Deep belowground biomass and Net Primary Productivity of coffee (*Coffea arabica* L.) in an agroforestry system of Costa Rica

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Introduction

Net primary productivity (NPP) plays a key role in the knowledge of the functioning, production and C sequestration of ecosystems. The part of C allocated to belowground organs is non-negligible and amounts to 33% of total NPP for fine roots (Jackson et al. 1997). Fine root turnover is rather high, particularly in tropical ecosystems (Jourdan et al. 2008). Nevertheless, belowground NPP (bNPP) was usually estimated from shallow soil samplings whereas it is now well-known that fine roots can grow deep into the soil and reach several meters in depth (Maeght et al. 2013). Agroforestry systems are often said to exhibit root competition which leads to deep rooting ecosystems. Coffee trees associated to native shade trees don't escape to this assumption. They are pruned every 5th year and resprout biomass represents a relatively small contribution to overall plant biomass, due to accumulation in perennial parts only (stumps, coarse roots). Our objectives here were to assess coffee root biomass and bNPP along the whole rooting profile (0-4.5 m) in coffee tree plantations as a function of distance to shade tree, between coffee trees and soil depth.

Methods

In this study, root biomass by root category was assessed on ten coffee plants, distributed according to an inventory of diameter at collar via 10 Voronoi trenches down to 1.5 m and 2 deep trenches along the full rooting profiles, down to 4.5 m. Fine root NPP was assessed by sequential coring with 8-cm-diameter cylindrical auger during 16 consecutive months in Costa Rica within the 0-30 cm soil horizon. We then extrapolated to the complete rooting profile of coffee trees using the Voronoi and deep trenches. Fine root bNPP calculations were performed using "decision matrix" (including fine root decomposition rate; Fairley and Alexander 1985) and "Max-Min" (McClaugherty et al. 1982) methods. Coarse root bNPP calculations were performed by allometry with the diameter at collar and annual growth rate.

Results and Discussion

The total root biomass within the entire coffee root profile (down to 4.5m deep) amounted to 22.4 t ha^{-1} which represented almost the same amount as the aboveground perennial organs (stumps - 25.7 t ha^{-1}) excluding the aerial renewal organs (sprouts, leaves, flowers and fruits). When adding the non-perennial aboveground compartments, the total coffee tree biomass amounted to 64.7t ha^{-1} with 65% and 35% of above- and belowground parts, respectively and a root:shoot ratio of 0.53. Coffee root biomass was spread out preferentially in shallow soil layers with 30% and 55% within the first 10cm and 30cm soil depth, respectively. 87 % and 92% % of root biomass were found within the first 1.0m and 1.5m of soil respectively. No significant differences in function of distances to shade trees were found. By contrast, a significant effect of the sampling positions was shown with more than two times higher coffee fine root biomass within the rows than within the adjacent inter-rows, whatever the soil depth. Fine root production of coffee trees in the 0–30cm soil layer amounted to 1.2 t ha^{-1} y^{-1}; while fine root contributed to only 5% of the total NPP, which is rather low as compared to previous studies. Fine root turnover rates ranged from 0.7 to 0.8 y^{-1} estimated by "Max-Min" and decision matrix calculation methods, respectively, rather low for tropical humid perennial plantations (Jourdan et al. 2008). Large monthly fluctuations of fine root standing biomass might indicate large necromass production through senescence and mortality processes each month, which was not shown in the necromass amounts. High observed fine root decomposition rates may explain such result.

Conclusion

Our results exhibited the first coffee root biomass estimates which integrates the total root profile, here down to 4.5m. High values of root production associated to low estimates of fine root turnover rates indicated a high potential of C sequestration in the belowground of these agroforestry systems.

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