BIOMASS GROWTH AND FARMER KNOWLEDGE OF *INGA EDULIS* IN PERUVIAN AMAZON

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Abstract

Inga edulis Mart. is popular with agroforesters for its rapid growth, tolerance of acid soils and high production of leafy biomass to control weeds and erosion. The objective was to determine the aboveground biomass growth of I. edulis, its correlation with other growth parameters and find out farmer knowledge about this species in Peruvian Amazon. The destruction analysis of 35 samples of Inga trees was done; the tree age was important criterion for selection. Trunk diameter at 10 cm, height of tree, and some other measurements were done. After cutting of trees, litter, leaf and wood biomass were collected and weighed. Data from destructive analysis were statistically analysed and highest correlation between parameters was sought. Best results were obtained when power function was used. Highest correlations were reached for dependence between wood biomass and diameter at 10 cm: $y = 0.0466x^{2.3713}$*;* $R^2 = 0.9235$*. It seems, that diameter of trunk is a more useful indicator of growth and biomass production than height. Short semi-structured interviews were also done with 20 farmers to determine farmer knowledge and use of this tree. Local farmers use this species mainly for fruit and fuelwood production, as a shade tree and highly valued is also ability to improve soil fertility.*

Key words: *Inga edulis* Mart., biomass growth, destruction analysis, Peruvian Amazon, correlation analysis, farmer knowledge

INTRODUCTION

Amazon rain forest has witnessed high rate of deforestation during the last 3 decades. The major cause of this deforestation is traditional small-scale shifting cultivation with the farmers using mainly slash-and-burn methods. Approximately 0.5% (350 000 ha) of the Peruvian Amazon is converted to cropland or pastures each year (TCA 1997), with greatest rates of deforestation occurring around population centres, such as Pucallpa, the capital of Ucayali region. Slash-and-burn agriculture is the primary cause of this deforestation. However, traditional slash-and-burn (or shifting cultivation) systems with prolonged fallow periods are no longer feasible in most parts of the tropics, farming systems that imitate in part the structure and processes of natural forest vegetation, such as agroforestry systems, have high potential to increase the productivity of farming systems and sustain continuous crop production (Stark 2000;Fagerström 2000).

One of the possible alternatives is utilization of native shrubs and trees. In a recent survey in the Ucayali region of the Peruvian Amazon, it was discovered that farmers and indigenous population use 155 tree species (Weber *et al.* 1997) for firewood, charcoal, construction materials, fibre, resin, fruit, medicine or other purposes. One of the most highly valued species by farmers is a leguminous tree *Inga edulis*, native in Amazonia (Villachica 1996) and locally known as *guaba*. *Inga* is a large genus of leguminous shrubs and trees found troughout tropical Latin America. Of the more than 100 species in the genus, *Inga edulis* Mart. is one of the most widely distributed and economically useful. In Latin America this fast growing, acid-soiltolerant tree, which improves soil fertility through nitrogen fixation, is traditionally used to shade perennial crops such as coffee and cacao, provide firewood and charcoal, and produce a sweet pulp suitable for human consumption (Flores 1997, Weber *et al.* 1997). More recent research has shown that *I. edulis* is also useful as a green manure with its high biomass production and helps control weeds and erosion in alley cropping and other agroforestery systems (Szott 1987; Alegre 1991; Salazar and Palm 1991; Fernandes *et al*., 1991).

For the follow-up studies the correlation between tree growth parameters and biomass production are needed to know. Previous work focused on that was done in Peruvian Amazon near Yurimaguas (Szott 1987; Szott *et al.* 1994) and in Costa Rica (Lawrence *et al.* 1995), where ecological and socio-economic conditions are different to our study. Our first objective was to determine amount of litter, leaf and wood biomass of *I. edulis* in Peruvian Amazon Basin around the city of Pucallpa and determine regression functions by analysing the data of 35 sample *Inga* trees. Data from destructive analysis were used to formulate regression between litter, leaf and wood biomass and diameter at 10 cm above ground, age, or height of tree. Allometric equations based on diameter at 10 cm aboveground, age or height of tree were developed from this sample in order to predict the biomass of the litter, leaves and wood. Second objective of our study was focused on farmers' use of *I. edulis* in study area, using semi-structured interviews.

SITE DESCRIPTION

The study was performed in two villages – Antonio Raimondi and Nueva Belén – located 20 km and 23 km respectively outside the city of Pucallpa in the Amazon basin of Peru (74°W, 8°S, with an average elevation of 150 m a.s.l). Pucallpa is characterized by hot and humid climate and only slight variation throughout the year. The rainfall ranges from 1500 to 2100 mm (a mean of 1546 mm in Pucallpa, with rainfall increasing to the west). Wet months are February – May and September – November; dry months are June – August and December – January. The mean annual temperature is 25.7°C, and mean annual relative humidity reaching 80%. Soil include alluvial, seasonally flooded, riverine systems Entisols (Fluvisols according to FAO/UNESCO classification system), with pH about 7 and average available P levels; and higher located, well-drained forest areas of acidic Ultisols (Acrisols according to FAO/UNESCO classification system) with very low available P levels. Trees of *I. edulis* are generally found on these upland soil, because this species does not withstand flooding. The drainage of the upland soils is good to moderate, with low content of organic matter and medium to high texture. The base saturation varies from 35-40%, while aluminium saturation is 30% to 70% (Tab. 1.). These upland soils lack sufficient essential nutrients for sustainable, repeated harvests of trees and annual crops. The upland terrain is usually flat or undulating. In general, these soils are of low quality for agriculture. The original vegetation is tropical semi-evergreen, seasonal forest, now largely affected by current farming practices.

Antonio Raimondi and Nueva Belén are examples of communities of households using traditional way of slash-and-burn farming for their livelihood. Most of the former forests are already cut down and large areas around the village are degraded fields covered by *Imperata* spp.. Farmers establish their fields either on the already degraded plots or look further away for rest of the forested land to clear it and open a new field.

MATERIALS AND METHODS

Inga edulis at study site

I. edulis is grown by farmers in study area as a component of their homegardens. The species is also naturally found in the remaining patches of primary forest and is also one of the species which naturally occur in fields left to fallow during shifting cultivation cycle. Local farmers also use other species of *Inga* genus, e.g. *Inga feuillei* DC. locally known as *pacay*, but not so widely as *I. edulis*. For this study only representative, clearly identified trees of different age and size which were found on farmers' fields and their homegardens were used.

Destruction analysis

For determination of tree aboveground biomass destruction analysis of 35 samples of *Inga* trees were used (06/30/2004 – 11/09/2004). This supposed co-operation with farmers, who were disposed to allow cut the trees on their plots, and also were able to tell age of each tree. It was also important criterion to cut the trees with different age for estimation of dependence between amounts of biomass on age. All trees were chosen in homegardens, where farmers plant them with other crops (annual and perennial), such as sugar cane, pineapple, coffee, cocoa, citruses, other fruit trees, etc.

As the trial was aimed on estimation of production of litter, leaf and wood biomass, collect litter biomass under crown of focused tree was done first. Collected litter biomass was given to sack and then weighted. Before cutting the tree, the diameter of main trunk at height of 10 cm above ground level and diameter of the trunk at a height of 1.3-1.5 m above ground level (diameter at breast height or dbh) were measured. The criterion used to select individuals of woody plants is usually measurement of the diameter of the trunk at dbh. But since *Inga* commonly branches close to the soil surface, dbh is not a good parameter for estimating biomass, then diameter at 10 cm is better to use for calculation of regression equations. Measurement of circumference of the trunk at heights 10 cm and dbh., height of 1. branching, height of tree, height of crown and width of crown was also measured. All this measurements was done with a standard tape in centimetres.

Subsequently the tree was cut with a chainsaw. From fallen tree, green leaves were collected and weighted with same technique as litter biomass. Trunk and branches were divided for smaller pieces and then weighted with Roman balance.

Dry matter of the litter, foliage and wood was calculated by weighing the fresh fractions and taking 10 grams sub-samples of litter and leaves, and 20 grams of wood for determination of percentage dry matter. These samples were determined by weighted with digital scales (max. 100 grams, difference 0.1 gram). These samples were dried to a constant weight in a forced air drier (max. 106°C) and then weighted. Weights of particular fresh biomass fractions (means litter, leaf and wood biomass) were then converted on weights of dry matter. In EKO-LAB Žamberk (Czech Republic) the content of basic elements (N, P, K) for random samples of particular biomass fractions were determined.

Statistical analysis

For statistical processing of measured values PC-program Excel (Microsoft) was used. Regression equations and coefficients were calculated for the relationship between litter, leaf or wood biomass and age, height or diameter at 10 cm.

Semi-structured interviews

To bring out the experiences with utilization of *I. edulis* trees among small farmers in study area we have chosen 20 of them for a simple semi-structured interview. The farmers were interviewed during 4 weeks in September 2004. The time spent with each farmer was between 30 and 60 minutes, depending on the interest – how much they specified each answer, language difficulties and if a visit of the plot was included.

RESULTS

Biomass growth

I. edulis produce high quality biomass, especially fresh leaves show high N content (Tab. 2.). Regression equations with coefficients of correlation are presented in table 3. A variety of linear, exponential, quadratic and power functions were fit to the data and the best-fitting equations selected. Best results for regression and correlation analysis were obtained when power function was used. Highest correlation for wood biomass was obtained for dependence between wood biomass and diameter at 10 cm: $y = 0.0466\ x^{2.3713}$; $R^2 = 0.9235$ (Fig. 1.). Also for leaf biomass high correlation was obtained for dependence on the trunk diameter: $y = 0.1564\ x^{1.1817}$; $R^2 = 0.7915$ (Fig. 2.). For litter biomass equation for dependence on the height of tree is: $y = 0.0344\ x^{2.481}$; $R^2 = 0.7733$ (Fig. 3.). On the other hand for dependence of litter biomass on tree age equation $y = 0{,}1035x^{2{,}021}$ with lower correlation $R^2 = 0{,}6137$ were obtained. Equally lower correlation for dependence between leaf biomass and height of tree were obtained: $y = 0{,}2735x^{1{,}5367}$; $R^2 = 0{,}6482$.

Semi-structured interviews

Semi-structured interviews with 19 questions were analyzed. Here are the answers of 20 interviewed farmers for more important questions:

1. What are the main purposes for growing *I. edulis*? - Majority of farmers mentioned more than one reason. Fruit and fuelwood was mentioned by all 20 farmers (100%); soil improvement by 19 (95%) farmers; shade tree by 18 farmers (90%); fodder for animals by 10 (50%) farmers and weed protection by 6 (30%) farmers;. Responses on this question show, that farmers knows about advantages of this tree and for this reason we can include *I. edulis* into multi-purpose trees.
2. How many trees of *I. edulis* do you have on your plot? - Three farmers (15%) grow up to 10 trees; seven farmers (35%) between 10 to 50 trees; three farmers (15%) grow between 50 to 100 trees; five farmers (40%) grow between 100 to 200 trees and two farmers (10%) grow more than 200 trees on their plots.
3. On which places *I. edulis* grows well? – 12 farmers (60%) claim that this species can be grown only on upland sites without flooding. 8 farmers (40%) think that it can be grown everywhere.
4. How do you establish this species and when? – All farmers establish *I. edulis* directly by seeds. 11 farmers (55%) answer that it can be established during whole year, 9 farmers (45%) would prefer only rainy season.
5. Do you grow *I. edulis* with other trees and crops? - Twenty crops were mentioned. They are listed in Table 4.
6. What maintenance is required? – 18 farmers (90%) make regular weeding, especially in initial phase of growing. 11 farmers (55%) make also some pruning and coppicing.
7. When starts fruit production? - Trees can start produce the fruits the first year of age – 6 farmers (30%); the second year – 9 farmers (45%); the third year – 5 farmers (25%).
8. How often is harvest? – 6 farmers (30%) harvest *I. edulis* tree times a year, 11 farmers (55%) two times a year; 2 farmers (10%) once a year and one farmer claim that it can be harvested whole year.
9. How long do you utilize the tree for production? - 4 farmers (20%) mentioned up to 5 years; 7 farmers (35%) mentioned up to 10 years; 9 farmers (45%) mentioned more than 10 years. Dry and unproductive trees farmers often cut down.
10. How many pods can produce one tree in one year? - Up to 100 pieces fruits per year – 4 farmers (20%); up to 200 pieces – 8 farmers (40%); up to 300 pieces – 5 farmers (25%); up to 500 pieces – 2 farmers (10%); up to 1000 pieces – 1 farmer.
11. What do you do with the pods? - Both main responses (market and direct consumption) were mentioned by all farmers. All farmers also confirm that there is a good market for pots in Pucallpa. Some kind of processing like juice, fresh drink, cream and yogurt.
12. What is the price for one hundred pods on Pucallpa market? - Range of 4 – 25 Peruvian Sols (US$ 1.2 – 7.7) per 100 fruits were mentioned, but the range S/. 10 – 20 were mentioned most frequently (six times). Farmers listed, that prices depend mostly on quality of the fruits and season when are sold.
13. What is durability of pods? - Up to three days is claimed by 8 farmers (40%); up to five days by 5 farmers (25%) and up to one week by 7 (35%).
14. Exists some pests and diseases or other negative factors for *I. edulis?* - Farmers mentioned five different pests, but they can't specify diseases. Responses are shown in Table 5.
15. Is *I. edulis* resistant to fire? – 14 farmers (70%) reported no resistance; however 6 farmers (30%) claimed that after burning it can resprout again.

DISCUSSION

Only few studies focused on correlation between tree growth parameters and biomass production of *I. edulis* were done (Szott 1987; Szott et al. 1994; Szott et al. 1995; Lawrence *et al.* 1995). They reported that the highest correlation was found between diameter of trunk at 10 cm and biomass growth, as also confirmed by our results. Thus, it seems, that diameter of trunk is a more useful indicator of growth and biomass production than height. The difference in-between the studies in that Szott (1987) reached highest regression coefficient using linear function, Lawrence *et al.* (1995) using quadratic function and in our study using power function.

I. edulis is in the study area grown by farmers mainly for production of edible and easily marketable fruit, which is reported nearly in every study made about this species (Flores 1997; Lawrence *et al.* 1995; Szott *et al.* 1995; Villachica 1996; Weber *et al.* 1997; etc.). The fresh pulp surrounding the seeds in a long pod is eaten mostly fresh or it can be easily processed to juices, creams and yoghurts, but it is not very common. The fresh fruit is perishable and farmers claim that it can be stored only up to several days, which is also mentioned by Villachica (1996). The trees are producing fruits twice a year around Pucallpa and harvest is usually around 200 to 300 pods per one tree, generally same amount reported by Flores (1997).

Other useful product mentioned by authors is fuelwood, which also confirms our study. Nearly all farmers use *I. edulis* fuelwood but mainly for their own needs. Market for *Inga* fuellwood is not developed in Pucallpa, as in other places (Lawrence at al. 1995), because better quality fuelwood is available in the area. The use of *Inga* for crop shade (mainly in coffee and cocoa plantations) has a long history and now *Inga* species are the most popular shade trees in most neotropical countries (Escalante et al. 1987; Lemckert and Campos 1981; Williams 1981). Also farmers around Pucallpa use this species very widely as a shade tree and almost all farmers grow *I. edulis* in combination with other trees and crops. Many farmers also value this spices as a soil improver. Nearly all farmers have at least some trees on their fields, usually up to one hundred, which they grow usually up to 20 years, because after then production of fruit is low. This fact is also reported by Flores (1997). Most farmers claim that *I. edulis* is mainly grown on up-land sites without flooding and it is susceptible to fire; even though some argue that if burnt it can resprout. Nearly all farmer use for establishment direct sowing, because seeds germinate very easy and survival rate is high, in opposition, most author in literature recommend the use of seedling (Flores 1997; Szott *et al.* 1995; Villachica 1996; Weber *et al.* 1997; etc.).

Most interviewed farmers claimed that trees need regular weeding, especially during establishment phase. About half of the farmers also do pruning and coppicing and some use a manure for better growth. According to farmers *I. edulis* can start to produce fruit during the first 3 years after establishment. Flores (1997) reported that fist pots can be produced in 2nd year, however Villachica (1996) reported 3rd and 4th year.

CONCLUSION

Equations for biomass growth of *Inga edulis* were determined and the best results were obtained for dependence on diameter of trunk at 10 cm. In agroforestry and ecosystem studies, the methods of a more accurate biomass determination are increasingly important and their results serve as a basis for a number of follow-up studies including element cycling, modelling of agroforestry systems and especially in this case possibility of weed protection. It is evident, that *Inga* is multipurpose tree popular among the farmers throughout the region with great importance. Most farmers in the study site use it for fruit and fuelwood production, as a shade tree and highly valued is also its ability to improve soil fertility.

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TABLES

Tab. 1.: Physical and chemical analysis of the soil at study site

depth	clay	loam	sand	texture	pH	Cox	CEC	N	P avail.	P tot.	K	Ca	Mg	Al	BD
cm	%	%	%		$CaCl_2$	%	mmol/kg	%	ppm	ppm	ppm	ppm	ppm	ppm	g/cm^3
0-10	18	33	45	loamy	4.1	0.92	84.52	0.127	6.5	205.0	156.5	245.5	95.5	0.48	1.3
10-30	20	35	45	loamy	3.9	0.51	79.14	0.091	4.,5	155.5	59.0	94.0	30.0	0.77	1.4
30-50	22	39	39	loamy	3.9	0.36	97.25	0.094	4.5	179.0	46.0	48.0	20.0	2.28	1.5

Notes: CEC…cationt exchange kapacity, BD…bulk density; C_{ox} - Nelson & Sommers; P avail., K, Ca, Mg, CEC – Mehlich III; P tot. – Sokolov; N – Leco, Al – mineralization in H_2SO_4

Tab. 2.: Chemical analysis of plant material

plant part	N %	P %	K %
Inga edulis			
leaves	3.18	0.17	0.87
wood	0.36	0.02	0.44
litter	2.20	0.09	0.31

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Tab. 3.: Regression equations and coefficients of correlation.

Dependence	*Regression equations*	*Regression coefficients*
litter / diameter	$y = 0.0244x^{1.6954}$	$R^2 = 0.7457$
leaf / diameter	$y = 0.1564x^{1.1817}$	$R^2 = 0.7915$
wood / diameter	$y = 0.0466x^{2.3713}$	$R^2 = 0.9235$
litter / age	$y = 0.1035x^{2.0211}$	$R^2 = 0.6137$
leaf / age	$y = 0.3621x^{1.5228}$	$R^2 = 0.7611$
wood / age	$y = 0.2611x^{3.03}$	$R^2 = 0.8732$
litter / height	$y = 0.0344x^{2.481}$	$R^2 = 0.7733$
leaf / height	$y = 0.2735x^{1.5367}$	$R^2 = 0.6482$
wood / height	$y = 0.1122x^{3.2312}$	$R^2 = 0.8304$
height / age	$y = 1.7067x^{0.7532}$	$R^2 = 0.6784$
diameter / age	$y = 2.2931x^{1.2081}$	$R^2 = 0.8452$
height / diameter	$y = 1.0385x^{0,6155}$	$R^2 = 0.7824$

Tab. 4.: Crops associated with *I. edulis* listed by farmers

Parallel crops	*Frequency*	*Percentage*
Citrus spp.	8	40%
Coffea arabica (coffee)	7	35%
Theobroma cacao (cacao)	5	25%
Manihot esculenta (cassava)	5	25%
Ananas comosus (pinaple)	5	25%
Pouteria caimito (caimito)	5	25%
Musa spp. (bananas and plantains)	5	25%
Pipper nigrum (pepper)	4	20%
Poraqueiba sericea (umarí)	4	20%
Pueraria phazeoloides (kudzu)	2	10%
Mangifera indica (mango)	2	10%
Mauritia flexuosa (aguaje)	2	10%
Zea mays (maize)	2	10%
Bactris gasipaes (pijuayo)	2	10%
Myrciaria dubia (camu camu)	1	5%
Rollinia mucosa (anona)	1	5%
Annona muricata (guanabana)	1	5%
Psidium guajava (guayaba)	1	5%
Saccharum officinarum (cana)	1	5%
Averrhoa carambola (carambola)	1	5%

Tab. 5.: Pests listed by farmers

Pests and diseases	*Frequency*	*Percentage*
ants	20	95%
caterpillars	17	81%
parrots	15	71%
monkey	8	38%
butterflies	1	5%
non-specific	7	33%

Figures

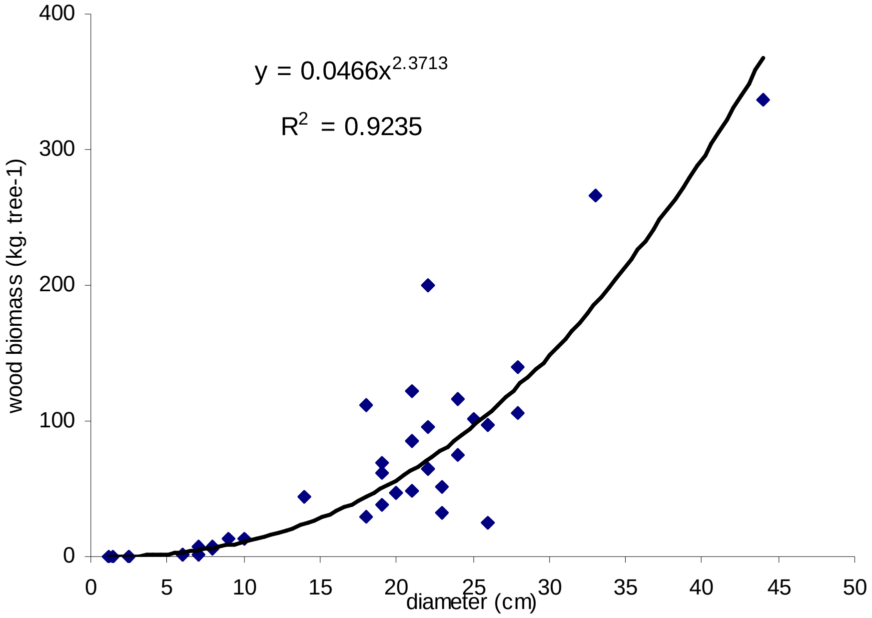

Fig. 1. : Biomass of wood in relation to diameter at 10 cm

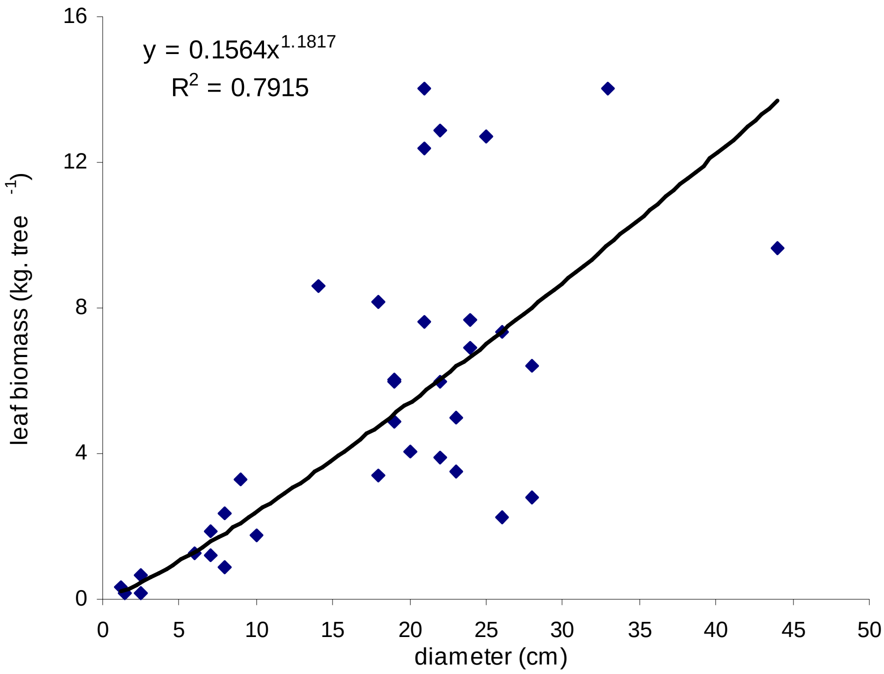

Fig. 2. : Biomass of leaves in relation to diameter at 10 cm

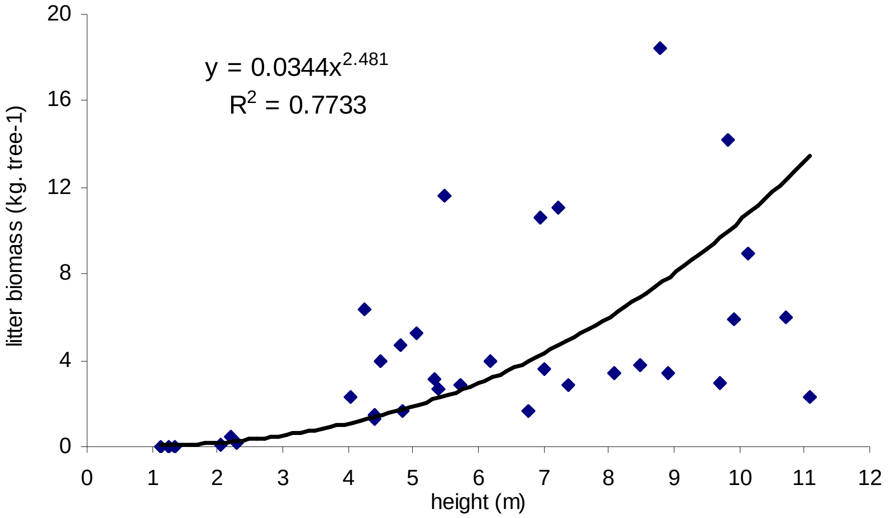

Fig. 3. : Biomass of litter in relation to height