Impact of removal of rubber plantation – a high altitude ecosystem for urbanization on CO_2 mitigating capacity by loss of carbon sink.

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Method Article

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Abstract

Mitigating climate change and global warming through carbon sequestration of tree ecosystem is of prime importance due to cost effective, environment friendly and ecological sustainability. Urbanization is a part of development and generally rubber plantations were usually removed for this purpose especially in Kerala, the southern state of India. Besides commercially high yield of latex, the economic produce of rubber plant and the associated income, rubber tree is fairly good sink for carbon in its biomass with an average carbon content of 42 per cent and substantial carbon stock in soil. This study pointed out the serious carbon sink loss from the removal of rubber plantation for urbanization, one of the major development activities which resulted in the damage of the self-sustained carbon friendly and economically sound perennial rubber ecosystem. The present popular clone (RRII 105) existing in major share (85 %) of the total rubber cultivation in India accounts carbon sink loss 57t/ha, 57.5t/ha, 43.2t/ha for 23 years and 148t/ha, 75t/ha and 62.1t/ha for 30 years from biomass, litter fall and sheet rubber respectively. The establishing modern clones RRII 414, RRII 429 and RRII 417 having higher growth rate and biomass recorded still higher (44–50 per cent) carbon sink loss compared to the existing popular clone RRII 105. The carbon sink loss in the form of stored carbon in soil is 56.5 with soil carbon content between 1.2 to 2 per cent. Due to the growth variation in extreme climatic conditions, the clones recorded differences in carbon stock and thereby carbon sink loss. The central region of Kerala showed higher loss and lower loss was in the drought affected northern region than South region. The total carbon sink loss for 23, 30 years were 214.2 and 341.5 t/ha respectively. Maintenance of green spaces/areas including vegetation having higher C-sequestration potential and trees having higher lignin content to increase carbon capture for mitigating the impact of removal of plantations especially in high altitude to some extent in the scenario of inevitable developmental activities and urban developments to become environment friendly. From the study it was clear that the removal of rubber plantation affecting the carbon sink loss greatly and thereby the CO_2 mitigating capacity and is a serious matter of concern.

Introduction

Urbanization is aggressive now a days for the purpose of developmental activities. Most of the agricultural areas, especially rubber plantations –a high altitude long resident ecosystem undergo construction activities. Among the Green House Gases (GHG’s), the major portion contributes by carbon dioxide (CO_2). The vegetation especially big trees in the form of plantations and forests acting as large sink of carbon by the fixation of atmospheric carbon in its biomass by the process of photosynthesis (Anjali et al., 2020). Urban development and the resultant removal of land becoming a cause for near future loss of carbon storage (Sallustio et al., 2015) which exponentially increasing the CO_2 in the atmosphere, GHG’s and global warming if the land take is in the form of tree plantations. Also urbanization is a major process for the damage of plantations and ecosystems and associated entities like changes in climate, water bodies, and microbiological functions thereby the complete ecosystem structure and damages. Rubber tree (*Hevea brasiliensis*), the major source of natural rubber and long duration crop is a quick growing in the initial phase (1–7 years) to attain the girth (50 cm) for tapping the bark of the tree for latex harvesting and is having high biomass accumulating potential (Karthikakuttyamma et al., 2004). Average biomass of the popular clone RRII 105 at 30 years is 1.2 t/tree (Jacob, 2003) and different clones have varied in biomass accumulation and some clones have biomass higher than this quantity (Ambily and Ulaganathan, 2016). Planting density of rubber plants is 550 plants/ ha at the time of planting and after causalities the mature tree stands comes around 350 trees. The carbon sequestration capacity of natural rubber plantation was estimated as 142 t/ha in tree biomass and 23 t/ha in the soil (Jacob, 2003) for the clone RRII 105. Karthikakutty amma (1997) studied the biomass accumulation of clone RRII 105 at 20 years age which accounts 192 t/ha C in the dry biomass. Jessy (2004) estimated the biomass of the clone PB 217 at 19 years and this comes to 155 t/ha C. Annamalainatahn *et al.* (2011) reported that in rubber plantation the net ecosystem exchange (NEE) CO_2 is 1–25 g/m^2 /day and a 4–5 years old rubber plantation sequestered 33.5 tons CO_2/ha/year and inferred as rubber plantation is a potential sink for sequestration of atmospheric CO_2. Rajagopal and Sebastian (2011) found that the use of biomass gasification technology in the block rubber production has been reduced the emission of CO_2 when compared to diesel fired dries, the advanced technology used presently is a beneficial effect of rubber processing sector to reduce CO_2 emission. Carbon sequestration potential of modern *Hevea* clones RRII 400 series was reported (Ambily et al., 2012). The carbon sink loss by removal of rubber plantation was not estimated and this is important in the environmental sustainability accounting and for policy decisions. In view of this the present study was conducted to estimates carbon sink loss by the removal of rubber plantation for urbanization in the scenario of CO_2 mitigating capacity of tree plantations.

Materials And Methods

For the estimation of carbon sink loss by the removal of one hectare rubber plantation, two planting age were taken *viz*. 23 years and 30 years from planting.. The usual replanting period in small holding and estate sector were around 20–25 and 30–35 years respectively. Hence the ages of 23 years and 30 years ages were selected. The carbon sequestration potential estimated for the modern *Hevea* clones of RRII 400 series clones and check clone RRII 105 (Ambily et al., 2012) in the experimental field of Rubber Research Institute of India (RRII), Rubber Board, Kottayam, Kerala, India used for the 23 years calculation. For the 30 years estimates the carbon sequestration potential estimated for clone RRII 105, RRII 203 and GT1 (Ambily and Ulaganathan, 2015) of the experimental field at Central Experimental Station (CES) Chethacakal, Patahnamthitta, Kerala, India were used. Average carbon content of rubber tree was taken as 42 per cent based on the study of the carbon content of plant parts of the clone RRII 105 (Jacob, 2003) and for RRII 400 series clones (Ambily et al., 2012). Carbon accumulated in the above-ground biomass was estimated as 42 per cent of the total dry biomass of the tree and from this it was scaled up by assuming 350 trees stand in mature plantation to obtain the carbon sink per hectare for 23 and 30 (Ambily et al. 2012; Ambily and Ulaganathan, 2015) years. The average organic carbon content was found to be in medium – high status in rubber plantation as per the rating followed for fertilizer recommendation for rubber trees (NBSS-LUP, 1999). Based on this three different values in medium to high status of the per cent organic carbon content observed in rubber plantation *viz*. 1.2, 1.5 and 2.0 in 0–

30 cm depth was taken and estimated the total loss of average carbon stock at 0–30 cm depth. The bulk density of rubber growing soils was considered as an average of 1.2 g/cm^3 (NBSS-LUP, 1999: recent soil survey, 2012 -unpublished). From this the carbon stock in soil in one hectare plantation was estimated by using the equation SOC stock (t/ha) = % OC *BD*D where OC = per cent organic carbon content, BD = bulk density g/cm^3, D = depth of the soil. This was given as the sink loss through soil carbon commonly for both 23 and 30 years. Annual input of carbon through litter fall was estimated by the data of litter fall (5–6 t ha^{-1}) study (Philip et al., 2003). This comes to 2–3 t ha^{-1} carbon and from this the sink loss through annual litter fall for 23 years and 30 years separately were calculated since this was an annual recycling process every year. The carbon content of dry rubber sheet was 85.38 per cent (Jacob, 2003) and this was used to estimate the carbon locked by rubber sheet in one hectare plantation and thereby the carbon sink loss through rubber sheet estimated for 23 and 30 years. The biomass accumulated, carbon storage and carbon sink loss of RRII 400 series and RRII 105 at 20 years age in three diverse environments in the traditional rubber cultivated areas in Kerala *viz*. Kanyakumari (South region), Chethackal, Kottayam (Central region) and Padiyoor (Drought affected North region) were also estimated and compared. From these the total estimates of the carbon sink loss per hectare by the removal of one hectare mature rubber plantation (23 and 30 years old) were generated.

Result And Discussion

The carbon content in different sink sources of rubber plantation (James, 2003) was given in Table 1. Among the carbon sink sources, per cent carbon content was highest in sheet rubber (85.38 per cent) followed by seed endosperm (63.48 per cent). Timber and coarse root recorded carbon sink of around 38 per cent. Other carbon sink sources like leaf lamina, petiole, small twigs (fire wood), fine roots and fruit wall were stored 42–47 per cent carbon. Among the sink sources of tree portions, contribution of largest removal is through timber including trunk and major branches. Along with this the small twigs and fire wood is removing from the field. The leaf, petiole and below ground root portions were allowed to decay in the field at the time of felling of the trees for replanting. But this loss is also significant when considering the carbon sink loss, because the release of carbon from the leaf and root residues takes time for further deposition as soil organic carbon. Even though the seed endosperm is having a large carbon content, the total quantity is less as compared to above-ground biomass and it is usually left in the field to decay. Based on this, the carbon content of rubber tree was estimated as 42 per cent of the dry biomass for the purpose of computation of carbon stock per tree (kg $tree^{-1}$) and carbon sequestration capacity (t ha^{-1}) by considering 350 trees in one hectare of rubber plantation.

The biomass accumulated, carbon stock and carbon sink loss of 7 clones including RRII 400 series clones (6 nos) and RRII 105 at the age of 23 years was given in Table-2.This clones were selected from the experimental field of clone evaluation trial at Rubber Research Institute of India (RRII), Kottayam, Kerala and is having same soil and management practices. The clones were different in biomass accumulation and thereby the carbon stock per tree and carbon sink loss in tons in one hectare basis. Among the clones RRII 429, RRII 414 and RRII 417 had higher biomass than RRII 430, RRII 105 and RRII

422. Correspondingly carbon stock and carbon sink loss also in the same pattern in these clones being the carbon storage is an entity related to biomass accumulation. The carbon capture pattern in RRII 400 series clones from 4th year (Ambily et al., 2012) was given in Fig. 1. There was increase of carbon capture up to 7 years uniformly in all the clones. There was a sharp increase in carbon capture from 5th to 7th year and afterwards up to 12th year also the carbon capture was recorded a steady increase irrespective of clones. However the trend was changed after 12th year for all clones and reflected the clone-wise changes in the carbon capture. Hence this is due to the characteristic growth pattern in *Hevea.* Carbon sink loss was RRII 429 (114), RRII 414 (106), RRII 417(102), RRII 430(60), RRII 105 (57) and RRII 422(54) ton per hectare. The differences among varieties were observed and the carbon sink loss ranges from 54–114 ton per hectare at 23 years age of popularly cultivated H*evea* clones of RRII 400 series and RRII 105.

The biomass accumulated, carbon storage and carbon sink loss of RRII 400 series and RRII 105 at 20 years age in diverse environments in the traditional rubber cultivated areas in Kerala and Kanyakumari was given in Table 3. The locations were *viz*. Regional Research Station (RRS) Padiyoor, Kannur district, the drought affected area, Central Experiment Station (CES), Chethackal, Ranni, Pathanamthitta district, the south-central area in Kerala and *Hevea* Breeding Sub Station (HBSS), Thadikarankonam, Kanyakumari, Tamil Nadu. Three locations were having extreme difference in agro-climatic conditions. Since the experiment fields were the clone evaluation trials of same clones planted uniformly for participatory clone evaluation trials, almost similar management practices were followed even though the soil conditions were varying. Because of the differences in agro-climate, total dry biomass accumulated, carbon stock and carbon sink loss showed variations in three locations. Since carbon sink is directly related to the biomass accumulation high biomass accumulating clones recorded highest carbon sink loss. Among the locations, the carbon sink loss was higher in the clones in Chethackal than Kanyakumari and Padiyoor. When comparing the clones in Kottayam at 23 years age, the biomass accumulation in Chethackal at 20 years age was comparable and almost equal rate of biomass accumulation was observed. The order of carbon sink loss was also similar in Chethackal, the south central region and Kottayam, the central region having annual rainfall ranged 3500–4000 mm and mean maximum and minimum air temperature prevailing is 31–32 ^{o}C and 22–23 ^{o}C respectively. In both these locations the higher biomass accumulating clones *viz*. RRII 414, RRII 429 and RRII 417 recorded the highest carbon sink loss than the comparatively lower biomass accumulating clones RRII 430, RRII 422 and RRII 105. In Padiyoor, the drought affected traditional area in northern region of Kerala; the biomass accumulation rate was lower due to less growth as a result of environmental stresses like high temperature and drought. Along with this a prolonged dry spell of about four to five months duration from the month of December to May annually is prevailing in this location. Even though the rainfall (3500 mm) is plentiful, moisture stress due to dry spells during this period affecting the growth and yield of rubber in this area (Vijayakumar *et al.*, 2000). The mean maximum and minimum temperature are 33 and 23^{o}C respectively. Therefore the biomass and thereby the carbon sink loss is less as compared to the location at Chethackal and Kanyakumari. In Kanyakumari, the biomass accumulation and the resulted crabon sink loss was higher than Padiyoor and lower than Chethackal. The climatic condition in Kanyakumari region is entirely different from that of Padiyoor region. In Kanyakumari area, the rainfall is 2000 mm annually and especially the rainfall is evenly distributed and does not exceed more than 350 m in any of the months. The south west and north east monsoons are equal and there were no marked temperature variations also. The carbon sink loss differences in these locations were attributed due to difference in growth in diverse agro-climatic conditions.

The biomass, carbon stock and carbon sink loss of RRII 105, RRII 203 and GT 1 at 30 years age was given in Table 4. The location was at CES Chethackal, the south central region of Kerala as mentioned above. The biomass accumulation was 1254, 1140 and 2045 kg/tree for the clone RRII 105, RRII 203 and GT 1 respectively. The corresponding carbon stock per tree was 527,479 and 860 and carbon sink loss per hectare was 148,138 and 258 ton per hectare. The clones were different in their biomass accumulation due to growth variation. Even though the clones were in the same location and under similar management practices, the variation observed in the growth was the clonal character. Among the clones highest biomass and carbon sink loss was recorded by GT 1 than RRII 105 and RRII 203.

The carbon sink loss from soil was given in Table 5. For calculation of soil carbon sink loss, the soil organic carbon content generally observed in rubber plantations was used. The same was calculated at a depth of 0–30 cm in the present study. In general rubber plantations were medium – high status in organic carbon status (NBSS-LUP, 1999). Three values *viz*. 1.2, 1.5 and 2.0 was used for calculation the bulk density in rubber plantation was 1.2 (NBSS-LUP, 1999). The carbon stock calculated was 43.2, 54.1 and 72.2 t ha^{-1} with an average value of 56.5 t ha^{-1} .

Total carbon sink loss through litter fall in rubber plantation was given in Table 5. Philip *et al.* (2005) reported that the annual litter fall in rubber is 5–6 t ha^{-1}. The carbon addition through this litter fall was accounted as 2–3 t ha^{-1} by using the carbon content of leaf as 42.8 per cent (Table 1). It was then accounted for 23 years and 30 years and comes to 46–69 and 60–90 t ha^{-1}. Average of this as 5.5, 2.5, 57.5 and 75 were taken for litter fall, carbon addition through litter fall, 23 years and 30 years carbon addition respectively and this was taken for the calculation of total carbon loss from the plantation.

Total carbon sink loss through rubber sheet, the economic produce of rubber tree was given in Table. 6. Annual sheet rubber production was 3.2 t ha^{-1} $year^{-1}$ and the carbon stock in rubber sheet was accounted as 2.7 t ha^{-1} $year^{-1}$ by considering the carbon content of sheet rubber as 85.38 per cent. For 23 years and 30 years the carbon loss calculated was 43.2 and 62.1 t ha^{-1} $year^{-1}$ respectively.

Total carbon sink loss from the removal of one hectare rubber plantation through the carbon sink sources *viz*. Tree biomass (57.0, 148 t ha^{-1}), soil carbon (56.5, 56.5 t ha^{-1}), litter fall(57.5, 75.0 t ha^{-1}) and rubber sheet (43.2, 62.1 t ha^{-1}) for 23 years and 30 years age respectively were estimated (Table. 8). Total carbon sink loss for 23 years and 30 years are 214.2, 341.5 t ha^{-1} respectively.

Anjali et al. 2020 reported that urbanization is imperative in the developing world and mankind, the formation of urban forests with high carbon sequestration potential is an important option to mitigate the adverse effect of removal of plantations and forests. This contributes various benefits including socially and culturally along with economy increase and aesthetically. Simultaneously carbon emission savings are also possible by urban forests. It was reported in this study that plantation of 2.4 billion trees amidst of the city in China can sequester 1261.4 of air pollution. Apart from this, it was also reported (Sallustio et al., 2015) that the loss of huge reservoirs of carbon stock in tree plantations, the urban areas is prone to higher emission of carbon dioxide and the urban soils really have lesser carbon storage also. Not only land take cause initial huge loss of carbon stock but also the same become a permanent decrease in carbon sequestration potential of the land removed. This study was also stressed the importance to develop appropriate methods for the assessment of impact of land take for urbanization and developments on carbon storage and thereby well-planned strategies and policies evolved is very essential. It was also suggested that impact of urbanization can be mitigated by preserving urban green areas (Strohbach and Haase, 2012). Strohbach *et al*. (2012) reported that about 37.3 and 44.1 Mg C ha^{-1} can be sequestered through the maintenance of 50 years long green space project in Germany. Russell and Kumar (2019) reported that if selection of trees having capacity of increased carbon sequestration like higher lignin composition supplied with efficient management methods can achieve a substantial storage of carbon even in the simulated tree crop ecosystem and agricultural fields. This is also options to mitigate adversities of urbanization through the removal of tree plantations. This is applicable in the in the case of rubber tree having higher lignin content for the selection of urban trees and the comparative ecofriendly nature of rubber ecosystem (Jacob, 2003a). It was also reported that the rubber ecosystem is a good candidate for plantation forestry with suitability of coming in Kyoto protocol (Jacob, 2005a). In the scenario of global warming and climate change, the importance of rubber ecosystem acting as a reasonably good carbon sink in terms of its relevance as plantation forestry was evident as reported by Jacob (2005a, b, c).

Kaul et al. (2010) reported that Indian forests can sequester 101 to 156 Mg C ha^{-1} in its biomass and are important CO2 mitigation options. Also the average carbon per hectare in soil comes to around 183 Mg C ha^{-1} in various types of forests in India. An average carbon stock at a depth of 0–1 m was reported as 20–25 Gt. In the process of urbanization, the development of an agroforestry system which means by preserving crops for agricultural purpose including various food crops, trees and vegetation diversity with higher carbon sequestration also should become a way out for mitigating the impacts of urbanization as well as providing the food sources from where the urban cities developed.

Conclusion

The observations from the study pointed out the serious carbon sink loss from the removal of rubber plantation for urbanization, one of the major development activities which are causing damages of the self-sustained carbon friendly and economically sound perennial rubber ecosystem. The present popular clone (RRII 105) existing in major share (85 per cent) of the total rubber cultivation in India accounts carbon sink loss 57 t ha^{-1}, 57.5 t ha^{-1}, 43.2 t ha^{-1} for 23 years and 148 t ha^{-1}, 75t t ha^{-1} and 62.1 t ha^{-1} from biomass, litter fall and sheet rubber respectively. The establishing modern clones RRII 414, RRII 429 and RRII 417 having higher growth rate and biomass recorded still higher (44–50 per cent) carbon sink loss compared to the existing popular clone RRII 105. The carbon sink loss in the form of stored carbon in soil is 56.5 t $ha^{-1}$with soil carbon content between 1.2 to 2 per cent. The total carbon sink loss for 23, 30 years were 214.2 and 341.5 t/ha respectively. Due to the growth variation in extreme climatic conditions, the clones recorded differences in carbon stock and thereby carbon sink loss. Among this the central region of Kerala (CES-Chethackal) showed higher loss and lower loss was in the drought affected northern region (Padiyoor) than Kanyakumari. The study helps to understand the huge loss of carbon and CO_2 mitigating capacity by removed rubber plantations and the importance of the steps taken as policy decisions to evolve remedial measures in the case of inevitable development activities and urbanization especially the high altitude tree plantation ecosystems.

Recommendation

The implications of the study pointed out the loss of huge reservoir of carbon in tree crop ecosystem and environment issues related to CO_2 mitigating capacity. It implies the need of close and strategic policies to the removal of long duration tree plantations with higher carbon sequestration potential especially in high altitude to maintain the environment sustainability. Also maintenance of simulated tree ecosystems with biodiversity rich and economically feasible green spaces must be a policy decision during urbanization.

Declarations

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Author Contribution

The research work was conceived, designed, executed and collection of data by three authors. The first author carried out the chemical analysis, data analysis, preparation of article and corrections in the manuscript.

Conflict of Interest

There is no conflict of interest from the authors for publishing of this manuscript.

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Tables

Table 1
Carbon content in sink sources of rubber plantation

Sink	C (%)
Leaf lamina	42.8
Petiole	47.19
Small twigs(fire wood)	40.18
Timber	38.50
Fine roots	45.98
Coarse roots	38.50
Sheet rubber	85.38
Seed (endosperm)	63.48
Fruit wall	46.35
Adopted from Jacob (2003)	

Table 2

Biomass, carbon stock (kg tree^{-1}) / carbon sink loss (t ha^{-1}) of RRII 400 series clones at 23 years age at RRII

Clone	Total dry biomass (kg tree^{-1})	C- stock/tree (kg tree^{-1})	C- sink loss by tree removal (t ha^{-1})
RRII 414	736	302	106
RRII 430	419	172	60
RRII 429	793	325	114
RRII 417	713	292	102
RRII 422	377	154	54
RRII 105	407	163	57
CD	41.35	14.47	5.06
Adopted from Ambily et al, (2012)			

Table 3

Biomass, C- stock (kg tree^{-1}) and C- sink loss (t ha^{-1}) of RRII 400 series clones (20 years) in diverse environments.

Clone	Total dry biomass(kg tree^{-1}) (Above ground)			Carbon stock (kg tree^{-1})			Carbon sink loss by tree removal (t ha^{-1})		
	PD	CES	KK	PD	CES	KK	PD	CES	KK
RRII 414	346.1 ± 29.1	627.6 ± 47.8	427.8 ± 29.1	145.3 ± 7.2	263.6 ± 20.1	179.7 ± 12.9	50.9 ± 2.5	92.3 ± 7.1	62.9 ± 4.26
RRII 430	290.8 ± 13.6	472.7 ± 32.5	319.6 ± 13.6	122.1 ± 2.1	198.5 ± 13.6	134.3 ± 5.7	42.7 ± 0.7	69.5 ± 4.8	47.1 ± 2.1
RRII 429	290.7 ± 109.3	695.8 ± 26.6	598.1 ± 109.3	122.1 ±6.6	292.3 ± 11.2	251.2 ± 45.9	42.8 ± 2.3	102.87 ± 3.9	87.9 ± 16.1
RRII 417	327.6 ± 37.9	615.8 ± 40.3	448.2 ± 37.9	137.6 ± 9.2	258.6 ± 41.4	188.3 ± 15.9	48.2 ± 3.2	90.5 ± 5.92	65.9 ± 5.6
RRII 422	281.7 ± 40.5	515.3 ± 20.3	406.7 ± 40.5	118.3 ± 8.9	216.4 ± 8.5	170.8 ± 17.1	41.4 ± 3.2	75.8 ± 2.98	59.8 ± 5.95
RRII 105	285.1 ± 20.9	465.63 ± 24.3	412.1 ± 20.9	119.7 ± 6.3	195.8 ± 10.9	173.1 ± 8.8	41.1 ± 2.2	57.9 3.05±	58.7 ± 4.52

*PD- Padiyoor (North); CES- Chethackal (Central); KK- Kanyakumari (South); ± mean standard error values

Table 4

Biomass, C- stock (kg tree^{-1}) and C- sink loss (t ha^{-1}) of RRII 203, GT 1 & RRII 105 at 30 years age at CES Chetackal.

Clone	**Total dry biomass (Above-ground) (kg tree^{-1})**	**Carbon stock kg tree^{-1}**	**Carbon sink loss by tree removal (t ha^{-1})**
RRII 105	1254	527	148
RRII 203	1140	479	138
GT 1	2045	860	258
Mean	1479.7	622	188
SE	285.1	119.9	31.8
Adopted from Ambily and Ulaganathan (2015) SE- standard error values			

Table 5

C- sink loss from soil (t ha^{-1})

Depth (cm)	**Average SOC (%)**	**Bulk density**	**Carbon sink loss from soil (t ha^{-1})**
0–30	1.2	1.2	43.2
„	1.5	„	54.1
„	2.0	„	72.2
Average			56.5

Table 6

Annual C- sink loss (t ha^{-1}) through litter fall in rubber plantation

Annual litter fall (t ha^{-1})	**Carbon content (%)**	**Carbon addition from litter fall (Annual- t ha^{-1})**	**Total carbon sink loss from litter fall (t ha^{-1}) (23 years) (30 years)**
Range - 5–6*	42.8	2–3	46–69 60–90
Average - (5.5)	-	(2.5)	(57.5) (75)
*Adopted from Philip *et al* (2005); values in parenthesis are average values			

Table 7

Annual C- sink loss (t ha^{-1}) through rubber sheet

Carbon content (%) (sheet rubber)	Sheet rubber production (t $ha^{-1}year^{-1}$)	Carbon stock in sheet rubber (t $ha^{-1}year^{-1}$)	Total carbon stock/sink loss from sheet rubber (t ha^{-1}) 23 years 30 years
85.38*	3.2	2.7	43.2 62.1
*Adopted from Jacob (2003)			

Table 8

Total C- sink loss by removal of rubber plantation (t ha^{-1})

Carbon sink sources	Carbon sink loss 23 years (t ha^{-1})	Carbon sink loss 30 years (t ha^{-1})
Tree biomass	57.0	148
Soil	56.5	56.5
Litter fall	57.5	75.0
Rubber sheet	43.2	62.1
Total	214.2	341.5

Figures

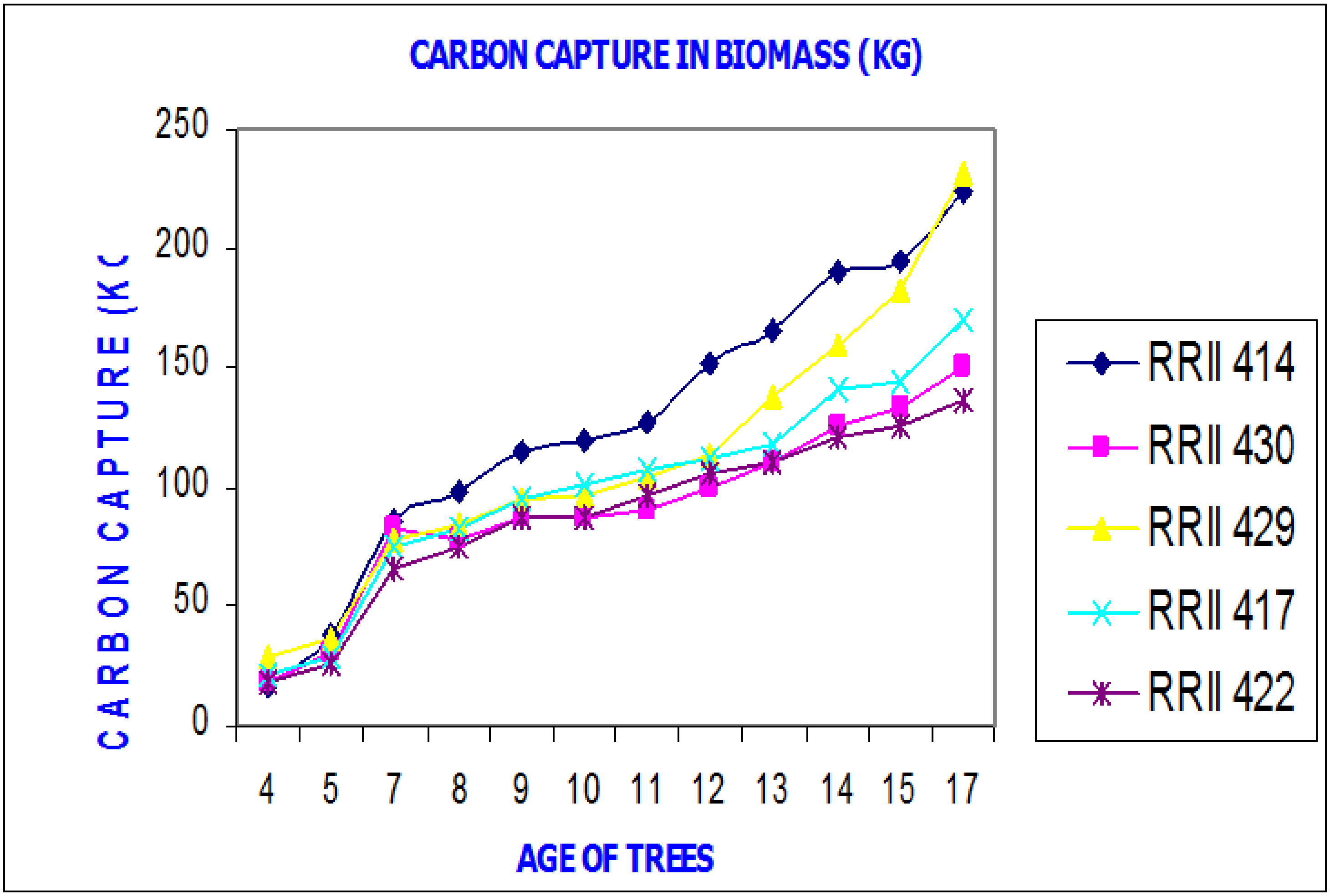

Figure 1

Growth curve showing the biomass accumulation and carbon capture in RRII 400 series clones.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- GJNRResearchSquareSuppli.filesFiguresandtables.docx