Abstract

Makumba, W., 2003. Nitrogen use efficiency and carbon sequestration in legume tree-based agroforestry systems. A case study in Malawi. PhD thesis. Wageningen University, The Netherlands.

Simultaneous cropping of maize with *Gliricidia sepium* and relay cropping of maize with *Sesbania sesban* are the two agroforestry systems for soil fertility improvement which fit well within the small land holdings in the densely populated southern part of Malawi, in Sub Saharan Africa. These systems have been promoted because of their postulated beneficial effects, i.c. provision of firewood and timber, restoring soil fertility, minimizing erosion. Nevertheless, crop yields in the farmers' fields are still low, which is attributed to low nutrient use efficiency due to competition between the trees and the crop for belowground resources and due to lack of synchronization between nutrient release by added tree prunings and nutrient demand by the crop.

This research was designed to understand the (1) patterns of decomposition, mineralization, immobilization and remineralization of high quality tree prunings (*Gliricidia sepium* and *Sesbania sesban*) and low quality crop residues (pigeonpea leaves, pigeonpea roots and maize stover); (2) interactions between low and high quality organic materials (3) distributions and densities of roots of trees and crops in simultaneous cropping systems; and (4) carbon sequestering and nutrient cycling legume tree-based systems.

Time of application of prunings was important for the synchronization of N release to N demand by the crop. Fertilizer substitution values (relative to CAN) of gliricidia prunings were 0.66, 0.32 and 0.20 for applications in October, December and February, respectively. Split applications of tree prunings prolonged mineral N in the topsoil but did not increase maize N uptake and yield.

Rates of decomposition followed the order: gliricidia > pigeonpea leaves > sesbania > stover > pigeonpea roots. The rates of mixtures were in between those of individual components. In both greenhouse and field, N uptake and yield of treatments with mixtures were lower than those with tree prunings but higher than those with crop residues. Maize stover immobilized N and remineralized it again after a few months.

Maize had a higher root density in the ridge (0-30 cm) than gliricidia. The reverse was true for the subsoil, suggesting little competition between gliricidia and maize for belowground resources. Maize was a stronger competitor for belowground resources than pigeonpea, because of the slow initial development of pigeonpea.

The gliricidia-maize system sequestered large amounts of carbon in biomass and roots, and increase soil carbon levels significantly. It also improved the water holding capacity and water infiltration rate. The deep rooting of trees and pigeonpeas facilitated the pumping of nutrients from the subsoil to the topsoil. However, because of the higher crop yield and nutrient withdrawal with the harvested crop in the Agroforestry systems compared to sole maize, nutrient depletion was also higher. Hence, the tree-legume Agroforestry systems will be not sustainable on the longer term without external nutrient input.

Preface

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This thesis is dedicated to my parents

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