Management and Impacts of Climate Change Programme GICC CRP 1999

3/99 - Effects of silviculture on carbon storage in forest soils – Parameter validation for carbon stocks trends models

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The initial objective of this project was to study the impact of silviculture on the trends in carbon stocks and fluxes to provide data in order to set values for the various parameters of the soil organic matter stocks trend model (Arrouays *et al.*, GICC MATE). Three types of factors were considered: age of the stand, soil-improving treatments/fertility and stand management. The three studies have been carried out and the main findings are summarized in Chapters A, B and C of this report. The resulting data were encoded and handed to the modelling team. Readings from experimental and testing sites show that carbon stocks in the soil (including the organic layers) depend on various local characteristics (soil, climate) and on the tree species. The high variability observed can be studied through integrated investigations on the scale of the ecosystem (hectare-sized plots) over a length of time. This can only be undertaken as part of the long-term monitoring of forest ecosystem observatories. Studies based on chronosequences show that the carbon is momentarily trapped in the various compartments of the ecosystem (soil, humus, branches, leaves, trunks, roots, etc.) and that solid-liquid-gas flows are permanently reshaping the equilibrium between these compartments. These equilibriums are also altered by human actions (silviculture, pollution) and climate changes.

The findings of investigations still under way show that changing stand management (changing over from coppice to high forest, altering the frequency of thinnings) affects the dynamics of the ecosystem (microclimatic alterations in terms of water, light and temperature). Carbon, as a source of energy for soil micro-organisms, is made use of, changed from one state to another and transferred from one compartment to another. After a thinning, for example, microbial activity is enhanced, in particular on acid soils. The organic matter from the humus and the all-organic layers of the soil is mineralized. The carbon trapped in the soil is set in motion, one part consumed by micro-organisms, another released to the atmosphere as CO_2. Mineralization of organic matter also releases nutrients and, the thinning having alleviated the competition for water, the productivity of the whole system is enhanced. The tree will grow faster and capture additional carbon inside its biomass. This effect was clearly highlighted when we experimented with forest ecosystems through soil-improving treatments.

Transfers were also recorded, but overall we did not find significant differences in the matter of stocks. Another lesson to be learnt from our research work on forest management and chronosequences is that ‘rich’ soils (pH > 5.5, degree of saturation > 75%) display an inherently high biological activity and, therefore, low carbon stocks in humus, since the organic matter is quickly incorporated into the mineral soil through biological activity. In this case, changes in forest management have little impact. On poor soils, on the other hand, a large proportion of the organic matter is concentrated in the humus. The humus layer thickens as the stand ages, but the rate of transfer to the soil is low, in the absence of sufficient biological activity. Upon a traumatic event such as a clearing operation or a tempest such as the one that occurred in 1999, intense mineralization concurs with carbon leaking out of the ecosystem.

Regarding the age effect, the soil behaves like a box (or compartment) within a system. One should not consider this 'box' separately – studies should be undertaken at the level of the entire ecosystem. Time scales should be taken into account (seasonal and annual cycles), and in particular the duration of the logging cycle, if long term trends are to be assessed. A decade is short-term for a forest.

In the case of strand structure (the various strata of the trees, shrubs and herbs), carbon stocking models can be designed by coupling the carbon to tree-growth models and by calculating the equivalent needed to account for the herb and shrub strata (nearly always overlooked).

As regards the soil, 'within' variability is high and obscures recorded values. The ancient history of forests seems to be an important factor for the present characterization of carbon stocks. Detailed studies to characterize organic matter and assess its residence time is the only way forward in this area.

The effect of stand management complicates the above patterns by adding another layer of complexity (or variability). Data recording in many different situations through investigations such as that carried out with AGRIGES for the soil is the only way to collect data that modern statistics are able to interpret. This involves a long process of analyses with little short-term scientific return. The soil treatment/fertility effect assessed within this particular project seems proven in other French sites (ongoing studies by INRA and ONF). The only measurable modifications in the short term (10 to 20 years) concern the organic layers (humus). In the soil layers (mineral layers), variability again hides any trend. These are slow processes that can only be examined in monitoring observatories. The investigations undertaken by our team keep to the scale of the forest stand, that is, to the working scale of one hectare. The modelling considered as part of the 2001 CARBOFOR contract takes into account regional and national scales. A long validation process will remain to be done and the tools to measure 'real' stocks and fluxes must be developed before even contemplating introducing the third dimension, that of time - and assessing the actual carbon stocks trends.