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POTENTIAL FOR LEGUME INTRODUCTION IN SHORT ROTATION PLANTATION FORESTS AS A MEANS TO IMPROVE PRODUCTIVITY AND SOIL FERTILITY? THE NEED FOR COORDINATED RESEARCH.

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Introduction

As most tropical forest plantations are established on low fertility soils, there are concerns about their sustainability with respect to long-term production and maintenance of site quality. This question is particularly relevant when current emphasis on improved productivity and profitability leads to intensive silvicultural practices (i.e., improved genetic material, short rotations, change of species) supposed to increase nutrient demands on the site. In various tropical countries a conservative management of litter and slash residues leads to a better stand growth, due to an improvement in the physico-chemical properties of the top soil (CEC, base saturation,…), as well as in nutrient availability (N mineralisation,…). But even when residues are retained on the site, soil N pools are likely to decrease over successive stand rotations, since high amounts of N are removed every 7-10 years with stemwood. This pattern is worrying as N availability is often a major limiting factor of tree growth in tropical areas. The balance of N budget could be achieved through heavy N fertilizations. But nitrogen fertilizers are expensive and their application may lead to inadequate ratios in the tree tissues between N and the other nutrients and to strong negative environmental impacts. A second option is the introduction of N-fixing species. Even if numerous studies dealt with the introduction of legume cover crops in forest plantations, there is a deep need in scientific basis to evaluate the effects of perennial N-fixing trees (NFT) introduction on tree growth, stand production, atmospheric nitrogen fixation, and soil properties (Fischer and Binkley, 2000).

The objective of the communication is to provide an out line of a co-ordinated research project on short rotations mixed plantations and describe the possible objectives and experimental approach. Various aspects would be studied: 1) Growth and nutrient content of NFT and non-N-fixing trees. It is needed to quantify the balance between the positive (nitrogen input, …) and the potential negative effects of the legume (competition for water, ...) on the growth of the non-N-fixing trees ant net production of the stand, and on soil fertility, 2) Nutritional status of the non-N-fixing trees according to the density of NFT, 3) N_2 fixation by NFT, 4) Nutrient cycling, and 5) soil properties. The operational goal will be to define management options likely to be applied in short rotation forest plantations to maintain or increase stand productivity over successive rotations.

Tentative experimental protocols

Two management options might be considered:

- NFT as understorey species. The main objective of the understorey would be to increase N inputs in the plantation, without disturbing the silvicultural management of the commercial non-N-fixing species
- NFT as wood growing species harvested at the end of stand rotation.

NFT as an understorey species. A randomised complete block would be set up with 3 replicates or more, using plots of 9 x 9 trees, at least. The non-N-fixing trees would be planted at the same density, regardless of the treatments. Fertilisers would be applied at planting for the non-N-fixing tree, according to the current silvicultural practices. No N fertiliser would be further applied (except for treatment 3). Fertilisers (except N) would be applied for NFT, according to the current silvicultural practices.

The core treatments would be as following:
1) NFT, at the same density as that of the non-N-fixing tree
2) Non-N-fixing tree with current fertilisation (except N) throughout stand rotation
3) Non-N-fixing tree with current fertilisation (including N) throughout stand rotation
4) Mixture non-N-fixing tree with current fertilisation (except N) throughout stand rotation + NFT (25 % of non-N-fixing trees)
5) Mixture non-N-fixing tree with current fertilisation (except N) throughout stand rotation + NFT (50 % of non-N-fixing trees)

Different optional treatments could also be tested as higher densities of NFT, mixture agricultural legume + non-N-fixing tree, cutting NFT regularly to reduce competition between NFT and non-N-fixing trees, or mixture 50 % non-N-fixing trees + 50% NFT.

The traits and measurements would include:
- Growth and nutrient content of NFT and non-N-fixing trees: height and $C_{1.30m}$; biomass of the various components of the trees and nutrient content at 1 year, 3 years and at the end of the stand rotation.
- Biomass and volume tables established at 1 year, 3 years and at the end of the stand rotation for the two species.
- Nutritional status of NFT and non-N-fixing trees: foliar N, P, K, Ca and Mg concentration, every year.
- Nutrient cycling (NFT and non-N-fixing trees): litter fall collected every 2 months separating the two species; litter decay, sampled with litter bags every 3 months; forest floor accumulation, sampled every year.
- Assessment of N_2 fixation by NFT: N accretion before planting, at 3 years, and at the end of the rotation.
- Soil properties before planting, and at 1 year, 3 years and at the end of the rotation.

Optional measurements could be also performed, as climate data, LAI of NFT and non-N-fixing trees, carbon characterisation (lignin,…) of the litter according to the species, i*n situ* and/or potential N mineralization during stand rotation, assessment of N_2 fixation by NFT using ^{15}N natural abundance method, tree disease…

NFT harvested at the end of stand rotation. The same modalities would be applied except that stand density (including NFT and non-N-fixing trees) would be the same whatever the treatments. No optional treatments would be tested.

Discussion

Four experiments, testing mixed plantations of eucalypts and acacias, have been established for one year in Brazil and in Congo following the proposed experimental design. Preliminary results will be presented during the conference. In 2004, five more trials should be established in Brazil by Cenibra and VCP, that manage around 300,000 ha of eucalypt plantations. Therefore, a co-ordinated research program on this issue should being developed. It should yield relevant information pertinent to various issues.

N_2 fixation. A common set of estimations in various countries should provide informative data on the amounts of N_2 fixed within mixed plantations. The results should also lead to a better prediction of N_2

fixation according to soil properties. N_2 fixation is usually promoted by adequate nutrient supply, especially phosphorus, but there are no evidence concerning the effects of soil nitrogen on N_2 fixation.

Soil properties. The change of some key soil parameters as pH and organic matter should be quantified. A decrease in soil pH is generally observed in mixed plantations. One of the effects of the pH decrease could be the difficulty for the NFT to nodule and to fix N_2. But in some cases no change in soil pH may be observed because an increase in acidic compounds in the soil is likely to be balanced by an increase in base saturation of the exchange complex. Fischer and Binkley (2000) indicated that soil organic matter often increases under nitrogen-fixing-species, owing to the increase in pools of carbon from nitrogen-fixing-species litter. But the authors suspected also that the increase in soil nitrogen lowers the rates of decomposition of old soil carbon, and stimulate the decomposition of labile carbon, as well. The proposed experiment should give data on the changes in soil C and N dynamics according to the organic matter properties by quantifying the biomass and nutrient content of litter floor before planting, the biomass and nutrient content of the litter according to the species mixture, and by characterising the carbon of the litter according to the species.

Plantation diseases. Very little work has been done to examine the impact of legumes on diseases of non-N fixing species. Red alder is likely to reduce the incidence of root rot in *Pseudotsuga menziesii* plantations. By contrast some annual and perennial leguminous species are very sensitive to infestation by nematodes that can lower N_2 fixation and contaminate the associated non-N fixing species, as well.

Mixed plantation management The results obtained should help forest managers to assess the site conditions and the silvicultural practices (legume tree density, …) required to manage mixed plantations. But the best management options (mixed plantations *vs* monocultures) will be chosen owing to i) economic analyses balancing the benefits (lower fertilisation or weeding costs, multiple resource values, …) and the over-costs (seedling production,…) of N_2 fixation, but also ii) ecological studies taking into account the impact of mixed plantations on soil properties (CEC, organic matter content,…) and biodiversity (flora and fauna).

References

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