ROOT CARBON IN SOME OF THE INDIAN TREE SPECIES

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ABSTRACT

Carbon allocation in roots is a least understood phenomenon in Indian trees and requires an intensive research in to this area. This is extremely difficult to dig out the entire root architecture of any tree in its entirety therefore; it becomes tough to understand the Root-Shoot ratio of any tropical tree. This has been tried to understand the root carbon in thirteen species grown on the national highway Number-2 under varying diameter classes and it was found that root: shoot ratio values (R:S) have been different for different species. This has been seen that almost all the trees of higher diameter classes have a root-shoot ratio in and around a bracket of 0.3 or slightly more whereas the trees of lower diameter have a band of root-shoot ratio of 0.2 or slightly more. Generally speaking, when the dry weight of the root is comparatively higher than the shoot then the root shoot ratio will come to be larger than the otherwise scenario. There are five species namely, Mango, Jamun, Mahua, Peepal and Bargad which are found to have larger Root-shoot ratio (all the trees falling in higher diameter class) despite of the fact that these trees are extremely vulnerable to damage by the local population. There are three aberrations in case of Mahua and Peepal in the diameter class of 102 cm, 93 cm and 114 cm which is found to have the root-shoot ratio of 0.20441707, 0.20209747 and 0.22771092 respectively. The reasons may be numerous but on having inspected the study area their shoot parts were found to be extensively damaged and may be this is the reason why we have lesser weight of shoot system.

KEY WORDS

Root architecture, Root-Shoot ratio, Carbon sequestration, Carbon emission, Tropical forest, Carbon allocation, Intergovernmental panel on climate change, Non structural carbohydrate, Photosynthesis, Lateral roots, Diameter at breast height

INTRODUCTION

The data on carbon dioxide concentration is regularly gathered by Mauna Loa Observatory since 1950s and in the longest data set, the highest carbon dioxide concentration was recorded in May 2019 and it was found to be 414.7 ppm. The data were released on June 4, 2019[1]. There has been a definite relationship between the carbon dioxide concentration in the atmosphere and rise in atmospheric temperature as found in recent studies. This has been found that nearly two thirds of total industrial carbon dioxide and methane emissions can be traced back to ninety major industrial carbon producers and these 90 carbon producers contributed ~57% of the observed rise in atmospheric CO_2, ~42–50% of the rise in global mean surface temperature (GMST), and ~26–32% of global sea level (GSL) rise over the historical period and ~43% (atmospheric CO_2), ~29–35% (GMST), and ~11–14% (GSL) since 1980[2]. Plantation plays a very important role in carbon sequestration and that is why restoration of trees has been a mainstay in carbon sequestration technique. A study has been carried out in which this has been found that 4.4 billion hectares of canopy cover could exist in the existing climate and there is an extra room for 0.9 billion hectares of restoration forest capable of storing 205 gigatonnes of carbon dioxide. This has also been estimated that if deviation does not occur from the current scenario then there is a possibility that the global potential canopy cover may shrink by ~223 million hectares by the year 2050, and with the majority of chunk of forest losses in the tropics[3]. In yet another study on the carbon sequestration potential of trees this has been observed that growth of the trees is not only dependent on carbon dioxide concentration but also on the available essential nutrients in the soil. This has been found that globally plants can increase biomass by 12% when it has a carbon dioxide concentration predicted to be present in 2100 and this will be equivalent to 6 years of current human-induced emissions. However, the result is based on plant and forest cover remaining at current levels so no further deforestation occurs, a task which is impossibility[4].

CARBON CAPTURE AND STORAGE IN DIFFERENT PARTS OF TREES

Carbon sequestration is a simple process of carbon capture and storages at different locations in the trees. The carbon is captured through a chemical process called Photosynthesis and once it is captured by plants, the CO_2 gas (or the carbon portion of the CO_2) is put into long-term storage. It is clear that Photosynthesis is not synchronized with carbon sinks and trees are capable of storing non-structural carbohydrates and their translocations and storage depend on many factors namely, age of the tree, species, months and weather conditions etc. These storages provide a buffer between carbohydrate supply and demand and also allow trees to resist drought through osmo-regulation. Roots are also found to be containing varying degree of carbon depending upon different species under different point of time[5]. Root biomass is extremely difficult to estimate because excavation of root system is tougher than expected therefore, the root-shoot ratio which is also indicative of the carbon present in the total biomass has largely been based on the assumption on the findings of IPCC and many other research articles that root biomass is equal to 20-26% of the aboveground biomass[6] .

STUDY ON ROOT-SHOOT RATIO

The root-shoot ratio is usually given as the ratio of the weight of the roots to the weight of the top of a plant. For most trees under normal conditions, the root-shoot ratio is 1:5 to 1:6; the top is 5 to 6 times heavier than the roots. If it were not for the weight of the trunk, however, the top and roots would weigh about the same. A cultural practice that brings about a reduction in the root-shoot ratio of a tree is commonly thought to be detrimental for the wellbeing of the tree. That is, proportionately more top than root growth is thought not to be in the best interests of a tree. However, any factor which improves growing conditions, such as favorable weather, fertilization, irrigation, aeration, or pest control, results in a reduced root-shoot ratio (weight). The root-shoot ratio is very important to understand the carbon storage pattern in Indian trees species however, the deep mechanism of above ground biomass and below ground carbon remains an area where lot more studies require to be done. A study has been carried out in order to understand the carbon storage pattern in thirteen species of varying diameters in a road side plantation done way back in 1983 and1984. The aim of my study is

(1) To determine the carbon in tap root and lateral roots in different tree species of varying diameter classes

(2) To find out the root-shoot ratio in different tree species under varying diameter classes

DESCRIPTION OF THE STUDY AREA

The study area was chosen very carefully in Kanpur Dehat district of Uttar Pradesh. This was a plantation of early 1990s (to be very precise 1983 and 1984) on both sides of Kolkota-Delhi National Highway number-2 with multi layering. Plantation and management is done on the basis of the management plan of Kanpur Dehat Forest Division and they are managed on certain fundamental principles in which all the aspects of forest working and its sustainable growth are taken into consideration. These principles and all the working prescriptions are laid down in a document which is called Management Plan and this remains valid for ten years from the date of issue. The management plan becomes the backbone of Forest Management which lays down the rules of forest practices. The Kanpur Dehat district occupies the central part of Uttar Pradesh on eastern bank of Yamuna river and encompasses a total geographical area of 3021 sq.km., lying in between 26N to 25 55'N latitude and 79"30'E to 80"E Longitude. Kanpur Dehat's climate is characterized by hot summer and dryness except in the south west monsoon season. The climate in Kanpur can be divided broadly into four seasons. The period from March to the mid of June is the summer season which is followed by the south-west monsoon, which lasts till the end of September, October and first half of November from the post-monsoon or transition period. The cold season spreads from about the middle of November to February. The climate is of a tropical nature and shade temperature varies from 20C to 480 C. Rainy season extends from June to September, with the period of maximum rainfall normally occurring during the months of July and August. About 89 percent of the annual rainfall is received during the monsoon months (June to September). The total rainfall in the district varies from between 450 mm to 750 mm. The annual rainfall in Kanpur Nagar was recorded 441 mm in actual in 2004 and 783 mm in general (Statistics Diary 2005). On an average there are 40 rainy days i.e. days with rainfall of 2.5 mm or more in a year in the district. This number varies from 35 mm at Narwal to 45 mm at Kanpur. The relative humidity varies from 15% to 85%. The relative humidity in Kanpur Dehat ranges from less than 30 percent in the summer season to 70 percent in monsoon season. The District Kanpur Dehat, a part of doab region of the river Ganga & Yamuna is generally plain area with minor undulation which slopes gently towards south-easterly direction. The main constituents (sand, silt and clay) of alluvium occur in variable proportions in different sections. The mineral products of the district of saline earth from which salt petre and salt are derived and limestone conglomerates (U.P. District Gazetteers Kanpur). Saltpetre, also spelled Saltpeter, also called Nitre, or Niter, any of three naturally occurring nitrates, distinguished as (1) ordinary saltpetre, or potassium nitrate, KNO_3; (2) Chile saltpetre, cubic nitre, or sodium nitrate, $NaNO_3$; and (3) lime saltpetre, wall saltpetre, or calcium nitrate, $Ca(NO_3)_2$. These three nitrates generally occur as efflorescences caused by the oxidation of nitrogenous matter in the presence of the alkalis and alkaline earths.The Uttar Pradesh Forest Department (UPFD) managed roadside (NH-2, STUDY AREA) plantations in Kanpur Dehat district contribute to livelihood for many villagers living nearby in form of fuel wood and fodder. Despite the relatively poor physical condition of the roadside plantations and their isolation, they are still important for carbon sequestration. Although the plantations are not harvested but many of them are cut illegally therefore, their replacements are done with immediate effect, starting another cycle of carbon sequestration. Roadside plantations should be considered as a near-term participatory management conservation success, even if the contribution to livelihoods and the carbon pool estimated are low compared to other protected forest systems in UP. Their ability to contribute to livelihoods and carbon sequestration could be increased by management actions (enrichment planting and strict implementation of rules in use) to assist their sustainable retention.

METHODOLOGY

Felling of tree in the study area is done by very expert people as this is a scientific process and involves many stages before cutting down. Firstly, all the trees were inspected by me on both side of the National Highway Number-2(study site) and their girths were measured at breast height (1.32m). All the readings were noted down in a pre-designed format indicating the lot numbers, name of trees, their diameter classes and the sides of national highway(whether left side or right of road) so that a difference, if any, could be studied on account of edaphic or any other local factors. Directional felling involves marking trees with a predetermined felling direction and is required to minimize damage to the felled tree as well as to other assets. This is principally required so as to facilitate easy log extraction and minimize ground disturbance, avoid disturbance to buffer areas, watercourses and exclusion areas; and prevent trees from hanging up during felling. Once the directional plan is finalized following precautions were taken before felling a tree

(1) It was made sure that there are no dead limbs or “hung-up” branches.

(2) Vines still attached to the stem or trailing from the canopy were cut. Vine cutting is best undertaken a year prior to harvesting.

(3) Two alternative escape routes were cleared away from the areas where trees were to be felled.

(4) Shrubs and saplings were cleared away from the base of the tree to provide an adequate working space.

(5) Fellers were not allowed to feel obliged to cut trees they think are unsafe to fell.

(6) Felling of trees require an utmost precaution and it was ensured that scarf and back-cut were properly done and wedges were used appropriately wherever it was required but once cutting of a tree was started, it was ensured that trees must be felled. This was also seen that stump height should be as low as practicable (30 cm is preferable) to maximize merchantable volume but in this case of felling the stump height was kept at 30 cm. In case of any issue was found where butt defect is obvious (the tree was cut immediately above this defect); or where a buttress exists (and it is not appropriate to trim), in which case the tree may be cut immediately above the buttress.333333

MEASUREMENT AT DBH

The enumeration of trees was completed in term of measuring its diameter and height while the trees were standing only. The main objective of the measurement of individual tree is to estimate the volume of the trees. Volume of a tree is usually dependent on diameter or girth at the breast height. Diameter or girth measurement is very important for calculating volume. In case of a standing tree the girth was measured at breast height which is within the easy reach of man standing on the ground. Breast height is defined as almost universally adopted standard height for measuring girth, diameter and the basal area of the standing tree. In India, Burma, USA South Africa, it is taken as 1.37 meter (4 feet 6 inches above ground level). Each individual tree was enumerated very carefully. The girth was measured through measurement tapes. The measurements were taken and duly recorded in the pre designated format. Each measured tree was marked in a specific manner by a chalk so as to remove any duplicity whatsoever. The diameter of each tree was recorded in a pre-designated format.

CARBON ESTIMATION IN STEM:

Species wise enumeration of diameter and height was measured for each separate plot of the study area. There are twenty-seven species which were planted on both sides of the national highway therefore; the data was recorded for these twenty-seven species in each of felling lots amounting to the total number of 8266 trees but the thirteen species which were decided to be used for finding out carbon in their roots were separated out and their data base (girth and height) were recorded in a separated sheet. Each tree in thirteen species listed in Table-1has been properly enumerated in terms of their girth and height.

VARIOUS STEPS INVOLVED IN CALCULATING CARBON IN STEM

A small piece of wood sample from each of thirteen species measuring about 6 inches x 6 inches was taken out at the place slightly above breast height. A fresh weight of each cut out sample of wood was immediately taken and duly recorded. Further, for the purpose of carbon estimation sample of narrow cylinder of wood was taken out with a help of Pressler borer at three places that is from, bark (0cm), 5cm and 10 cm from the surface. The samples i.e. wood pieces and narrow wood cylinder were sealed properly in a container and brought to the laboratory for further analysis of carbon content. The dry weight of the wood pieces was also taken in the laboratory.

ESTIMATION OF VOLUME OF STEM

Circumference of each of thirteen species was recorded at breast height level and the diameter for each individual species was calculated by using following formula.

Diameter = Circumference / π

(The value of π is 3.14.)

The next stage was to work out the volume of each and every species listed in the study area therefore, regression equations developed for some individual species by Forest Survey of India[(7)], some references from the book titled "Carbon Stocks in India's Forests, published by FSI in 2011[(9)], some equations were used from the book titled "Volume equations" published by FSI, some references from "Carbon Sequestration in Natural Shrea robusta forest of South Kheri forest Division"[(8)] in 2013, and volume table prepared the Additional chief conservator of forest (Management), Nainital vide its letter number 333-TC/37-7-1(1) dated 26th June 1978 were extensively used. Regression equations for some species developed by Chaturvedi and Khanna[(10)] (1982) were also used in finding out volume of some of the species.

ESTIMATION OF GREEN WEIGHT

Green weight of each species was calculated by simply multiplying volume of individual species with the wood density of those particular individual wood densities of each species as given in the list of wood densities for tree species from tropical America, Africa and Asia (Sandra Brown 1997)[(11)] Therefore, the green weight is equal to: Green weight = volume x density

ESTIMATION OF DRY WEIGHT OF A WOOD SAMPLE AT THREE PLACES

The study was designed in such a way that the carbon content of the stem of each species is found out at three positions firstly, at the outer surface (say, 0cm) and secondly, at the depth of 5 cm from the surface and thirdly at 10 cm depth from the surface. The green tissue at all the positions were taken properly, that is, the tissue at the surface area was chiseled off and tissues from the depth of 5 cm and 10cm were taken through borer and weighed accurately to be recorded in a pre-designed format. These samples were dried in the laboratory at a controlled constant temperature of 70^0 C until the wood sample is completely dried. The dry weight for each species is recorded in a format (Table-2)

CALCULATION OF DRY WEIGHT FACTOR

Dry weight factor for each of the species has been calculated by the dry weight of the sample of stem of an individual species divided by green weight of the sample of the stem of that species. Green weight/Fresh weight of the stem is the weight which was taken at the time of sample collection of individual tree species. One issue also needs special mention here because we have taken samples from three places of the stem for each species therefore, the averages of three dry weights will be taken into consideration while finding out dry weight factor. Similarly, we have to take average green weights in order to find out the total carbon of the stem. This can be summed up in the following equations

Dry weight factor =Average dry weight of the sample / Average green weight of the sample

CALCULATION OF TOTAL DRY WEIGHT OF THE STEM

The dry weight of a stem of an individual species is calculated by using the following formula.

Dry weight of a stem = Green weight of the particular species x dry weight factor of that species.

We can calculate the dry weight of stem from the above factor for all the species in the study area.

WALKLEY-BLACK METHOD TO FIND OUT CARBON

The Walkley-Black [12] (WB) method used for determining organic carbon (OC) utilises a specified volume of acidic dichromate solution reacting with a determined amount of wood sample in order to oxidise the OC. The oxidation step is then followed by titration of the excess dichromate solution with ferrous sulphate which gives a volume of ferrous sulphate in ml. The OC is calculated using the difference between the total volumes of dichromate added and the volume titrated after reactions. In case of soil, the problems with this procedure include excessive organic matter in it (the limit for this procedure is approximately 6%) and difficult end point determination which can be found in dark-coloured soil solutions. The use of a lighted stir plate can be of assistance in the end-point determination.

CALCULATION OF CARBON FACTOR

The percentage of carbon for the different parts of the trees of all the twenty seven species is worked out on the basis of above stated procedure of titration and the carbon factor is multiplied with the dry weight of the stem to find out the total carbon stock of the stem. The process of titration to find out carbon content in branches, foliage and roots will remain the same.

UPROOTING PROCESS

A tree needs its roots. It uses the roots to draw moisture and nutrients up out of the ground so it can live and grow. Secondly, the roots help hold the tree up and let it remain upright despite high winds or heavy snow/ice on its branches. This is extremely important to dig out a complete root system of a tree in order to find out carbon in it and this is equally difficult as well. This is not only important to take a complete root out of the soil but lateral roots are also equally important to be dug out completely so that it could be processed for its own carbon content in it. To dig out a root system, an excavator or back hoe was used in case it's a large tree but hand digging is the best technique when it comes to removing tree roots of shrubs, bushes, and other small plants. All that a person needs is a shovel, root saw, grub hoe, and a lopper. We need to pull the roots off the ground by using the grub hoe with the axe head. The ideal time for removing tree roots is during the summer. We have certain thumb rules in the forest to know the expansion of root beneath the soil and a couple of them are mentioned for references. Firstly, we measure the diameter of the tea trunk with a measuring tape in feet and multiply the feet measurement of the tree-trunk diameter by 12, and again add the diameter in the resultant. Now, add 1.5 into the final sum. Now, we convert this whole calculation into inches and measure this distance away from the base of the tree and this gives the expansion of root system beneath the root. Each tree is different in size and species, but another good thumb rule that exists in forests helped us to guide. Generally, it is expected the size and depth of the root system to be equal to the height and width of the tree's branches. So, for example, if our tree is 25 feet tall and the branches are 40 feet wide, expect the underground root system to go as deep as 25 feet and by spread over 40 feet but again it depends upon the species but by and large the bulk of the root system will be in a 10 foot by 10 foot area just beneath the trunk at ground level. Excavation around the tree in a wide circle, say a radius of 10 feet away from the trunk, and dig down 10 feet by manual workers was done. An utmost care was taken that all the lateral roots were cut from its base and kept separately. Once the tap root is excavated, it is ensured that all its left lateral roots are cut properly and kept aside. All the roots(including laterals) are washed properly to free it from soil and dirt and left in open but secured place for a couple of days to dry. After it is dried in open sun, it is weighed properly and recorded in a predesigned format. A sample of 6 inches by 6 inches is cut from each tap root of thirteen species chosen for study and kept in a cloth bag with proper labels. Similarly, the samples of lateral roots of the same size were cut and kept in a bag with proper label.

DRY WEIGHT OF THE TAP ROOT AND LATERAL ROOTS

A small part of the samples of tap root and lateral roots of all the thirteen species were taken out through borer and weighed properly. A proper care was taken that all the data were immediately written in a pre-designed format. These samples were dried in the laboratory at a controlled constant temperature of 70^0 C until the wood sample is completely dried. The dry weight for each species is recorded in a format.

CALCULATING DRY WEIGHT FACTOR OF THE ROOT SYSTEM

Dry weight factor for each of the thirteen species has been calculated by the dry weight of the sample of root of an individual species divided by green weight of the sample of the root of that species. Green weight/Fresh weight of the root is the weight which was taken at the time of sample collection of individual tree species. One issue also needs special mention here because we have taken samples from two places of the root for each species that is at the surface of root at 0 cm.

and other at the 3 cm. depth of root, therefore, the averages of two dry weights will be taken into consideration while finding out dry weight factor. This can be summed up in the following equations and the result has been shown in table 1. As far as the lateral roots are concerned the samples are taken from one place only through borer only.

Dry weight factor =Average dry weight of the sample / Average green weight of the sample

TABLE -1 NAMES OF SPECIES IN WHICH THE ENTIRE ROOT SYSTEM IS DUG OUT

BOTANICAL NAME OF THE PLANTS	DIAMETER THE TREE AT DBH(CM)	GREEN WEIGHT OF THE MAIN TAP ROOT(IN KG)	DRY WEIGHT OF TAP ROOT (IN KG)	DRY WEIGHT OF LATERAL ROOTS (IN KG)	TOTAL WEIGHT OF ROOT (IN KG)
1.Mangifera indica (MANGO)	119	991.89	902.43	400.57	1303
	124	1018.68	926.8	379.2	1306
	73.24	859.65	545.34	236.77	782.11
	50.95	444.41	296.9	107.43	404.33
2.Syzygium cumini(JAMUN)	88	1318.73	1204.4	405.6	1610
	87	1311.5	1197.8	403.2	1601
3.Madhuca longifolia (MAHUA)	175	1937.221	1185.5	611.5	1797
	102	980.27	909.3	396.7	1306
	93	667.96	619.6	287.4	907
4.Accacia nilotica (DESHI BABUL)	11.7	35.6	32.85	8.45	41.3
5.Albizia lebbeck(SIRIS)	9.5	15.37	14.2	6.4	20.6
6.Azadirachta indica(NEEM)	11	32.78	30.5	12.7	43.2
7.Dalbergia sissoo(SISHAM)	7.8	7.05	6.76	4.7	11.46
8.Dalbergia sissoo	47.77	320.88	205.2	102.34	307.54

(SISHAM)					
9.Dalbergia sissoo (SISHAM)	19.74	58.26	35.58	20.26	55.84
10.Morus alba (SHAHTUT)	12.1	28.1	26.16	11.2	37.36
11.Ziziphus mauritiana(BER)	8.9	13.18	11.5	9.8	21.3
12.Eucalyptus	15.6	183.49	167.35	82.3	249.65
13.Ficus religiosa(PIPAL)	114.64	1970	1295.23	527.8	1823.03
14.Ficus benghalensis (BARGAD)	108.28	3854.17	1793.93	827.68	2621.61
	85.98	2474.91	1007.87	675.57	1683.44
15.Pongamia pinnata(KANJI)	50.95	210	129.16	70.38	199.54

RESULTS

Root-shoot ratio is very important in order to understand the carbon stock dynamics in the root ecosystem and its relationship with the shoot. The study mainly centered around finding out the carbon in the different parts of 8266 planted trees on the NH-2 but it was also contemplated to find out root carbon and root-shoot ratio of trees. However, it was very difficult to dig out the entire root system of 8266 trees in the study area therefore; it was decided to dig out the root system of some thirteen tree species in different diameter classes. Therefore, their entire root system was dug very carefully. The root shoot ratio has been worked out and given in the following table 2. The result is very interesting and is almost in conformity with the other studies except a few aberrations which may be explained ecologically. This has been found that almost all the trees of higher diameter classes have a root-shoot ratio in and around a bracket of 0.3 or slightly more whereas the trees of lower diameter have a band of root-shoot ratio of 0.2 or slightly more. Generally speaking, when the dry weight of the root is comparatively higher than the shoot then the root shoot ratio will come to be larger than the otherwise scenario. There are five species namely, Mango, Jamun, Mahua, Peepal and Bargad which are found to have larger Root-shoot ratio (all the trees falling in higher diameter class) despite of the fact that these trees are extremely vulnerable to damage by the local population. The second reason is stated to be the genitival trait of the trees which also defines the root architecture. This will be appropriate to explain at this juncture that entire root system of the thirteen tree species were dug with utmost care and all the lateral roots were cut and weighed properly therefore, it could be possible to get the real time data of main tap root and lateral roots. The real time data for the above ground components were already worked out for the carbon analysis. There are three aberrations in case of Mahua and Peepal in the diameter class of 102 cm, 93 cm and 114 cm which is found to have the root-shoot ratio of 0.20441707, 0.20209747 and 0.22771092 respectively. The reasons may be numerous but on having inspected the study area their shoot parts were found to be extensively damaged and may be this is the reason why we have lesser weight of shoot system. Similarly, there are three tree species in which the root shoot ratio are relatively higher than normal and they are namely, Neem and Shisham. The plantation of Neem is extremely tough on the public places because they are lopped for mouth wash or a tooth brushing therefore, their root system keeps growing while the stem remains stunted and this is why the dry weight of roots is higher than the shoot. Shisham is also lopped for small timber therefore; the root system keeps growing while stem gets stunted as shown in the following table 2.

FIGURE-1 ROOT-SHOOT RATIO OF SOME SELECTED SPECIES

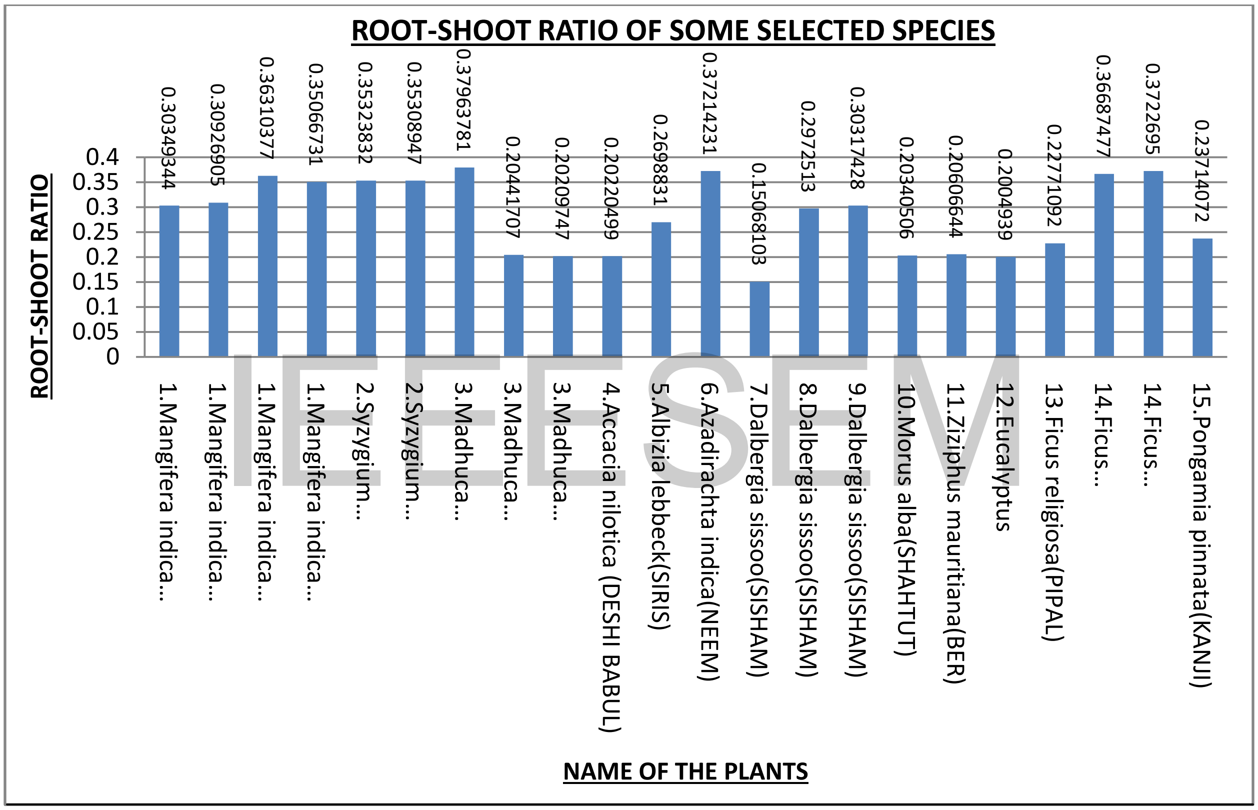

TABLE 2- ROOT-SHOOT RATIO OF INDIAN TREES

NAME OF THE PLANTS	DIAMETER CLASS OF THE TREE(CM)	GREEN WEIGHT OF THE MAIN ROOT SYSTEM(IN KG)	DRY WEIGHT OF TAP ROOT (IN KG)	DRY WEIGHT OF LATERAL ROOTS (IN KG)	TOTAL DRY WEIGHT OF ROOT (IN KG)	SHOOT BIOMASS OF THE TREES (IN KG)	ROOT-SHOOT RATIO	CARBON IN THE ROOT
1.Mangifera indica (MANGO)	119	991.89	473.576938	495.477621	969.05456	3193	0.30349344	473.37242
	124	1018.68	486.367798	508.859998	995.227796	3218	0.30926905	486.157756
	73.24	859.65	410.439076	429.419933	839.859009	2313	0.36310377	410.261824
	50.95	444.41	212.183132	221.995594	434.178726	1238.15	0.35066731	212.091499
2.Syzygium cumini(JAMUN)	88	1318.73	634.157344	621.604881	1255.76222	3555	0.35323832	597.900543
	87	1311.5	630.680546	618.196902	1248.87745	3537	0.35308947	594.622525
3.Madhuca longifolia (MAHUA)	175	1937.221	712.140262	788.780599	1500.92086	3953.56	0.37963781	581.442033
	102	980.27	457.309875	496.091317	953.401191	4664	0.20441707	369.338278
	93	667.96	319.540575	345.966409	665.506984	3293	0.20209747	257.810884
4.Accacia nilotica (DESHI BABUL)	11.7	35.6	18.6124436	18.5932744	37.205718	184	0.20220499	18.9193783
5.Albizia lebbeck(SIRIS)	9.5	15.37	8.74433421	8.258301	17.0026352	63	0.2698831	9.40434627
6.Azadirachta indica(NEEM)	11	32.78	21.031453	13.737803	34.7692559	93.43	0.37214231	18.439615
7.Dalbergia sissoo(SISHAM)	7.8	7.05	3.65437103	3.65365898	7.30803	48.5	0.15068103	3.78775195

8.Dalbergia sissoo (SISHAM)	**47.77**	**320.88**	**166.328308**	**166.2959**	**332.624208**	**1119**	**0.2972513**	**172.399127**
9.Dalbergia sissoo (SISHAM)	**19.74**	**58.26**	**30.1991001**	**30.1932159**	**60.392316**	**199.2**	**0.30317428**	**31.3013374**
10.Morus alba (SHAHTUT)	**12.1**	**28.1**	**15.1093925**	**14.5877469**	**29.6971394**	**146**	**0.20340506**	**14.0386441**
11.Ziziphus mauritiana(BER)	**8.9**	**13.18**	**6.16801199**	**5.98990801**	**12.15792**	**59**	**0.20606644**	**5.60755002**
12.Eucalyptus	**15.6**	**183.49**	**72.5026215**	**110.548307**	**183.050929**	**913**	**0.2004939**	**73.3267379**
13.Ficus religiosa(PIPAL)	**114.64**	**1970**	**275.730065**	**299.517815**	**575.24788**	**2526.22**	**0.22771092**	**292.370886**
14.Ficus benghalensis (BARGAD)	**108.28**	**3854.17**	**1088.44343**	**328.42693**	**1416.87036**	**3862**	**0.36687477**	**539.832354**
	85.98	**2474.91**	**698.931166**	**210.895496**	**909.826662**	**2444**	**0.3722695**	**346.647006**
15.Pongamia pinnata(KANJI)	**50.95**	**210**	**26.485158**	**26.634363**	**53.119521**	**224**	**0.23714072**	**23.5132258**

DISCUSSION AND CONCLUSION

There have not been much of studies done in this area therefore; there isn't much literature on this subject in Indian conditions either. A study was done on the Relationships among Root–Shoot Ratio(R: S), Early Growth, and Health of Hybrid Poplar and Willow and this was found Root-shoot ratio was dependent on the growth indices of poplar and willow and not on health[13]. There has been yet another very interesting study on the root-shoot study in the Brazilian savanna, or Cerrado. The Brazilian savanna is called as "upside-down forest" because of the higher biomass value in below ground than the above ground biomass value. The Brazillian savanna is characterized by open grass land a wide range of ecological conditions and plant biomass. The study was carried out in 102 trees and it was tried to find out how these trees differed between open- (cerrado sensu stricto) and closed-canopy cerrado (cerradão) within the same region in south-eastern Brazil. This was found that root-shoot ratio was higher in open area than the closed cerrado chiefly in deciduous forest species Root: shoot ratio in the open cerrado was lower than reported for the same cerrado type in central Brazil. Soil fertility did not differ between cerrado types, but soil water was lower and light availability was higher in the open cerrado. Therefore, this was concluded that the lower root-shoot ratio in closed cerrado was probably because of lower light and higher soil[14]. Allocation of carbon to different parts in a tree depends on many factors namely, environmental, genetical and nutritional. Optimal partitioning theory claims that trees allocate more resources to the organ which needs most resources that means that a plant sends more carbon to below ground if the limiting resources are water and nutrients and relocate more resources to above ground if the limiting factors are light and CO2. This theory has-been supported by recent research showing that the Root: Shoot of an individual plant is modulated by environmental factors[15]. The R: S ratio in the study of thirteen species has been found to be varying with the varying diameters and in certain cases this has been found to be in the lower range despite trees falling in higher diameter classes. For example, the root-shoot ratio in Madhuca longifolia and Ficus religiosa is found to be in the lower range compared to their higher diameter classes. The R: S ratios for these two species have been found to be in the range of 0.22771092 and 0.20441707 with their diameters range in the vicinity of 175 cm and 114.64 cm respectively and they have multiple reasons for this. This is also found in the lower range in the case of Pongamia pinnata as shown in the above table. The distribution of trees in the different diameter classes is also highly skewed in the sense that 73.09 % of the total trees fall under three diameter classes namely, 0-10, 10-20 and 20-30 cm and it becomes extremely difficult to explain as to why the plants remained in these lower diameter classes despite the plantation being carried out in 1983. This also fails to justify that after 36 years of plantation most of the plants should have gone to the higher diameter classes if the growth would have gone right but it remained stunted. There are two plausible reasons for this highly skewed number firstly, as the plants kept on dying over the years they were replaced immediately. And secondly, because of the sodic soil the growth was not as desirable as normally happens with the plantations raised on the normal soil. The third dimension which is more acceptable to me as a practicing forester is the absolute failure in protecting the plantation done on the sides of National highway-2 way back in 1983 therefore, this could be concluded very safely that damage of the seedlings by livestock or lopping of branches for fodder or fuel wood by villagers living nearby inhibited the growth of trees and it remained stunted. Normally, agroforestry models tree-assisted reclamation of sodic soils has been found viable under Indian conditions .The success of plantation largely depends on suitable management with factors such as method and depth of planting, planting distance, irrigation water availability and the kind of tree species greatly influencing the extent of reclamation. It is found that establishment and growth in many species were considerably higher when planted in auger-holes containing 3 kg gypsum and 8 kg FYM than those raised on trenches in a highly alkali soil (ESP= 94). This has been observed that air-dried shoot and root biomass of mesquite in a strongly alkali soil (pH= 10.3) were the maximum in auger holes of 90 cm depth compared to shallow depth (30 cm) in the trench and pit methods of planting. In trenches and pits, root growth was confined to the upper 60 cm surface while roots in the auger hole planted trees grew over 2.5 m deep piercing the hard CaCO3 layer and bringing further improvements in soil properties. The spacing of plants also matters in the biomass enhancement and it is observed that growth and biomass production in mesquite trees was significantly higher when trees were planted at 4m x 4 m spacing and the side branches were lopped in comparison to close space (2 m x 2 m) planting without lopping. In arid and semi-arid regions, low water availability often hampers tree and crop establishments in sodic soils. Use of some potential species in sodic soil reclamation is constrained by their less remunerative nature. For example, Acacia-based system was more efficient in sodicity alleviation than those involving Populus and Eucalyptus but the benefit-cost ratio was the highest (2.88) in Populus-based system and the lowest (1.86) in Acacia-based system [(16)].Enormous increase in human and cattle population created pressure in study area to fulfill the requirement of fuel wood, timber, fodder and food, which resulted in huge lopping and illicit felling in the road side plantation trees. The sodic soils cover an area of 1.2 mha in Uttar Pradesh, which may be rehabilitated by adoption of forestry system. This is the main reason why plantations are taken up on the sodic soil. The plantation carried out on the sides of National Highway -2(Study Area) had sodic soil in the entire stretch with the Ph level varying in between 7.8-10.2.The chief characteristic of sodic soils from the forestry stand point is that they contain sufficient exchangeable sodium to adversely affect the growth of most plants in the early stages. For the purpose of definition, sodic soils are those which have an exchangeable sodium percentage (ESP) of more than 15. Excess exchangeable sodium has an adverse effect on the physical and nutritional properties of the soil, with consequent reduction in tree growth, significantly or entirely. The soils lack appreciable quantities of neutral soluble salts but contain measurable to appreciable quantities of salts capable of alkaline hydrolysis, e.g. sodium carbonate. The electrical conductivity of saturation soil extracts are, therefore, likely to be variable but are often less than 4 dS/m at 25 °C. Under sodic conditions, poor soil structure, restricted water movement and nutrient toxicities are the major constraints to root growth. Some of the tree species which were planted in the study area and found thriving on the sodic soil are namely, Prosopis juliflora, terminalia belirica, Pongamia pendula, Zizyphus mauritiana, Acacia nilotica, Albizia procera, Leucaena leucocephala, Azadirachta indica,Eucalyptus hybrids etc. There has been a very important study on the root-shoot ratio and a paper was published as “Unearthing the hidden world of roots: Root biomass and architecture differ among species within the same guild” in which authors had harvested 40 trees of six different species and all three components were calculated namely, aboveground biomass (AGB), coarse root belowground biomass (BGB), and total biomass (TB). This was found that BGB contributes ~27.6% of a tree's TB, lateral roots extend over 1.25 times the distance of crown extent. Carbon allocation in the roots varied among species, and that AGB is a strong predictor of TB.[17]

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