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Subsoil root activity in tree-based cropping systems

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The vertical uptake distribution of water and nutrients from soil is an important study topic because soil resources are not equally distributed throughout the soil profile. This has been recognized for a long time, and assessments of nutrient and water changes with depth are commonly done. The measurement of actual water or nutrient uptake by plants from the subsoil is, however, not regularly performed due to the large amount of work involved. Root distribution of crops (van Noordwijk and Brouwer, 1991) as well as other plant communities (Canadell et al., 1996) have been reported in sufficient detail to allow for general conclusions on subsoil resource use, but this level of information is not available for tree-based cropping systems. In this publication tree-based cropping systems are defined as cropping systems where trees play an important part in the production. These are comprised of fruit tree plantations, but also simultaneous and sequential agroforestry systems. The ability of trees to access subsoil nutrients and water depends on several factors such as tree species, soil physical and chemical properties, tree management and the cropping system. In the following, I demonstrate the importance of subsoil resources, their use by tree crops, the factors influencing this ability, tree management effects and resulting implications for tree cropping.

Subsoil resources

The quantification of subsoil root activity is obsolete if no resources are present in the subsoil. Numerous studies have shown that soil moisture can be equal or higher in the subsoil than in the topsoil. The ratio between available soil water present in the subsoil compared to the topsoil varies greatly, but is generally higher with larger evaporation and with access to ground water. Less obvious are the amounts of subsoil nutrients available to plants. The soil organic matter contents are usually higher at the topsoil and are responsible for the retention and release of nutrients. Also nutrients added to soil by litterfall and fertilization usually accumulate at the topsoil. High precipitation and temperature lead to high leaching which transports nutrients down in the profile. These nutrients constitute an important resource for the cropping system but are usually percolating below the root zone of the tree. In some cases, however, adsorption of nutrients can also be considerable in the subsoil and retard or temporary prevent leaching below the root zone. Anion adsorption may be significant and large amounts of nitrate (Cahn et al., 1992) and sulfate (Manderscheid et al., 2000) can be stored in acid subsoils. This accumulation is a valuable resource especially in those soils and climates, where available nutrient contents are low, leaching is high and the soils are deeply weathered such as in the humid tropics. Nitrate leaching can be very rapid under these climatic and edaphic conditions and adsorbed nitrate was found to a depth of 5 m under four different tree crops in the central Amazon (Fig. 1).

Subsoil root activity

Root abundance of plants is usually highest at the topsoil. Trees and tree crops are usually not an exception and generally have their maximum root length density in the first centimeters of soil or even in the litter layer. In comparison to root abundance measured as the amount of root tips, unit weight, or length of roots per unit soil weight or volume, root activity reflects the actual uptake of nutrients or water by roots. Several different approaches are available to assess root activity at different depths which use plant uptake or input of radioisotopes, uptake of stable isotopes, or depletion of water or nutrients (Lehmann and Muraoka, 2001; Wahid, 2001). These techniques give better estimates about the activity of roots than root abundance, but cannot determine absolute uptake from a specific soil depth. Rather they give relationships between the uptake from different depths.

Also root activity measurements by IAEA (1975) revealed that many studied trees took up more resources per unit soil depth from the topsoil than the subsoil. Some exceptions exist where root activity was higher at 20-40cm than 10cm depth (IAEA, 1975). Similarly, our results show that peach palm

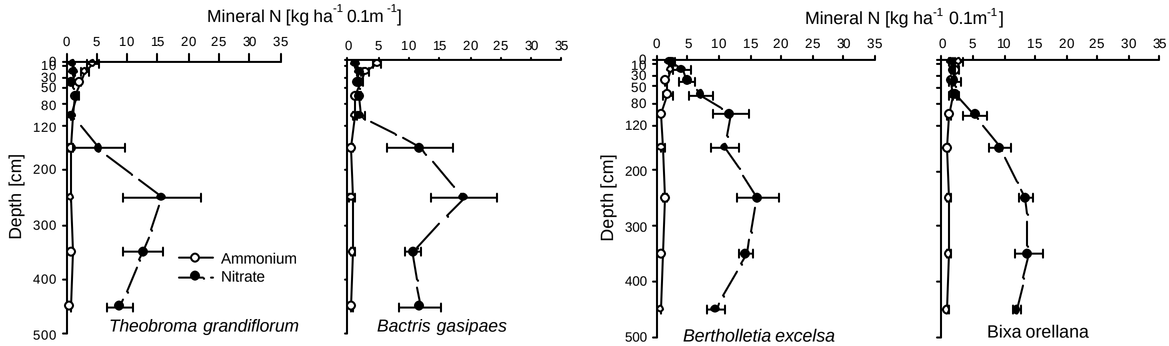

Figure 1 Nitrate and ammonium contents of a Xanthic Ferralsol of the Central Amazon under four different tree crops before the rainy season; mineral N extracted with 1N KCl for two hours; means and standard errors (N=3).

(*Bactris gasipaes*) had a higher uptake of applied tracers from 60 than 10cm depth (Fig. 2). However, these calculations disregard the fact that even if the uptake from a soil layer with a thickness of 10cm is 10 times larger than the uptake from a soil layer with a thickness of 1m, the total uptake is still the same from both layers. Similarly, the relative contribution of the soil layer at a depth of 60-150cm to total uptake was higher than the one at 10-60cm for both tree crops (Fig. 2). Even *T. grandiflorum* with an uptake of only 19% at 150cm depth compared to 10 and 60cm depths took up more resources from 60-150cm (60%) than 10-60cm (40%). Considering the large amount of plant-available nitrate present in the subsoil (Fig. 1), this root activity distribution leads to a significant N resource use from the subsoil.

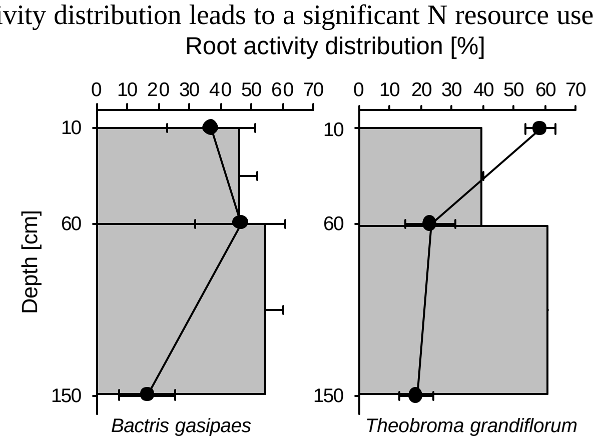

Figure 2 Root activity distribution under two fruit trees in the central Amazon; the lines indicate the measured root activity at three depths (10, 60, 150cm), the bars are the proportions of root activity between 10-60 and 60-150cm depth; root activity patterns determined by applications of both ^{32}P and ^{15}N (recalculated from Lehmann et al., 2001; means and standard errors, N=3).

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