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DYNAMICS OF ROOT AND LEAF DECOMPOSITION IN CHRONOSEQUENCE OF RUBBER PLANTATION (*HEVEA BRASILENSIS*) IN SW CHINA

NIZAMI SYED MOAZZAM[1,2*], ZHANG YIPING[1] AND SHA LIQING[1]

[1]*Key Laboratory for Tropical Forest Ecosystem, Xishuangbanna Tropical Botanical Garden, CAS, Meglun 666303 Xishuangbanna-China*
[2]*Integrated Mountain Areas Research Centre, Karakoram International University, Gilgit 15100 Pakistan*
[*]*Corresponding author's email: moazzam@xtbg.org.cn; director.imarc@kiu.edu.pk*

Abstract

This study highlighted the dynamics of stand parameters as well as root and leaf litter decomposition in the chronosequence (49, 32, 24 & 12 years old plantations established in the year 1965, 1982, 1990 and 2002) of the rubber plantation in Xishuangbanna SW China. Litter trappers were installed on the study site to collect the leaf litter and litter bag experiment was carried out to investigate the rate of root and leaf litter decomposition. The study revealed significant variation of stand characteristics during the decomposition process. The monthly litter fall and root biomass (all categories; kg m^{-3}) showed positive correlation with stand characteristics and age. Remaining leaf litter mass % in the litter bags reduced with the passage of time and was significantly different in the chronosequence. The highest root decomposition rate (55%) was shown by fine roots and minimum (32%) by coarse roots during the study period. The investigations on elemental composition of the leaf and root provides basic important information for rate of nutrient cycle along with decomposition rate in rubber plantation and result are quite helpful for simulating the below ground carbon stock of rubber plantation in SW China.

Key words: Stand Characteristics, Decomposition rate, *Hevea brasilensis*, Chronosequence, Xishuangbanna.

Introduction

The decomposition of forest litter is ultimate source of providing organic as well as inorganic elements for cycling of the nutrients (Mudrick *et al*., 1994). This process is affected by climate factors, species composition, topography, litter fall quality; understory vegetation; soil acidity, fertility, litter quality and biological activities (Paudel *et al*., 2015, Zhang & Wang 2015). It is assumed that decomposition rate increases exponentially with temperature. For instance studies revealed that with every 10 degrees temperature increase results in increase of decomposition rate by a factor of 2. But it is also noticed that litter decomposition does not stop in winter even under snow depths, although its rate is low (Taylor & Jones, 1990). However, the effects of soil moisture are little bit complex with respect to decomposition rate. Decomposition is slower in dry soils because of the drying of bacteria and fungi too. In a wet soil its rate seemed low as well, because of anaerobic conditions. The rate of decomposition is high at optimal water contents.

The patterns of nutrient release vary from species to species. It is much more related to litter quality and variation in the climatic factors (Khiewtam & Ramakrishnan, 1993). For instance in deciduous forests the humus profile is normally thinner in comparison to coniferous forests (Van Wesemael & Veer, 1992, Nakane, 1995).

In recent years, number of studies have investigated the litter decomposition dynamics in different ecosystems. However, a comprehensive study on decomposition process of different root classes and leaf litter at different age has not been carried out in relation to stand parameters. Therefore this study was designed to understand the stand dynamics and decomposition process of roots and leaf litter in chronosequence of rubber (*Hevea brasilensis*) plantation at Xishuangbanna prefecture of south western China for generating basic information in carbon simulation study. The main objective of the study was: (1) To investigate the leaf and root litter mass loss at different ages (49, 33, 24 and 12 years old) of rubber plantation. (2) To determine the mineral-element concentrations and C-N-P relationships of all sized roots and leaves (3) To investigate the stand dynamics (leaf area index (LAI), dbh, basal area of trees, soil temperature, moisture %, pH and total carbon) (4) To determine the monthly litter fall and total root biomass in all the age groups.

Material and Methods

Study site: This study was carried out in rubber plantations situated in Xishuangbanna Tropical Botanical Garden (XTBG, 21º 41`N, 101º25`E), at the northern corner of the Asian tropical zone at 570 m ASL elevation. The MAT and MAR is 22˚C and 1496 mm respectively. The area enjoys typically seasonal climate driven by monsoon rainfall from the Indian Ocean. The area enjoys three prominent seasons *viz a viz* a cool-dry season (November–February), hot-dry season (March–April) and rainy season (May–October) (Cao *et al*., 1996).

Measuring stand characteristics

Soil temperature and moisture: In order to investigate the soil temperature and moisture %, temperature and moisture sensors were probed into the soil within the litter layer at sixteen different points on each site and data was collected once in a month.

Soil sampling (for investigating bulk density, pH and Soil Organic Carbon SOC): To investigate the relationship between decomposition rate and stand attribute in chronosequence, soil monoliths from the depth of 0- 20, 20-40, 40-60, 60-80 and 80-100cm were collected using an auger of 5cm diameter, once in each season (hot-dry, rainy and foggy-winter) during the entire study period. Moreover, soil bulk density (gm cm^{-3}) was also determined following standard protocol (Buckman & Brandy, 1960).

$$\text{Soil bulk density BD} = \frac{\text{Weight of soil (gm)/}}{\text{volume of the soil core (cm}^3\text{)}}$$

For determining soil pH and total carbon (g kg^{-1}), soil samples were dried at 65ºC for 48 hours. After that, each sample was sieved through 2mm mesh and send to laboratory for analysis. The soil pH and total carbon were determined by LY/T 1239-1999 and Vario MAX CN (Elemental Analysen systeteme GmbH (Germany) respectively.

Measuring leaf area index: Monthly leaf area index of the study plots was taken once in each month with the help of LAI-2200 Plant Canopy Analyser (LiCor Biosciences) during entire study period.

Trees DBH increment: In each plot, ten random trees were marked for estimation of diameter at breast height (dbh) and basal area (BA) increment throughout the study period (March 2014–February 2015). For this purpose a dendrometer were installed at breast height position (1.37m) and every month increase in diameter was measured with the help of digital calliper.

Litter fall: In each age group plot, 10 litter collectors of $1m^2$ were installed before the start of the experiment. These were at least 1m above the ground level. The 1mm nylon mesh was used to prepare these collectors. All the litter fall from the trees of every month was collected, dried and weighed.

Preparing the litterbags

Leaf litter: Leaf litter was collected before starting the experiment in January 2014 from the rubber *(Hevea brasilensis*) plantation of four different ages (49; 32; 24 and 12 years old). The leaves were flattened on the newspaper (to ovoid the breaking, moisten with distilled or deionised water) and oven dried for 1-2 days (Adams & Angradi, 1996).

Root biomass and leaf litter: Root litter was collected from the same areas by excavating soil from (70*65*50cm) $0.225m^3$. All the roots were brought to the laboratory and classified into three classes using digital calliper (Ironton® 6in. Stainless Steel Digital Fractional Calliper):

a) Fine roots (diameter <2mm)
b) Medium roots (diameter 2-10mm)
c) Coarse roots (diameter >10mm).

After classification they were placed in trays (according to size class) and dried in oven, set at 80ºC for 2 days. After that they were cooled in desiccators, and weighed again (dry weight). After removal from oven repeated weighing after every 5-10 hours was carried out to get constant weight. Attention was paid to ovoid the material from cook or char. The dry weight of roots was considered as their total biomass.

Litter bags both for leaf and root litter were prepared using nylon mesh size 1mm to estimate the relative loss rate constant (k) in the soil. The sizes of the bags and weight to be put for each root class and leaf litter were finalized after reviewing the literature. The sizes, weight and number of bags selected are given in Table 1.

Installing the litterbags: In each plot, 30 bags filled with leaf litter were placed over the soil surface to know the decomposition rate. A tag with initial weight was attached with each bag. The leaf filled mesh bags were also tight with some wood peg at some place and location was marked with an identification mark. It was decided that 5 bags will be collected after every 60th day.

For root litter bags 30 bags for each aged plantation were prepared (overall 120 for each root class) with the plan of removal at the rate of 5 bags of each class after every 60th day from the initiation of the experiment. A tag of the initial weight of roots was also put inside each bag. These bags were buried in the soil at a depth of 10cm in each plot at 6 different places (to be removed at a rate of 5 bags of each class after every 60th day).

After removal, every time all the bags were brought to the laboratory, dried, cleaned from soil and weighed for loss. Each of the content was separated and cleaned after removal from the mesh bag. Final weight was determined by subtracting the initial weight with the present weight.

Chemical analysis: The analysis for the mineral element contents in all the root sizes and the litter fall (including stem, leaves and branches) of the rubber plantation was also carried out with the root and litter samples collected at the start of the research. Chemical analysis was carried out after homogenizing and passing all the components through a 0.2 mm sieve. The atomic absorption spectrophotometry (GBC Scientific Equipment, Australia) was used to determine elemental composition. The famous micro-Kjeldahl method was followed to determine the contents of nitrogen (N) and phosphorus (P). In order to determine the organic carbon the wet digestion method was adopted (Vitti *et al*., 2016). Over all three replicates were prepared from each sample to carry out chemical analysis.

Table 1. Size and weight of the litter bags for different root categories.

S. No.	Category	No. of Bags	Size (cm)	Weight (gm)	Reference
1.	Fine roots (<2mm)	30*4=120	10*10	5	(Fujii & Takeda 2012)
2.	Medium roots (2-10mm)	30*4=120	10*15	10	(Olajuyigbe *et al*., 2011)
3.	Coarse root (>10mm)	30*4=120	30*30	100	(Lu & Sha 2009)
4.	Leaf Litter	30*4=120	20*25	10	(Tang *et al*., 2010)

Calculations and analyses: The following equation was followed to determine decomposition rate constant, k, from the decay curve (Beets *et al*., 2008).

$M_o / M_t = e^{-k*t}$
$\mathrm{Ln}\,(M_o / M_t) = k * t$

where M_o = initial mass of litter, M_t = mass of litter at time removal time, t = time for decomposition n (usually in years) and k = decomposition rate constant.

The percentage of decomposition at different times was also determined by the following equation:

$$R = (100 - 100 \text{ X } e^{-kt}) * 10\,0\ \%$$

Results and Discussion

Stand structure and dynamics: The average stem density (n ha^{-1}) in the rubber plantation was 430±10 trees ha^{-1} with 1.32 ± 0.40 average depth (cm) of leaf litter. The above ground litter fall (Mg ha^{-1} yr^{-1}) was 3.84±0.24 in all the ages.

Soil temperature and moisture: The monthly data recorded (March 2014-February 2015) for investigating the temperature dynamics at 10cm depth of the soil in all the aged groups. The highest temperature was in the month of June and July 2014 and the lowest was in January 2015 (Fig. 1). However, a significant difference ($p<0.001$) was pointed by the one way ANOVA for soil temperature among all the ages.

The monthly data recorded (March 2014-February 2015) for soil moisture dynamics at 5cm depth indicated that among all the plots, the highest moisture was in the month of August 2014 and the lowest in January 2015 (Fig. 2). However the one way ANOVA revealed that there were non-significant differences ($p>0.001$) on the soil moisture.

Soil bulk density, pH and total carbon: The results of the soil physio-chemical properties (bulk density g cm^{-3}); pH and total carbon (g kg^{-1}) in different seasons and at different depth in chronosequence of the rubber trees have been mentioned in Table 2. Data on soil properties were subjected to two way ANOVA for testing the differences due to sites (different aged plot) in different seasons and depths. A significant effect ($p<0.001$) was indicated within different depths and among the sites in all the seasons. The pH value during the hot, dry (summer) and cool dry (foggy) season was significantly different ($p<0.001$) among all the ages, but non-significant ($p>0.001$) during the rainy season. However, it significantly differs among depth within same age in all the seasons.

The two way ANOVA of the total carbon g kg^{-1} pointed out significant difference in total carbon ($p<0.001$) in chronosequence and different depths within and among the chronosequence of rubber plantation in all the seasons.

Leaf area index (LAI): The study revealed that LAI among all the ages of the rubber plantation differ significantly ($p<0.001$). The LAI showed an exponential growth curve. Among all the ages, it was at peak during the month of September and lowest in the February (Fig. 3).

The Pearson's correlation coefficients (*r*) between the age and LAI showed positive relationship and P-values <0.001. Among LAI values of all the months by different ages, 49 years showed maximum, while 12 years old plantation showed minimum values (Fig. 3).

The studies in the past have considered LAI as an index to model the dry matter accumulation and litter decomposition in rubber plantations (Hu *et al*., 1982, Xie 2009, Xie *et al*., 2010). The variation of LAI pointed out by our study is consistent with the phonological change of rubber trees in Xishuangbanna and Hainan Island (Chen *et al*., 2015). Moreover, our study revealed lowest value during February (1.44, 1.38, 1.27 and 1.18 respectively in the chronosequence) mainly because rubber trees shed their leaves during this time. Almost complete defoliation occurs during 2–3 weeks in winter in Xishuangbanna and Hainan had also been reported earlier (Righi & Bernardes, 2008). The reason for this may be lowering of air temperature and temporary drought. The trees start shedding leaves after the rainy season. This deciduous nature has been correlated positively with the age in addition to site conditions *viz a viz* nutrient supply and moisture etc. (He & Huang, 1987). In our study high values of LAI`s standard deviation pointed out in rainy season probably due handsome availability of nutrient to young trees for canopy development, while at the middle and mature age most of the nutrients are used in latex production instead of canopy development.

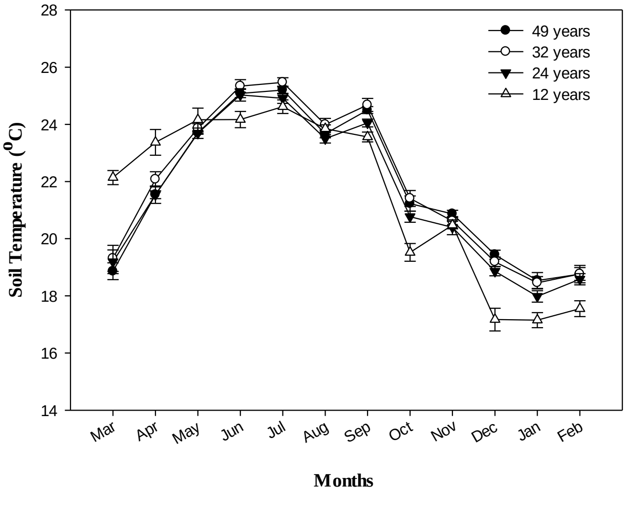

Fig. 1. Monthly soil temperature (°C) of the study plots.

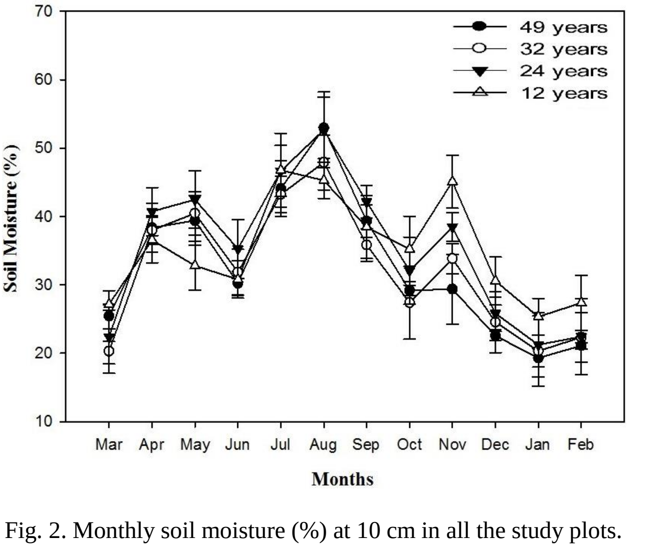

Fig. 2. Monthly soil moisture (%) at 10 cm in all the study plots.

Table 2. Soil Bulk density (g cm^{-3}), pH and Total Carbon (g kg^{-1}) in different seasons at five different depths in the study plots of different age.

	Age	Season	Property	Soil Depth (cm)				
				0-20	20-40	40-60	60-80	80-100
1.	49	Hot, dry	Bulk density	1.28	1.38	0.94	0.99	0.92
2.	32			1.06	1.46	1.41	1.50	1.49
3.	24			1.46	1.86	1.78	1.70	1.85
4.	12			1.29	1.34	1.92	1.36	1.99
5.	49	Rainy		1.41	1.58	1.59	1.66	2.03
6.	32			1.43	1.45	1.48	1.55	1.83
7.	24			1.30	1.47	1.51	2.04	2.21
8.	12			0.85	0.81	1.72	1.74	2.13
9.	49	Cold, dry		1.74	2.11	1.91	1.89	2.44
10.	32			1.79	1.89	2.42	2.44	2.77
11.	24			1.83	1.87	2.20	2.38	2.66
12.	12			1.67	1.98	2.15	2.92	3.36
13.	49	Hot, dry	pH	4.24	3.99	3.94	3.91	3.91
14.	32			5.33	5.31	5.31	5.59	5.63
15.	24			4.97	2.72	4.26	4.55	4.39
16.	12			4.97	4.93	4.73	5.05	5.32
17.	49	Rainy		4.25	4.27	4.3	4.32	4.3
18.	32			5.24	4.77	4.56	4.53	4.83
19.	24			5.34	5.79	5.39	5.16	5.24
20.	12			4.66	4.66	4.45	4.86	4.82
21.	49	Cold, dry		4.49	4.49	4.48	4.39	4.40
22.	32			5.41	5.61	5.96	5.95	6.11
23.	24			5.51	5.54	6.40	6.77	6.72
24.	12			4.98	5.09	5.18	5.13	5.27
25.	49	Hot, dry	T. Carbon (g kg^{-1})	15.13	13.47	9.57	9.21	7.59
26.	32			17.55	16.97	15.66	11.68	11.72
27.	24			16.02	11.57	8.32	6.05	4.56
28.	12			16.87	10.99	8.61	6.4	3.7
29.	49	Rainy		15.86	11.13	9.43	8.67	7.81
30.	32			15.65	12.06	9.99	8.03	5.97
31.	24			22.69	8.88	5.28	4	3.26
32.	12			21.62	12.03	4.13	2.87	2.36
33.	49	Cold, dry		19.72	12.12	10.02	8.40	8.10
34.	32			17.77	16.04	8.07	5.95	6.11
35.	24			23.23	12.50	9.43	7.85	6.57
36.	12			18.02	10.24	2.56	2.38	1.18

Tree DBH and basal area (BA) increment: Both the diameter and BA of the trees in all the ages showed an increment with the time (Fig. 4a & b). There was a significant difference ($p<0.001$) in both BA and DBH inherent across the months in all the age groups, as indicated by ANOVA.

Litter fall: The positive correlation was found between the amount monthly litter fall (t ha^{-1}) in all aged plots. A significant difference ($p<0.005$) was revealed by two way ANOVA in litter fall amount among and the ages during the entire study period. The maximum amount of litter fall in all the ages was in the month of January and minimum was in October (Fig. 5). Among all the age groups, the maximum monthly litter fall was in the 49 years old plantation followed by 32, 24 and 12 respectively

Litter fall being the initial stage of biogeochemical cycle in an ecosystem, considered as fundamental process in nutrient cycling and is the ultimate process of transferring organic matter and elements to the soil from the biomass (Robertson & Paul, 1999, Righi & Bernardes, 2008). Litter production also varied in different ecosystem as influenced by many factors (Vitousek *et al*., 1994). The litter accumulation of forest floor mass is usually low in moist topical forests and in many ecosystems usually 2 to 11 t ha^{-1}. Our experiment revealed an amount of litter fall equalled to 11.5, 11.25, 10.74 and 10.46 t ha^{-1} in 49, 32, 24 years old plantations In contrast, 9.85±1,04 & 9.23±1.29 Mg ha^{-1} of litter fall at 10 years old rubber plantation of Xishuangbanna South-western China was reported previously (Ren, 1999, Tang *et al*., 2010). Moreover, positive correlation was found between litter fall and increase in age. The correlation between the decomposition rate of litter with the soil temperature and moisture was also positively correlated in all the age groups, which were also consistent with the litter decomposition study of Tang *et al*., 2010 in the same ecology.

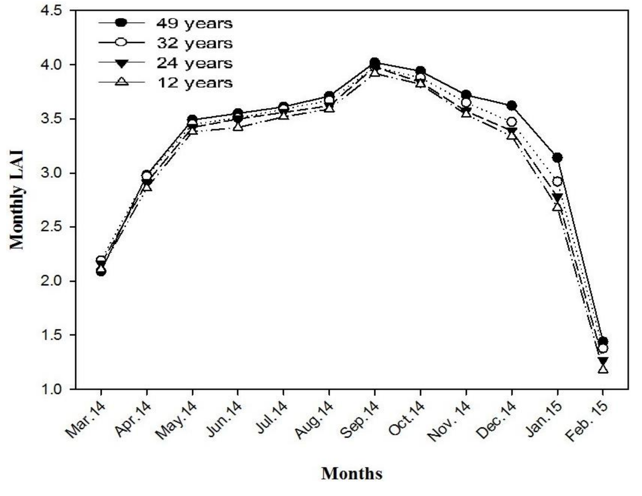

Fig. 3. The dynamics of LAI in all the study months during the study period.

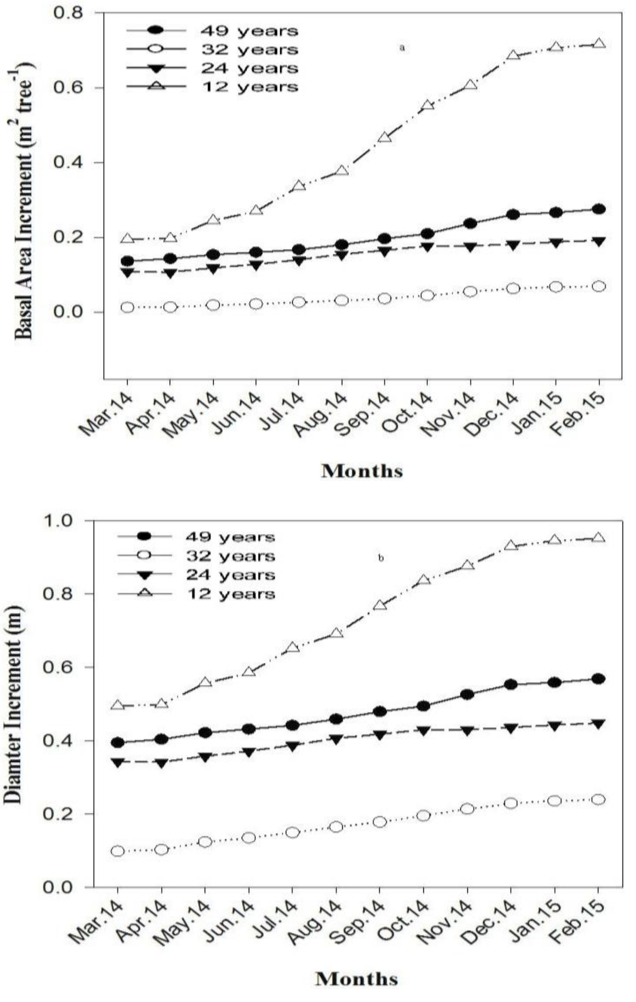

Fig. 4. a) Monthly Basal area increment (BA; m^2 $tree^{-1}$) and b) Monthly DBH (m) of rubber trees in all the ages during the study period.

Root Biomass: The average biomass of the fine roots having diameter <2mm (Value; kg m^{-3} ± SD) for the 0-50cm was maximum in younger 12 years old plantation, 1.0854±0.1456) and minimum in older 49 years old plantation (0.7766 ±0.0980). The biomass of the medium roots having diameter 2-10mm was maximum in the 22 years old plantation (1.37 ±0.10) and minimum (1.15±0.07) in the 32 years old plantation. However, the density of the coarse roots having diameter >10mm was maximum (47.2132 ±3.9920) in older plantation of 49 years and minimum (28.6974±2.6890) in the 32 years old plantation (Fig. 6). The ANOVA pointed out significant variation ($p<0.001$) in root density between the plots while Pearson`s correlation pointed out positive correlation among ages.

A positive correlation was observed for root biomass of fine (>2mm), Medium (2-10mm) and Coarse (>10mm) roots and age. The biomass of the fine roots ranged from 0.772-1.08 Kg m^{-3} which is slightly higher than the value reported for the tropical deciduous forests (Jackson *et al*., 1996). The dynamics of root biomass increases with age, which is consistent with the previous studies. For example, (Makkonen & Helmisaari, 2001) revealed higher root biomass in Scots pine (*P. sylvestris* L.) at exploitable age. However, disagreeing with these highest values of fine root biomass across a European beech chronosequence was found at intermediate-aged (Claus & George, 2005). It was pointed out that correlation between age and fine root biomass dynamics differ significantly with individual trees (Chen *et al*., 2004, Finer *et al*., 2007, Helmisaari *et al*., 2007, Finer *et al*., 2011).

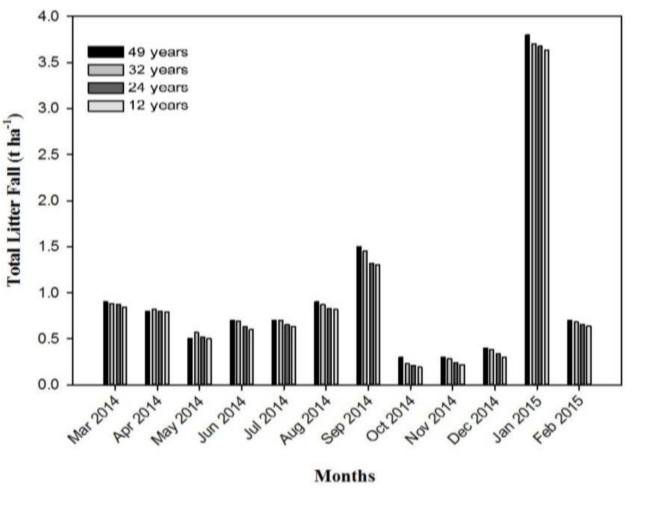

Fig. 5. The dynamics of total amount of litter fall (gm m^{-2}) during the study period in all the plots.

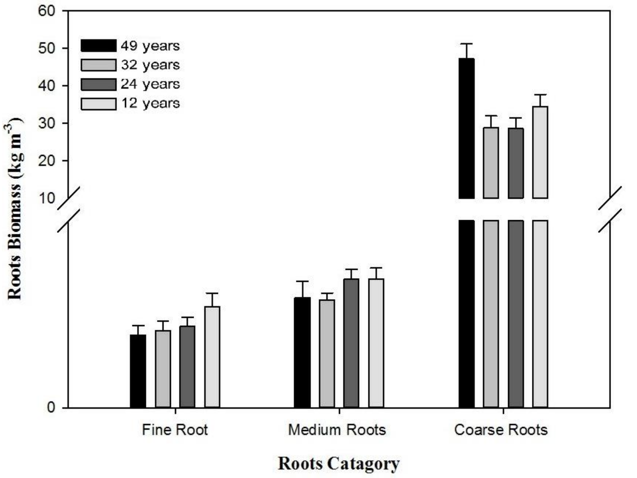

Fig. 6. Root biomass in all the aged plots at a depth of 0-50cm.

Root decomposition: The study revealed that in the chronosequence plots mass remaining % in the bags reduced with the passage of time. The fine root decomposed more quickly (45-55%) in all the aged plots. The ANOVA results showed significant difference ($p<0.001$) in decomposition rate of fine roots among all the ages (Table 3). The medium roots showed (19-37%) decomposition rate; while the coarse root category showed minimum 21-32% decomposition of initial mass during the study period. It was also revealed that there was no significant difference ($p>0.001$) in the rate of decomposition of coarse roots among all the ages (Table 2).

Overall, for the entire roots categories, the rate of decomposition was fast at the start of the experiment and gradually it decreased. The decomposition rate was highest in 32 years old plantation and minimum in the 12 years old plantation in case of fine roots (Fig. 7a). The rate of decomposition of medium roots was highest in 1990 plot and minimum in the 2002 plot (Fig. 7b). While in case of coarse roots highest decomposition rate was in 1990 and minimum in the 2002 plot (Fig. 7c). The significant effect ($p<0.001$) of age on decomposition of all roots categories was indicated by ANOVA.

Basically the rate of decomposition (R%) in all the root categories (Fine, Medium and coarse) of the chronosequence of the rubber plantation was same *viz a viz* slow in the start and then gradually increased (Table 2). Likewise, mass remaining % in all the roots categories was higher in the start of the experiment and then gradually decreased (Fig. 7a, b, c). The annual decomposition coefficient of fine (<2mm), Medium (2-10mm) and coarse roots (>10mm) in 1965 plot was 0.0019, 0.0012 and 0.0011. However, the annual decomposition coefficient of fine (<2mm), Medium (2-10mm) and coarse roots (>10mm) in 1982 plot was 0.0002, 0.0012 and 0.0009. Comparatively, the annual decomposition coefficient of fine (<2mm), Medium (2-10mm) and coarse roots (>10mm) in 1990 plot was 0.0019, 0.0015 and 0.0007 while the annual decomposition coefficient of fine (<2mm), Medium (2-10mm) and Coarse roots (>10mm) in 2002 plot was 0.0019, 0.0007 and 0.0019. The general decomposition coefficient of fine (<2mm), medium (2-10mm) and coarse roots (>10mm) in rubber plantation given by (Lu & Sha, 2009) are 0.0030, 0.0019 and 0.0017 which is comparable with this study. After completion of one year decomposition experiment the maximum loss rate was shown by fine roots among all the age classes with an average loss of 55%, while medium roots showed 42% while the coarse root loss was minimum 24%. The ANOVA revealed non-significant effect of age on the decomposition of different category of roots. Generally it is considered that smaller roots have more nutrient (N, P and K) concentrations which lead to high rate of decomposition (Usman *et al*., 2000, Yang *et al*., 2004). However, studies in the past had revealed rapid decomposition of large sized roots despite lower nutrient concentrations (50% lower N in larger roots; McClaugherty *et al*., 1984).

Leaf litter decomposition: The leaf litter decomposition revealed that in all the chronosequence plots remaining mass % in the bags reduced with the passage of time. The decomposition rate was highest (37%) in 32 years old plantation and minimum (16%) in 2002 plot (Fig. 8). The ANOVA pointed out that there was a significant difference ($p<0.001$) in the rate of decomposition of leaf litter among all the ages (Table 4). Overall, among all the ages the rate of leaf litter decomposition was fast at the start of the experiment and gradually it decreased. The coefficient of decomposition (K) of each plot is presented in Table 4.

Elemental composition in leaf litter and roots: The chemical analysis of the leaf and roots of rubber trees revealed that leaves have 527.41 ±1.77 (g kg^{-1}) of Carbon. Among the different categories of roots, coarse roots have maximum carbon concentration (Table 5). The N concentration was highest in fine roots as compare to medium and coarse roots. However, the highest C: N ratio was also showed by coarse roots while fine roots showed highest N: P ratio.

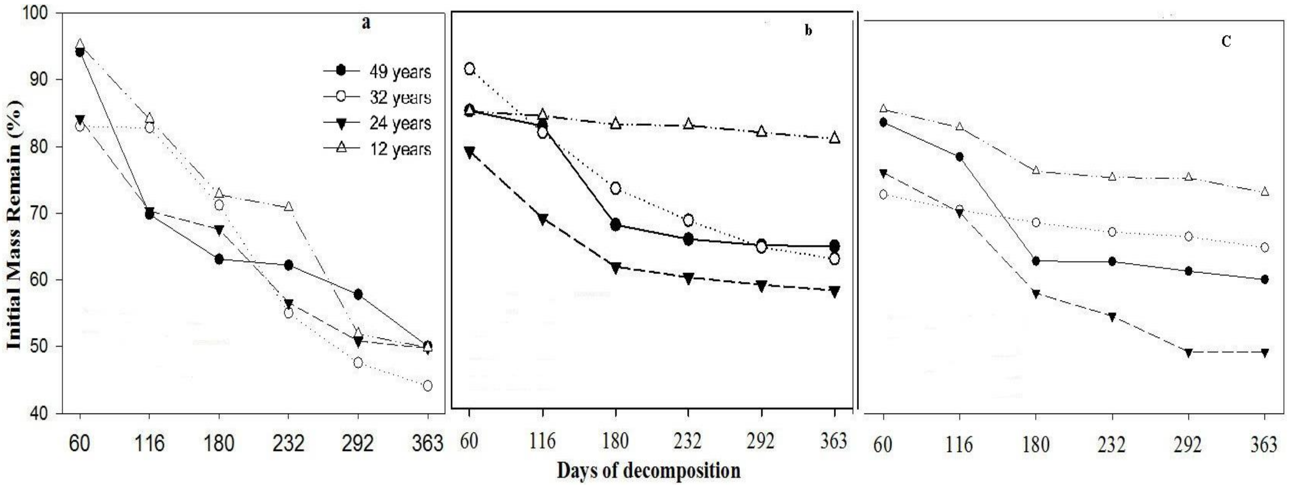

Fig. 7. Decomposition percentage of the Initial Mass of a) fine root <2mm diameter; b) medium roots 2-10mm diameter and c) coarse roots >10mm during the entire study period.

Table 3. Decomposition coefficient (κ) and percentage of dry mass loss (R%) for all roots category in chronosequence of Rubber plantation during different days of decomposition.

S. No.	Age	Root category	Property	Removal Day					
				60	116	180	232	292	363
1.	49	Coarse	K	0.0023	0.0016	0.0020	0.0015	0.0013	0.0011
			R%	12.95	17.33	30.57	30.62	31.85	32.92
		Medium	K	0.0026	0.0016	0.0021	0.0018	0.0014	0.0012
			R%	14.91	17.22	32.17	34.33	35.26	35.41
		Fine	K	0.0009	0.0030	0.0025	0.0020	0.0018	0.0019
			R%	5.77	30.15	36.86	37.79	42.18	49.94
2.	32	Coarse	K	0.0041	0.0023	0.0011	0.0011	0.0010	0.0009
			R%	22.11	24.03	18.95	22.88	27.45	28.83
		Medium	K	0.0014	0.0017	0.0017	0.0016	0.0015	0.0012
			R%	8.59	18.20	26.65	31.47	35.52	37.32
		Fine	K	0.0030	0.0016	0.0018	0.0025	0.0025	0.0022
			R%	16.92	17.17	28.76	44.96	52.42	55.87
3.	24	Coarse	K	0.0035	0.0024	0.0023	0.0008	0.0008	0.0007
			R%	19.32	24.37	34.66	17.55	22.11	24.14
		Medium	K	0.0039	0.0032	0.0027	0.0022	0.0018	0.0015
			R%	21.04	31.13	38.52	40.14	41.28	42.11
		Fine	K	0.0028	0.0030	0.0021	0.0024	0.0023	0.0019
			R%	15.85	29.63	32.39	43.40	49.18	50.24
4.	12	Coarse	K	0.0008	0.0014	0.0017	0.0014	0.0022	0.0019
			R%	11.30	13.59	19.15	19.94	19.99	21.83
		Medium	K	0.0027	0.0014	0.0010	0.0008	0.0006	0.0005
			R%	14.99	15.67	16.99	17.12	18.18	19.14
		Fine	K	0.0008	0.0014	0.0017	0.0014	0.0022	0.0019
			R%	4.74	15.87	27.18	29.16	48.10	50.16

Table 4. Decomposition coefficient (κ) and percentage of dry mass loss (R %) for leaf litter in chronosequence of Rubber plantation during different days of decomposition.

S. No.	Age	Property	Removal day					
			60	116	180	232	292	363
1.	49	K	0.0027	0.0017	0.0018	0.0014	0.0013	0.0011
2.	32		0.0007	0.0016	0.0021	0.0018	0.0015	0.0013
3.	24		0.0007	0.0012	0.0010	0.0009	0.0007	0.0006
4.	12		0.0007	0.0011	0.0009	0.0007	0.0006	0.0005
5.	49	R%	15.0660	18.5769	28.2235	28.6533	31.6045	33.7718
6.	32		4.1231	17.1404	31.0660	34.0549	35.3105	37.3434
7.	24		3.9399	13.2121	16.3355	18.5202	19.1128	20.4789
8.	12		4.1231	11.6836	14.5417	14.6056	15.6163	16.1167

Table 5. The concentration of mineral contents (g kg^{-1}) in all sizes roots and leave litter in Rubber Plantation (mean ± SE).

Minerals	Root categories			Litter fall types		
	Fine	Medium	Coarse	Stem	Leaf	Branch
C	377.8 ± 5.34	465.87 ± 4.56	475.33 ± 3.49	474.89 ± 4.09	527.41 ± 1.77	465.37 ± 3.45
N	15.39 ± 1.45	8.04 ± 0.99	6.1 ± 1.33	3.88 ± 0.99	31.09 ± 1.78	6.72 ± 2.56
P	2.31 ± 0.08	1.44 ± 0.07	1.83 ± 0.09	0.98 ± 0.01	4.19 ± 1.19	1.65 ± 0.67
K	7.14 ± 1.1	5.39 ± 1.49	6.62 ± 1.57	3.65 ± 0.87	12.98 ± 2.09	4.71 ± 0.45
C: N ratio	24.55 ± 2.44	57.94 ± 3.03	77.92 ± 3.99	122 ± 1.34	16.96 ± 3.24	69.25 ± 3.67
N: P ratio	6.66 ± 3.38	5.58 ± 1.34	3.33 ± 0.96	3.99 ± 1.01	7.42 ± 1.86	4.07 ± 1.00

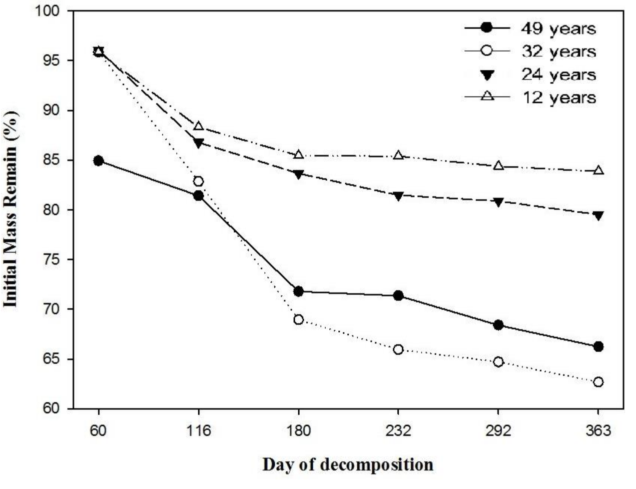

Fig. 8. Decomposition percentage of Initial Mass of leaf litter in chronosequence of rubber plantation during the entire study period.

Conclusions

Despite of renowned importance of roots and litter in influencing forest carbon and nutrient cycling, the investigations on correlation between roots and leaf litter decomposition rates are still limited. A novel contribution of this study is the simultaneous discovery of the patterns of stand dynamics, litter fall and decomposition of three categories of root (fine, medium & coarse) in the chronosequence of rubber plantation of Xishuangbanna South Western China. The results showed among the chronosequence there is significant variation in soil temperature at 5cm depth but the soil moisture % is non-significant. For different age groups, all the soil physio chemical properties (Bulk density, pH and Total Carbon) varied significantly. The LAI, root biomass (fine, medium & coarse), leaf litter fall positively correlated with chronosequence. There is non-significant effect of age on the decomposition of particular root category but significant effect was found within same age for different root (fine, medium, coarse) categories. So in carbon simulation studies the rate of decomposition and input of carbon by different roots categories can be considered subsequently in case of rubber trees.

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