Single-tree effects in agroforestry with perennial crops - an approach to the optimization of tropical land-use systems

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The concept of single-tree effects has been developed in forest ecology by studying gradients of soil characteristics around individual trees which provide information about the specific effects which a tree of a certain species, age and size exerts on soil properties. In this project, we analyze single-tree effects in agroforestry in comparison to perennial monocultures, fallow and primary rainforest with the objective of characterizing the specific ecological role that a certain plant species plays when it is included in man-made ecosystems as a function of its morphological and physiological properties. We hypothesize that the understanding of such species-specific roles can help in the optimization of agroforestry and other land-use systems according to pre-defined objectives, such as the minimization of nutrient leaching, increasing chemical or physical soil fertility etc. With this intention, we analyzed the small-scale patterns of above- and belowground biomass and nutrient accumulation, soil fertility, soil solution composition, quantity and nutrient concentration of rainwater, throughfall and stemflow, soil hydrology, soil physics and microclimate in a number of man-made and natural vegetation systems of differing structure and composition during two years. These included a polycultural system with Bactris gasipaes, Theobroma grandiflorum, Bixa orellana, Bertholletia excelsa and Pueraria phaseoloides at two fertilization levels; three monocultures with Bactris gasipaes either for fruit or for heart of palm and Theobroma grandiflorum; a young fallow dominated by Vismia spp. and primary rainforest.
The measurements produced evidence for differences of agronomic significance between the investigated plant species and cropping systems at numerous levels. Root excavations which, for the first time, produced an approximate three-dimensional picture of the root systems of a complex agroforestry association, revealed that Bactris had the most extensive root system of all the species at 3 years age which evidently supported its rapid aboveground development, whereas Bertholletia attained similar growth rates with a much smaller fine root system that, in addition, mainly explored the subsoil. A detailed investigation of subsoil fertility brought evidence of a considerable accumulation of mineral nitrogen below 1.5 m depth under all the tree species in the experiment, and also under some primary forest trees. In the topsoil, highest P availability was found under Bixa, whereas the soil under Pueraria still contained relevant amounts of mineral nitrogen when little fertilizer nitrogen was left under the trees due to plant uptake and leaching. Two tree species, Bactris for fruit and Bertholletia, concentrated significant amounts of rainwater around their stem in the form of stemflow. Bixa had the lowest amounts of stemflow, but the highest concentrations of nutrients in it, especially of P. Most of the P and about half of the N in rainwater, throughfall and stemflow were in the organic form.