

## ROOT LAYERING IN A TROPICAL FOREST AFTER LOGGING (CENTRAL VIETNAM)

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### Abstract

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Indigenous stands of tropical rain forests in the region of Kon Ha Nung are one of the most preserved forests in the whole Vietnam. Despite the logging activities mainly in the 1970's, it was possible to preserve intact forests free from any primary harvesting. In the past, other stands were influenced by the logging to various extent. Some of those stands are managed presently; others were left to natural development. This paper deals with the influence of harvesting activities on the root system in forest stands. In primary stands and in stands with known harvest intensity, samples of root systems were collected. The total weight of dry basis and mainly their layering within the soil profile were assessed. The collected roots were divided into three classes: class I –  $\leq 1.0$  mm, class II 1.1–5.0 mm, class III – over 5.0 mm in the diameter. In the monitored plots, the total weight of dry basis of fine roots to 1.0 mm ranged from 2.34–3.24 t·ha<sup>-1</sup>. The weight of dry basis of roots from 1.0–5.0 mm ranged from 6.57–9.69 t·ha<sup>-1</sup>. The majority of roots of class I is presented in the top 10.0 cm of the soil and their share drops with the increasing depth. The roots of class II are distributed more equally. It was impossible to prove the influence of the logging on the root system.

root layering, root mat, tropical rain forest, selective logging

Increasing number of papers focuses on the study of tropical rain forest and they deal with the issue from different perspectives. This can be credited both to the general attractiveness of this ecosystem and the easier accessibility of tropical regions and mainly to the society-wide interest in the issues of tropical forest conservation. This relates to the urgent need of finding optimal ways of management of natural resources of tropical forest. The traditional protection ideas in sense of conservation of these stands are facing the increasing pressure on the resources due to the growing population in such regions. Considerate forest management of existing forests seems to be the optimal and general applicable approach in sense of the sustainable use of tropical rain forest; this should be followed by strict conservation of the most valuable parts of the stands. Should the forest management be considerate, the impact of the logging activities on the forest stands has to be studied thoroughly. There are several authors researching mainly the change

in the tree species and plants diversity and the standing volume all over the tropical region. Our detailed knowledge of tropical rain forest decreases both upwards and downwards from the forest floor (Turner, 2001). It is the space under the forest floor, mainly the root system that is the focus of this case study.

Several authors focus systematically on the issue of roots in the tropical forests such as Pavliš, Jeník (2000); however, this issue does not receive the deserved attention, probably due to the complexity of the field research. The layering of the root biomass and distribution of roots in space are far more complicated in the tropical forests than elsewhere. (Longmann and Jeník, 1974). Tree root systems can be divided into two parts: fine and coarse, based on the diameter. Coarse roots are generally woody and provide a mechanical and conductive service to the tree. Water and mineral nutrients are taken up by the fine roots that ramify through the mineral soil and sometimes the litter layer as well (Turner, 2001).

In the tropical rain forest, the majority of the root system is concentrated in the top soil layers, if not near the forest floor (Montagnini, 2005). If the concentration of the root biomass close to the forest floor is significant (Vance, 1992: 50 to 70% of the total root biomass), a mat is presented on forest floor, i.e. a thick layer providing via mycorrhiza for the nutrients flows released in course of the litter decomposition directly into the plant without any contact with the mineral soil (Herrera *et al.*, 1978).

In other cases, the root abundance in the top layers of the soil profile is more equal and the intensity of the fine roots decreases continuously with the increasing distance from the forest floor. The concentration of fine roots close to the forest floor is usually linked to the closed nutrients cycle in the tropical forests and it is considered as the answer to their insufficient presence in the deep soil layers (Richards, 1996).

However, Kingsbury and Kellman (1997) explain this phenomenon—on the example of forest in south east Venezuela – as the reaction to high aluminium concentration in deep soil layers rather than to the lack of nutrients.

This paper does not deal with the nutrient cycles in the tropical rain forest; moreover it focuses on the long-term impact of logging activities on the root system in forest stands on the example of the tropical rain forest in the area of Kon Ha Nung, in the Gia Lai province, Vietnam. The objective is to quantify the root mass in the soil profile and to try to identify the influence of performed harvesting activities on the root biomass. The hypothesis is that the harvesting activities significantly influence the root layering and the total root biomass.

## MATERIAL AND METHODS

In the Kon Ha Nung region, one of the most preserved indigenous forest stands of tropical rain forest of Vietnam are present. Nowadays the majority of these stands are managed by the Forest Science Institute of Vietnam (FSIV). The area of the forests managed by the FSIV amounts to approximately 1,500 ha. This forest complex was divided into several groups according to the management and conservation for the purpose of the research. Stands free of any primary harvest were left without any human related activity. On harvested areas, trees were planted under the canopy and the stands are thinned and harvested. In 1978, permanent sampling plots were established in order to monitor the impact of the harvesting activities on the species composition and standing volume in this area. Usually the history and the intensity of logging on these plots is documented exactly, therefore, it is possible to monitor the logging impact on the forest stands and on the development dynamics. Based on this plot information, sites for the research of changes in the root system in the forest stands influenced by the harvest were selected.

The changes in the root system were monitored on four sampling plots with a different extent of influence caused by logging. Plot No. 1 was influenced by logging to 45% in 1978; plot No. 2 is the indigenous intact forest free of any logging; the forest on plot No. 3 was exploited illegally by the local community. The forest stand is harvested extensively; however, it has still closed canopy. The forest on the plot No. 4 is harvested intensively and it is disrupted (further details see Chat, 2001).

The analyses of the root system focused mainly on the fine roots which play the major role in nutrient supply in plants. The samples were collected using a probe with the diameter of 7.3 mm, which was hammered into the soil in 10 cm sections till reaching the total depth of 80 cm.

Samples from three probes were collected on each sampling plot. The probes were located in the corner of equilateral triangle with the side of 1.0 m in length and with the centre crossing the centre of the permanent sampling plots. Firstly, the collected samples were weighed in their original status. Then the roots were wash out from the samples. After drying, the roots were divided into classes based on the diameter: class I:  $\leq 1.0$  mm, class II: 1.1–5.0 mm, class III: over 5.0 mm. The root dry basis was weighed with the accuracy of 0.001 g. The method ANOVA with repeated measuring at the significance level of 0.05 was used for the analysis of variance of dry mass of roots.

## RESULTS

The results of layering of class I roots show that the majority of the fine roots is present in the top 10 cm of the soil profile (Fig. 1). Their mass drops with the growing depth; over 50 percent of the total root mass recorded in individual probes is located in the top 30.0 cm of the soil. The difference in root occurrence at individual depths is significant ( $P < 0.001$ ). Plot No. 4 shows increased root occurrence in the layer from 40.0 to 50.0 cm. As already stated above, this plot is highly damaged and with a high level of insolation, which results in significant dry out on the top soil layers. In the depth of 50.0 cm, a impenetrable soil layer was probably created, this is confirmed also by the high resistance when making the probe. The roots retrieving from the overheated top layers and trying to reach the water are accumulated then above this layer. Nevertheless, the difference between the values from the same layers of individual plots is not significant ( $P = 0.15$ ), possible to see on Fig. 3. Therefore, it was impossible to prove the influence of the logging intensity on the layering of the root system in the soil.

The layering of class II roots does not show such any explicit tendencies of the drop with increasing depth as in case of roots of class I. However, also here, the concentration of roots in the upper 50.0 cm of the soil was recorded; the occurrence of roots in deeper layers is significantly limited (Fig. 2). Similarly to class I roots, there is no difference

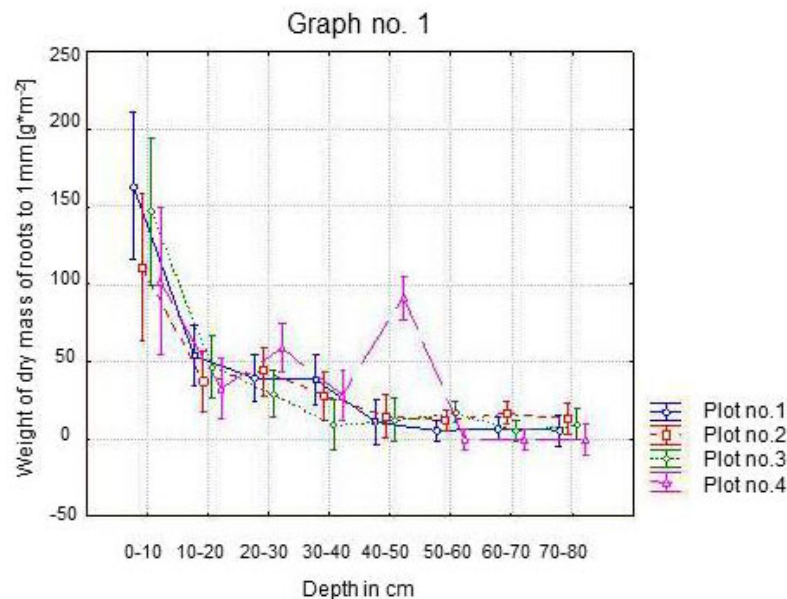
between individual sampling plots ( $P = 0.239$ ). And again, also in this case it was impossible to prove any statically significant differences between the individual sampling plots (Fig. 4). However, the difference between the root occurrence in individual soil layers is significant ( $P < 0.001$ ).

Class III was not represented in the collected samples.

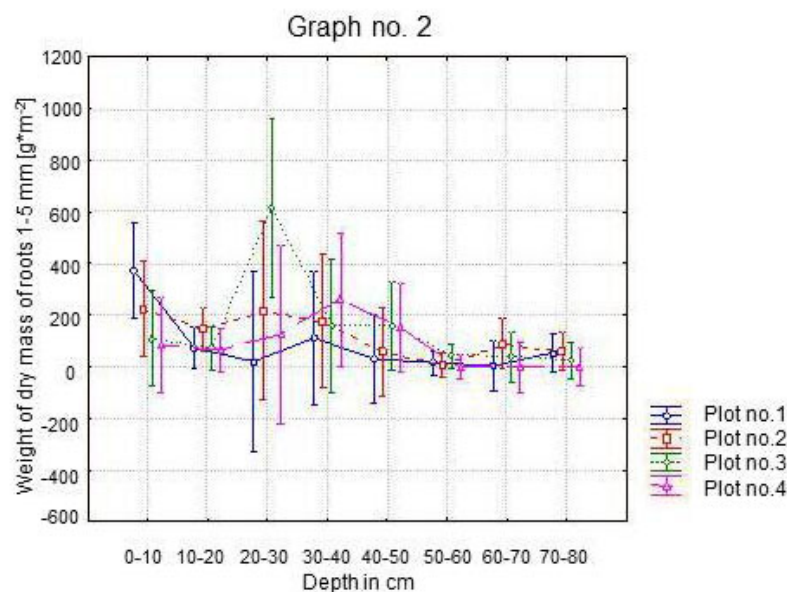
The hypothesis of the clear impact of the logging on the total weight of the roots and their distribution within the soil could not be confirmed.

## DISCUSSION

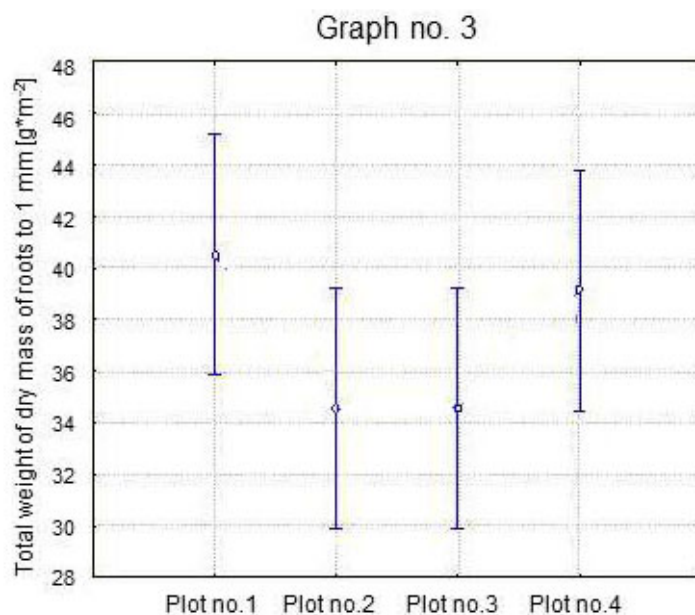
As already stated above, the layering of the root biomass and distribution of roots in space are far more complicated in the tropical forests than elsewhere (Longmann and Jeník, 1974). Different authors dealing with the issue of roots in the tropical forests give different values of the root mass in the stands. These values are hard to compare as the classification of roots based on the diameter is not unified. E.g. Cavelier (1992) divides the roots into four categories: very fine up to 1.0 mm, fine 1.0–2.0 mm, medium coarse 2.0–5.0 mm and coarse over 5.0 mm in his research. This classification appears



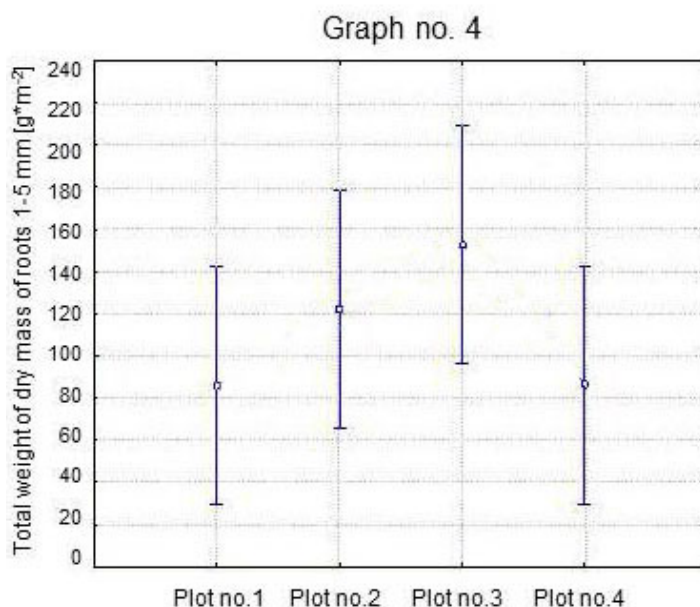
1: Distribution of roots to 1.0 mm in soil profil show the diferent among various layer, but no between plots



2: Distribution of roots 1.0–5.0 mm in soil profil show the diferent among various layer, but no between plots



3: Total weight of dry basis of roots to 1.0 mm on each plots



4: Total weight of dry basis of roots 1.0–5.0 mm on each plots

to be too detailed; from the perspective of the root function, it is sufficient to classify the roots into three groups: up to 1.0 mm, 1.0–5.0 mm and over 5.0 mm. Some authors – e.g. Vance (1992) – classify the roots with the diameter up to 2.0 mm as fine roots. On the other hand, e.g. Aruchalam *et al.* (1992) divided the roots into fine (up to 2.0 mm) and coarse (2.0–15.0 mm) within the research in north east India. Roots over 15 mm are not taken into account at all.

Despite all differences in the values of the total root mass, there is a common agreement regarding the root layering within the soil profile. According to the majority of the authors, most of the roots, and

mainly fine roots, are located in the top 10.0 cm of the soil. Aruchalam *et al.* (1992) gives the occurrence of 59.0–62.0% of the total fine root mass in the top 10.0 cm of the soil; whereas the coarse roots are concentrated mainly in the layer ranging from 10.0 to 20.0 cm (38–48 %). On the monitored sampling plots, 40.8–50.44% of the total mass of the fine roots up to 1 mm and 23.6–54.2% of the roots with diameter ranging from 1.0 to 5.0 mm were located in the top 10.0 cm of the soil; 14.2–17.1% of the total mass of the fine roots up to 1.0 mm and 7.5–19.0% of the roots with diameter ranging from 1.0 to 5.0 mm were located in the layer 10.0–20.0 cm. However, number of sampling is limited and is not



possible apply the results for tropical rain forests general. Skript option on this problem, require more numbers of sampling.

Aruchalam (1996) gives that the total mass of fine roots (up to 2.0 mm) ranges from 2.8–9.4 t·ha<sup>-1</sup> in renewed 16-year old stands. Cavalier (1992) reports that the average weight of fine roots (up to 1 mm) reaches 1.44 t·ha<sup>-1</sup> in tropical rain forest on Costa Rica. Vance *et al.* (1992) points out the influence of the slope and the location within the slope profile on the total weight of fine roots (up to 2.0 mm) which varies from 300 to 1,300 g·m<sup>-2</sup> (0.3–1.3 t·ha<sup>-1</sup>). The total weight of roots in the tropical rain forest ranges from 11.2–132.2 t·ha<sup>-1</sup> (Vitousek and Sanford, 1986). It is apparent that the values vary significantly and are influenced by several external factors. Moreover, the comparison thereof is difficult due to the applied methods. On the monitored plots, the total weight of dry basis of fine roots up to 1 mm ranged from 2.34 to 3.24 t·ha<sup>-1</sup>; the weight of dry basis of roots 1.0–5.0 mm ranged from 6.57 to 9.69 t·ha<sup>-1</sup>. A paper dealing with the influence of previous logging on the root system in tropical rain forest could not be found.

The acquired results fully confirmed the tendency of tropical rain forest to concentrate the roots close to the forest floor mainly regarding the fine roots. The creation of the thick root layer – so called root mat – was not observed, even though the concentration of the roots close to the forest floor exceeded the limit defined by Vance (1992) and amounting to 50% of the total biomass of fine roots, which is necessary for creation of this phenomenon. Roots with bigger diameter (over 1.0 mm) provide rather conductive

than absorption service to the tree, their distribution within the soil is more equal with their majority located in the layer from 10–30 cm.

No impact of logging on the distribution and structure of the root system could be proved. The dynamics of root formation on open forest floor is significant in tropical forest. Based on the example from Costa Rica, Raich (1980) gives that the mass of fine roots reaches 92% of the original value one year after the disruption. It seems to be apparent that unless the forest stands are totally disrupted (as in case of plot No. 4), the root system is not influenced by logging activities in long term and the absorption capacity of the stand remains sufficient.

## CONCLUSIONS

It was possible to prove the concentration mainly of fine roots in the top layers of the soil profile, which is in accordance with the widely acknowledged idea of surface root concentration in tropical rain forests. Even though, the concentration of fine roots in the top 10 cm of the soil was high, the root mat was not observed. The assumed influence of the logging intensity on the total root mass and root layering could not be confirmed, although certain deviations were observed on the plot No. 4 due to the root accumulation at the depth of 50 cm, where an impenetrable layer was formed, above which the roots, which are in search for sources, accumulate. Therefore, the results of study do not indicate a influence of logging activities to the total root mass. Rigorous option on this problem, require more numbers of sampling.

## SUMMARY

The paper focuses on the long-term impact of logging activities on root system in forest stands based on the example of tropical rain forest in the Kon Ha Nung region, in Gia Lai province, Vietnam. The objective is to quantify the root mass in the soil profile and to try to define the influence of performed harvesting activities on the root biomass. In the forest stands with known logging history, the occurrence of roots within individual soil layers was monitored. Samples were collected in 10 cm layers up to the depth of 80 cm. Collected roots were divided into three classes: class I – ≤ 1.0 mm, class II – 1.1–5.0 mm, class III – over 5.0 mm. The root dry basis was weighed with the accuracy of 0.001 g. The method ANOVA with repeated measuring at the significance level of 0.05 was used for the analysis of variance.

The total mass of fine roots up to 1.0 mm ranged from 2.34 to 3.24 t·ha<sup>-1</sup>. The difference in root occurrence of class I at individual depths is significant ( $P < 0.001$ ). Generally, the difference between the values from the same layers of individual plots is not significant ( $P = 0.15$ ). Therefore, it was impossible to prove the influence of the logging intensity on the layering of the root system in the soil. The layering of class II roots does not show such explicit tendencies of the drop with increasing depth as in case of roots of class I. However, also here, the concentration of roots in the upper 50 cm of the soil was recorded; the occurrence of roots in deeper layers is significantly limited. Similarly to class I roots, there is no difference between individual sampling plots ( $P = 0.239$ ). And again, also in this case it was impossible to prove any statically significant differences between the individual sampling plots. However, the difference between the root occurrence in individual soil layers is significant ( $P < 0.001$ ). The mass of roots with diameter 1.0–5.0 mm ranged from 6.57 to 9.69 t·ha<sup>-1</sup>. Class III was not represented in the collected samples.

Generally it was possible to prove the tendency of the tropical rain forest to concentrate roots close to the forest floor, however, the commonly reported root mat was not observed. On the monitored

sampling plots, 40.8–50.44% of the total mass of the fine roots up to 1.0 mm and 23.6–54.2% of the roots with diameter ranging from 1.0 to 5.0 mm were located in the top 10 cm of the soil; 14.2–17.1% of the total mass of the fine roots up to 1.0 mm and 7.5–19.0% of the roots with diameter ranging from 1.0 to 5.0 mm were located in the layer 10–20 cm. Their mass drops gradually with the increasing soil depth.

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