deforestation especially in tropical and sub-tropical areas, where forests develop fast without any adverse effects from reduced albedo (IPCC, 2019, Griscom *et al*., 2017; Houghton *et al*., 2015). The Special Report of IPCC (IPCC, 2019) also highlighted the mitigation potential range of 0.4–5.8 Gt CO_2 yr^{-1} from avoided deforestation and land degradation, as well as a carbon sequestration potential of 0.5–10.1 Gt CO2 yr^{-1} in vegetation and soils from afforestation/reforestation.

Punjab is the largest province of Pakistan. It has experienced population growth and urban development over the past many years. Its population density increased from 100 persons/km^2 in 1951 to 492 persons/km^2 in 2010 (CDPR, 2011). Massive population and urban strength affected the land use and forest cover severely in Punjab. Government of Pakistan decided to restock and rehabilitate the existing forest areas in Punjab under the title of "Green Pakistan Programme Reclamation and Development of Forest Areas in Punjab (Phase-I)". Under Green Pakistan program, Changa manga, Daphar, Chichawatni, Lal Suhanra National Park, Ladam Sir-II, Abbasia plantations, Machu and Inayat forest sites were included to work on.

In order to nexus forest rehabilitation program with the climate mitigation, present study aimed to monitor and assess the tree species of historical plantations in Punjab, Pakistan. These plantations were part of the Green Pakistan Program and had age of 2 years. Current study attempted to assess plant biomass carbon of different tree species in different forest areas. Objective of the study was fulfilled by measuring height and diameter of tree species in different forest areas, calculating fresh and dry biomass, and sequestered carbon by plant body. Current results will be helpful in climate change

mitigation programs by forest restoration and rehabilitation.

Methodology

Study area

Punjab, the biggest province of Pakistan has meager forest cover. Green Pakistan program was started by GOP in 2015-16. Under this program different forests were aimed to rehabilitate and restock; present study analyzed the historical plantations of Punjab from the Green Pakistan Program. Historical plantations include Changa manga, Daphar, Chichawatni, Lal Suhanra National Park, Ladam Sir-II, Abbasia plantations, Machu and Inayat.

Changa manga

The Changa Manga lies in Latitude of 31.0833° North and longitude of 73.9667° East ranging to 50 km² (12,510 acres) area. It is recognized as national park and the biggest man-made forest in the country (Changa Manga Railway Forest, 2007). It is situated near Chunian which is about 70 km south of Lahore. It was planted primarily for fuelwood in 1864 to run steam engine at the time of British in Sub-continent (Khan, 1962). Presently *Dibergia sisso,* and *Eucalyptus globulus* are the main species growing over a major portion of the plantation area. Other species growing are *Moris alba*, hybrid-poplar, *Bombax ceiba*, *Melia azedarach* and *Acacia nilotica* (GOP, Forest Department).

Daphar

It is one of the important plantations in the Punjab, covering 7135 acres of land, situated between 32-26 north to 73-11 east. Daphar Irrigated plantation is in Tehsil Malakwal of District Mandi Bahauddin about 9.6 km from south of Pakhowal Railway Station. Daphar was originally dry tropical forest known as "Rakh" before it was cleared from 1882 to 1901. The original vegetation comprised primarily *Acacia leucophloea*, *Capparis decidua*, *Ehretia laevis*, *Lycium europaeum*, *Prosopis cineraria*, *Salvadora oleoides*, *Tamarix aphylla*, *Tecoma undulate*, *Zizyphus mauritiana* and *Zizyphus nummularia*. Height of trees ranged from 15 to 30 feet. Presently, trees of *Acacia nilotica* and *Dibergia sisso,* and *Eucalyptus globulus* have also grown (GOP, Forest Department).

Chichawatni

Chichawatni Plantation is one of the major plantations in the Punjab. The total area of the plantation is 11531.70 Acres. The soil is fertile and canal water supply is available from LBDC, which runs along northern boundary of plantation. Although major part of the plantation contains good crop due to mesquite infestation and drying of *Dibergia sisso* crop due to Shisham Die Back. Part of the area of plantation (298 Acres) which was invaded by mesquite was included in the said scheme for rehabilitation/reclamation.

L**al Suhanra National Park**

Laal Suhanra National Park is located in the southeastern Punjab of Pakistan with altitudes ranging from 125 to 140 meters. The flora of Park consists of 212 species belonging to 162 genera and 50 families. The Dicots having 41 families, 118 genera and 158 species, were the most diverse and dominating group of plants in this area followed by Monocots with 5 families, 40 genera and 50 species, Pteridophytes with 3 families, 3 genera and 3 species and Bryophytes represented by monotypic species.

Abbasia

Abbasia Plantation is an estate in Punjab and has an elevation of 98 meters. Abbasia Plantation is situated southeast of Chak Number Seven.

Ladam Sir-II

Ladam Sir-II forest division is located near Bahawalpur.

Machu and Inayat

The objective behind creating Layyah Forest Division was to stabilize sand dunes and retrieve vast tract of land by growing Forest plantations spread over whole the tract. The gross area of Layyah Forest Division is 34701.51 with net as 17954.47 acres. The remaining area either consists of un-commanded and dunes or without vegetation. The Forests are not fully stocked with trees. The plantations are either dry or poorly managed due to less supply of irrigation water coupled with continuous scarcity of funds needed for their rehabilitation. Adequate quantity of water was provided through Inayat, Machu and Rajan Shah Canals from which these plantations were raised. The quantity of canal water available for the Forests reduced gradually and consequently, the Forests suffered adversely. The main source of canal water supply is from Thal Canal System. Water shortage is the main problem of Plantation.

Monitoring and assessment of forest cover

Table: 1 Plant species that were under government program to improve their status were:

Common name	**Scientific name**	**Common name**	**Scientific name**
Sufaida	*Eucalyptus camaldulensis*	Kiker	*Acacia nilotica*
Toot	*Moris alba*	Siris	*Abizzia labbek*
Ethretia	*Ehretia laevis*	Farash	*Tamarix aphylla*
Shisham	*Dibergia sisso*	Peepal	*Ficus religiosa*
Malaina	*Gmelina arboreav*	Lasoora	*Cordia myxa*
Neem	*Azadirachta indica*	Poplar	*Populus deltoids*
Tun	*Cedrela toona*	Jaman	*Syzygium cumini*

Plant species that were targeted by the program are given in the **table 1**. Existing plant species, their number, height and diameter were measured by field analysis.

Sample Size Determination for Plantation covers

Unit of Analysis was "number of planted species per Acre". To evaluate the number of planted species per acre measuring tape method was used and the data of the sample area was extrapolated. For this purpose, planted species were counted in a circle of 37.2 feet radius. It was 1/10 of the acre[2].

Sample size = 4,347.46158 ft^2

Radius = r = 37.2 ft.

Pie = π = 22/7 = 3.14

Area = A = πr^2

A = 22/7 x 37.22 ≈ 4,347.46158 ft^2

01 Acre = 43,474.6158 Square Feet (ft^2)

No. of Planted species per Acre = No. of planted species counted per sample size x 10

Height and Diameter of the Planted species

To evaluate Height (H) of the planted species, it was directly measured in meters (m) using meter rod. Diameter of the stem measured in centimeter (cm) using digital vernier caliper. Measurement of height and diameter were carried out to calculate growth of the planted species.

Tree Biomass and Carbon content

W = Above-ground weight of the tree in pounds

D = Diameter of the trunk in inches

H = Height of the tree in feet

For trees with D < 11:

$$W = 0.25D^2H$$

For trees with D >= 11:

$$W = 0.15D^2H$$

The root system weighs about 20% as much as the above-ground weight of the tree. Therefore, to determine the total green weight of the tree, multiply the above-ground weight of the tree by 120% (Clark *et al*., 1986).

Determine the dry weight of the tree

The average tree is 72.5% dry matter and 27.5% moisture. Therefore, to determine the dry weight of the tree, multiply the weight of the tree by 72.5%. The average carbon content is generally 50% of the tree's total dry weight as by IPCC (Watson *et al*., 2000).

Results

Monitoring of actual number of plants in different forest areas

More than 90% of the target number of planted tree species was observed in all forest areas (**table 2**). Target plants were grown on 10×6 spacing per acre and their number was 726. All of the forest areas were found to be planted more than 90% against target; however, there were more than 100% actual planted species against target, such as in Changa Manga (112.95), Daphar (101.93%) and Chichawatni (112.53%).

Table 2: Total number of actual and targeted plants per acre along with percentage cover

Forest Name	Actual No. of Plants/Acre	*Target No. of Plants/Acre	Actual %age	Target Area (Acres)	Actual No. of Plants (Forest)	Target No. of Plants
Changa Maanga	820	726	112.95%	224	183,680	162,624
Daphar	740	726	101.93%	140	103,600	101,640
Chichawatni	817	726	112.53%	298	243,466	216,348
Pirowal	680	726	93.66%	101	68,680	73, 326
Laal Suhanra	690	726	95.04%	77	53,130	55,902
Ladam Sir-ll	665	726	91.60%	105	69,825	76,230
Abbasia Plantation	710	726	97.80%	50	35,500	36,300
Machu	685	726	94.35%	69	47,265	50,094
Inayat	670	726	92.29%	56	37,520	40,656

*Target number of plants per acre was planned with 10 × 6 spacing.

Measurement of height and diameter of tree species

Height (m) and diameter (cm) of different plant species in different forest areas showed variations among each other as shown in **table 3**. Eucalyptus height and diameter is higher than other plant species in most of the forest areas. Eucalyptus height and diameter ranges between 2.67 (m) and 1.67 (cm) to 5.43 (m) to 3.52 (cm) with minimum values in Pirowal and highest in Changa Manga, respectively. *Acacia nilotica* height and diameter ranged between 3.62 m and 1.48 cm to 1.65 m and 1.48, respectively. *Moris alba* was present on in two areas (Changa Manga and Chichawatni) and grown with almost same heights and diameters. *Abizzia labbek* height and diameter was highest in Machu (4.03 m and 4.53 cm) and lowest in Chichawatni (1.91 m and 0.90 cm). Some species were only present in Chichawatni, such as, *Bombax ceiba, Ficus religiosa, Gmelina arborea, Cordia myxa, Azadirachta indica. Populus deltoids, Cedrela toona* were only found in Changa Manga Forest. *Tamarix aphylla* were present in Chichawatni, Lal Suhanra Park and Machu with different heights in meter (2.14, 1.72 and 2.56) and diameters in centimeter (1.48, 1.32 and 2.31).

Plant species count in different forest areas

Plant species count was highest in Changa Manga (820) and lowest in Laddam Sir-II (665). Major species grown was Eucalyptus as compared to other species in different forest areas (**table 4**). Only eucalyptus was observed in in Daphar, Laddam Sir-II and Abbasia and only *Acacia n*ilotica was in Abbasia. Diversity of species were observed in Chichawatni (11 sp.), Changa Manga (7 sp.), Pirowal (5 sp.) and Machu (4 sp.).

Table 3: Average Height (m) and Diameter (cm) of different plant species in different forests

Specie	Changa Mana		Daphar		Chichawatni		Pirowal		Lal Suhanra		Ladam Sir-II		Abbasia		Machu		Inayat	
	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D	H	D
Eucalyptus camaldulensis	5.43±0.57	3.52±1.40	4.63±0.67	3.38±0.53	5.21±1.26	4.12±1.63	2.67±0.25	1.67±0.29	5.08±0.47	3.40±0.85	2.69±0.55	2.50±0.78	-		3.65±0.62	3.40±0.52	3.70±0.70	3.42±0.56
Acacia nilotica	-		-		3.62±0.20	1.48±0.84	2.18±0.48	2.50±0.51	-		-		2.59±0.46	1.93±0.28	1.65±0.11	2.73±0.32	-	
Moris alba	2.17±0.39	2.27±0.30	-		2.76±0.58	2.31±0.80	-		-		-		-		-		-	
Abizzia labbek	-		-		1.91±0.49	0.90±0.32	3.41±0.41	3.25±0.34	-		-		-		4.03±0.7	3.53±0.5	-	
Ehretia laevis	3.48±0.5	3.06±0.48	-		2.75±0.41	2.27±0.21	-		-		-		-		-		-	
Tamarix aphylla	-		-		2.14±0.01	1.48±0.009	-		1.72±0.04	1.32±0.02	-		-		2.56±0.10	2.31±0.50	-	
Bombax ceiba	-		-		2.55±0.77	2.40±1.22	-		-		-		-		-		-	
Ficus religiosa	--		-		2.45±0.01	2.57±0.01	-		--		-		--		-		-	
Gmelina arborea	-		-		3.67±0.65	3.69±1.79	-		-		-		-		-		-	
Cordia myxa	-		-		3.97±0.02	2.94±0.01	-		-		-		-		-		-	
Azadirachta indica	-		-		2.90±1.08	2.80±0.41	-		-		-		-		-		-	
Populus deltoides	1.79±0.26	2.09±0.25	-		-		-		-		-		-		-		-	
Cedrela toona	1.07±0.22	2.07±0.23	-		-		-		-		-		-		-		-	
Syzygium cumini	1.45±0.33	2.45±0.23	-		-		1.56±0.21	2.34±0.22			-				-		-	
Dilbergia cisso	1.65±0.33	2.01±0.25					2.53±0.51	2.09±0.29										

Table 4: Number and percentages of different plant species in different forest areas

Changa Manga	**%**	**Count**	**Chichawatni**	**%**	**Count**	**Pirowal**	**%**	**Count**
E. camaldulensis	51	417	*E. camaldulensis*	56	461	*E. camaldulensis*	34	230
M. alba	07	57	*A. nilotica*	03	28	*A. nilotica*	15	105
E. laevis	20	163	*M. alba*	08	68	*A. labbek*	16	110
P. deltoides	06	49	*A. labbek*	05	44	*S. cumini*	17	115
C. toona	03	29	*E. laevis*	07	61	*D. cisso*	18	120
S. cumini	07	58	*T. aphylla*	05	27			
D. cisso	06	47	*B. ceiba*	02	14			
			F. religiosa	04	34			
	100	820	*G. arborea*	04	34		100	680
Daphar	**%**	**Count**	*C. myxa*	03	22	**Inayat**	**%**	**Count**
E. camaldulensis	100	740	*A. indica*	03	24	*E. camaldulensis*	100	670
Laddam Sir II	**%**	**Count**		100	817	**Abbasia**	**%**	**Count**
E. camaldulensis	100	665				*A. nilotica*	100	710
Lal Suhanra	**%**	**Count**				**Machu**	**%**	**Count**
	91	630				*E. camaldulensis*	07	50
E. camaldulensis	07	60				*A. nilotica*	19	130
T. aphylla						*A. labbek*	43	290
	100	690				*T. aphylla*	31	215
							100	685

Plant biomass carbon (lb.) by different tree species

Plant biomass carbon was stored more in eucalyptus in most forest areas owing to its highest height and diameter values. Eucalyptus has stored up to 22.44 lb. carbon in Chichawatni; however, it stored only 1.91 lb. in Pirowal forest area. Other species stored very low carbon as compared to eucalyptus except *Abizzia labbek* (12.69 lb.) in Machu as shown in **table 5**.

Table 5: Carbon content (lb.) per plant species and total plants in different forest areas

Changa Manga	**C/Plant***	**C/Total Plants****	**Chichawatni**	**C/Plant***	**C/Total Plants****	**Pirowal**	**C/Plant***	**C/Total Plants***
E. camaldulensis	17.34	7230.78	*E. camaldulensis*	22.44	10344.84	*E. camaldulensis*	1.91	
M. alba	2.82	160.74	*A. nilotica*	2.0	56	*A. nilotica*	4.44	1439.8
E. laevis	8.22	1339.86	*M. alba*	3.75	255	*A. labbek*	9.17	361.2
P. deltoides	1.97	96.53	*A. labbek*	0.38	16.72	*S. cumini*	2.17	1008.7
C. toona	1.51	43.79	*E. laevis*	3.57	217.77	*D. cisso*	1.69	249.55
S. cumini	2.19	127.02	*T. aphylla*	1.18	31.86			334.8
D. cisso	1.69	79.43	*B. ceiba*	3.70	51.8			
		Total=9078.15	*F. religiosa*	4.02	136.68			Total=3394.05
Daphar			*G. arborea*	12.66	430.44	**Inayat**		
E. camaldulensis	13.43	9938.2	*C. myxa*	8.61	189.42	*E. camaldulensis*	11.06	7410.2
Laddam Sir II			*A. indica*	5.76	138.24	**Abbasia**		
E. camaldulensis	4.24	2819.6			Total=11868.77	*A. nilotica*	2.45	1739.5
Lal Suhanra						**Machu**		
E. camaldulensis	14.97	9431.1				*E. camaldulensis*	10.78	539
T. aphylla	0.76	45.6				*A. nilotica*	3.10	403
						A. labbek	12.69	3680.1
						T. aphylla	3.41	733.15
		Total=9476.7						Total=5355.25

*carbon (lb.) of plant biomass sequestered by single plant
**carbon (lb.) total count (Carbon of single species multiplied with total count of the that species).

Plant biomass carbon (lb.) per acre

Overall assessment of plant biomass carbon in different forest areas showed the highest values in Chichawatni (11868.77 lb.) in 298-acre area, while, lowest values in Abbasia plantations (1739.5 lb.) in 50-acre area. Per acre tree biomass carbon was highest in Inayat (132.33 lb.) and lowest in Laddam Sir-II (26.85 lb.).

Table 6: Plant Biomass Carbon (lb.) per acre in different forest areas

Forest Name	Area (Acres)	Plant Biomass Carbon (lb.)	Plant Biomass Carbon (lb.)/ Acre
Changa Manga	224	9078.15	40.53
Daphar	140	9938.2	70.99
Chichawatni	298	11868.77	39.83
Pirowal	101	3394.05	33.60
Laal Suhanra	77	9476.7	123.07
Ladam Sir-ll	105	2819.6	26.85
Abbasia Plantation	50	1739.5	34.79
Machu	69	5355.25	77.61
Inayat	56	7410.2	132.33
	Total = 1120	Total = 61080.42	Average = 54.54

Discussion

It is proven now that forests play a vital role in carbon locking in an ecosystem by safe and affordable way (Griscom, 2016). Before industrialization, global warming was halted by forests and woodlands of the world by absorbing one quarter of atmospheric CO_2 (IPCC, 2018). As in our study, Green Pakistan Program was aimed to restore forests in different areas of Punjab in its first phase, thereby reducing carbon dioxide in Pakistan. After 2 years of assessment, forested area of 1120 acre sequestered 61080.42 lb carbon with 54.54 lb /acre average value (**table 6**). According to IPCC Climate Change and Land Use report during 2007 to 2016, 23% of total net anthropogenic emissions were from agriculture, forestry and other land use activities. Of this, net emissions of 5.2±2.6 Gt of CO_2 Yr^{-1} were mostly were because of deforestation, partly offset by afforestation/reforestation emissions and removals by other land use activities (IPCC, 2019). Reforestation is a potential strategy for conserving the soils on degraded land by reducing soil erosion, and can increase soil organic matter, serve as a carbon sink, and improve the landscape by providing habitat for wildlife (Cao *et al*., 2007).

Although forest cover is increased by afforestation but ecological restoration goals are achieved if selected tree species are suitable for local environment. For rapid restoration of degraded environment these tree species should

be able to tolerate the poor soils and to quickly establish a high wood volume and canopy cover (Cao *et al*., 2011). Under the "Green Pakistan Programme Reclamation and Development of Forest Areas in Punjab (Phase-I)" afforestation has been widely implemented. Fast growing tree and shrub species were mostly planted for forest restoration; mostly *Eucalyptus camaldulensis* was planted (**table 3**) taking it as a fast-growing plant. Eucalypts are recognized as the some of the fastest growing trees. *E. camaldulensis* has been proven most adaptable in all agro-ecological zones and is the most common species planted in Pakistan. It can withstand in irregular rain falls, high temperatures, low relative humidity and saline-sodic soils (Ahmad, 1996). Pakistan Forestry Institute clarified the uncertainties about eucalyptus plantation in Pakistan in a seminar. It has been highlighted in aforementioned seminar that water consumption by eucalyptus had been wrongly depicted for years; however, its consumption was less than shisham (*Dilbergia sissoo*) as well which is native. The main purpose to grow this plant is to meet the demand for fuel-wood, timber, lumber and biomass. It is a tall, evergreen, requires little care after plantation (Dhakku, 2019).

Mixed cultures were planted in Changa Manga (7 species), Chichawatni (11 spcies), Pirowal (5 speices), Machu (4 species) and Lal Suhanra (2 species) and monocultures were in Daphar, Inayat, Laddam Sir II. Monoculture was preferred over mixed one owing to the get faster growth with less competition. Kanowski and Catterall, 2010 found that dense trees with large diameters had more wood density and stored carbon. However, monoculture are profitable options for foresters; henceforth, 45% of restoration plans around the world are based on monoculture (Lewis *et al*., 2019). Monoculture of eucalyptus were present on most of the sites because of the growth potential of eucalyptus on marginal lands; rapid growth of it on proper land with short maturation time as compared to other plant species. Lewis *et al*. 2019 pointed out an approach using by nations that marginal agricultural lands were to be converted into valuable lands by using plantations eucalyptus for paper and *Hevea braziliensis* for rubber.

Chichawatni, Changa Manga and Daphar were larger areas compared to other ones (Table 2). Henceforth, the target number of plants were more in these areas. Mismatch in actual and target number of plant species indicated the negligence of gardeners. This carelessness also affected the growth of plant species. Variation in growth of different species (Table 3) in different areas was mainly due to differences in climatic, edaphic and topographic variables in these forest sites. As the tree species and their age were same, then there were soil and climatic factors which influenced the growth factors and secondly human interference was responsible for that. Estrada-Villegas *et al*. (2020) explained that up to 45% edaphic factors and early conditions caused variations in successional growth of trees and

lianas. It was also found that soil nutrients had significantly positive effect on the growth of tree biomass while topography of an area significantly distribute similar large lianas over time.

Conclusion

Restoration of forests in different areas of Punjab proved successful in curbing atmospheric carbon dioxide. Restoration of historical and already forest lands were really fruitful in growing new plants. Among different plant species *Eucalyptus camaldulensis* growth was the most owing to its fast growth rate and adaptability to withstand climate change. Mono-culture of eucalyptus plant proved successful as compared to the mixed-cultures in terms of growth and yield; however, variations in growth of plants at different areas were due to geography and climate. Other reason of poor growth at some sites was because of gardeners' negligence, as they sew two plants at one pit.

References

Ahmad, T. 1996. Eucalyptus in Pakistan. Reports submitted to the regional expert consultation on Eucalyptus, Bangkok, Thailand, 280p.

Akita, N. and Y. Ohe. 2021. Sustainable forest management evaluation using carbon credits: from production to environmental forests. *Forests*, 12(8): 1016.

Bastin, J. F., Y. Finegold, C. Garcia, D. Mollicone, M. Rezende, D. Routh and T. W. Crowther. 2019. The global tree restoration potential. *Sci.*, 365(6448): 76-79.

Cao, S. X., L. Chen, Z. D. Liu. 2007. Impact of three soil types on afforestation in China's Loess Plateau. *Landscape Urban Plan*, 83: 208–217.

Challenge, B. 2011. The challenge: A global effort. IUCN, Switzerland.

Clark III, A., J. R. Saucier and W. H. McNab. 1986. Total-tree weight, stem weight, and volume tables for hardwood species in the southeast. *Georgia Forest Research Paper*, (60).

Dhakku, N. A. 2019. Eucalyptus trees — a good fuel source at the cost of high-water consumption. *Dawn*, Retrieved from https://www.dawn.com/news/1483325.

Estrada-Villegas, S., M. Bailón, J. S. Hall, S. A. Schnitzer, B. L. Turner, T. Caughlin and M. van Breugel. 2020. Edaphic factors and initial conditions influence successional trajectories of early regenerating tropical dry forests. *J. Ecol.*, 108(1): 160-174.

Griscom, B. W. et al. 2016. *Proc. Natl Acad. Sci.*, USA 114, 11645–11650.

Griscom, B. W., J. Adams, P. W. Ellis, R. A. Houghton, G. Lomax, D. A. Miteva and P. Woodbury. 2017. Natural climate solutions. *Proc. Natl. Acad. Sci*, 114(44): 11645-11650.

Houghton, R. A., B. Byers and A. A. Nassikas. 2015. A role for tropical forests in stabilizing atmospheric CO_2. *Nature Climate Change*, 5(12): 1022-1023.

IPCC (Intergovernmental Panel on Climate Change). 2018. Global Warming of 1.5° C: An IPCC Special Report on the Impacts of Global Warming of 1.5° C Above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Intergovernmental Panel on Climate Change.

IPCC. 2019 Climate and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. See https://www.ipcc.ch/report/srccl/.

Kanowski, J and C. P. Catterall. 2010. Carbon stocks in above-ground biomass of monoculture plantations, mixed species plantations and environmental restoration plantings in north-east Australia. *Ecol. Manag. Restor.*, 11(2): 119-126.

Lewis, S. L., C. E. Wheeler, E. T. A. Mitchard and A. Koch. 2019. Regenerate natural forests to store carbon. *Nature,* 568: 25–28.

Pan, Y., R. A. Birdsey, J. Fang, R. Houghton, P. E. Kauppi, W. A. Kurz, O. L. Phillips, A. Shvidenko, S. L. Lewis, J. G. Canadell, et al. 2011. A large and persistent carbon sink in the world's forests. *Science*, 333: 988–993.

Rajeev, J and S. Hukum. 2020. Carbon sequestration potential of disturbed and non-disturbed forest ecosystem: A tool for mitigating climate change. *Afr. J. Envir. Sci. Technol.*, 14(11): 385-393.

Seddon, N., A. Chausson, P. Berry, C. A. Girardin, A. Smith and B. Turner. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philos. Trans. R. Soci. B*, 375(1794): 1-12.

Smith, P., J. Adams, D. J. Beerling, T. Beringer, K. V. Calvin, S. Fuss, S and J. C. Minx. 2019. Land-management options for greenhouse gas removal and their impacts on ecosystem services and the sustainable development goals. *Ann. Rev. Environ. Resour.*, 44: 255-286.

Summit, U. C. 2014. New York declaration on forests. United Nations, New York, NY.

Watson, R. T., I. R. Noble, B. Bolin, N. H. Ravindranath, D. J. Verardo and D. J. Dokken. 2000. IPCC special report on land use, land-use change, and forestry.