INTERNATIONAL SYMPOSIUM

Forest soils under global and local changes : from research to practice

ABSTRACTS

15 to 18 September 2004
Bordeaux, FRANCE

De l'art de conférer, par Montaigne

« … Le plus naturel et le fructueux exercice de notre esprit, c'est à mon gré la conférence… L'étude des livres, c'est un mouvement languissant et faible qui n'échauffe point, là où la conférence apprend et exerce en un coup. Si je confère avec une âme forte et un fier jouteur, il me presse les flancs, me pique à gauche et à dextre, ses imaginations élancent les miennes. Et l'unisson est de qualité toute ennuyeuse dans la conférence.

… Nulle proposition ne m'étonne, nulle croyance ne me blesse, quelque contraire qu'elle soit à la mienne. »

Extrait : Essais – Livre III, chapitre VIII

Forest Soils International Symposium co-organized by:

International Union of Soil Sciences

International Union of Forest ResearchOrganizations

Institut Européen de la Forêt Cultivée

Institut National de la Recherche Agronomique

Ecole National de Ingénieurs des Travaux Agricoles de Bordeaux

Scientific Committee

Partap KHANNA (Chairman)

Jacques RANGER (France)

Manuel MADEIRA (Portugal)

Agustin MERINO (Spain)

Ted FARRELL (Ireland)

Janusz ZWOLINSKI (South Africa)

Peter CLINTON (New Zealand)

G. GLATZEL (Austria)

K Jiri KULHAVY (Czech Republic)

K. MEIWES (Germany)

K. MORISADA (Japan)

Zhi-Hong XU (Australia)

Organizing Committee

Jean-Michel CARNUS (Chairman, INRA)

Jacques RANGER (co-chair , INRA)

Etienne SAUR (co-chair, ENITAB)

Christophe ORAZIO (IEFC)

Mark BAKKER (ENITAB)

Pierre TRICHET (INRA)

Laurent AUGUSTO (INRA)

Philippe CHERY (ENITAB)

Claudia ANTONIOTTI (IEFC)

Mathilde VALIN (ENITAB)

Contents

Plenary session 1 : « CARBON AND GREENHOUSE GASES »

Forest soils and CO_2 emissions – from policy to research to management – status and developments

Rainer Baritz

Federal Institute for Geosciences and Natural Resources, D-30566 Hannover, rainer.baritz@bgr.de

Abstract

The role of forest soils in greenhouse gas budgets, and even more so under climate change, seems to be a controversially discussed issue in research and policy. This effect becomes apparently enhanced as the more research results are published. The following presentation will systematically analyse and integrate the political, the research, and the management dimension. High uncertainties, contradicting research outcomes, a lack of political lobby and information transfer cause the lack of position and direction of forest (soil) management at the political level – but not necessarily at the environmental one.

Need for information on soils

The demand for reliable research information has become increasingly focussed on the requirements for the Framework Convention on Climate Change, the Kyoto Protocol, the MCPFE Criteria and Indicators for Sustainable Forestry, the European Climate Change Programme, and the European soil protection initiative ("Soil Thematic Strategy"). There is a need to increasingly work on changes in forest soils as high uncertainties are placed here, and the main focus of research is still on forest vegetation (sinks) rather than soils.

Sources for soil information

The data used for identifying the role of soils (as sinks or sources for greenhouse gases) stem partly from soil inventories and partly from other research activities. The research includes (a) flux measurements, (b) radiocarbon research, and (c) modelling, while modelling integrates data from inventories as well as from a and b activities. There are many scenarios interacting soil-climate-management practices where forest soils can either be considered sources for CO2 and GHG emissions, or sinks. Greatest uncertainties exist when this information is to be aggregated from individual site level to landscape level or even to continental scale for use by the soil and climate policy makers. Changes due to management practices are almost impossible to detect in the political time scales when the data are based on available and established inventory tools. The effect of a single management change is difficult to trace down at landscape scale or national inventories. Therefore, models are increasingly used, but the model results have to be up-

scaled. Under such situations the politically used figures are difficult to verify, partly because uncertainties cannot be completely determined.

Forest soil management

The hypothesis that modern day forest management practices have undertaken necessary steps to preserve soil carbon, or rehabilitate sites with historically degraded soil carbon pools, or minimize N losses, will be pursued in this presentation, and critically discussed. It seems that if forest is preserved, or non-forest land is afforested, positive effects on soil carbon retention or its protection against climate change may result. On the other hand, for example, best (forest ecological) practice is controversial between public and private "forest soil users" in its interpretation depending on the function receiving preference. Given the magnitude of research publications, there is still an enormous research gap regarding C and N cycles, restricting their use for specific forest management and forest policy options.

Do three years of exposure to elevated CO_2 influence the soil solution chemistry in a mature mixed forest?

Inga K. Bucher-Wallin*, Patrick Schleppi*, Jürg B. Bucher*, Matthias Saurer**

** Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), CH-8903 Birmensdorf, Switzerland*

*** Paul Scherrer Institute (PSI), CH-5232 Villigen, Switzerland*

Abstract

Under increased atmospheric CO_2 concentrations, the vegetation is expected to grow faster and bind more C. Due to depletion or immobilisation of essential nutrients, the predictions for carbon net uptake are much lower in models including nutrient cycling than in models lacking this feedback [1]. The C cycle is tightly coupled to the N cycle, and it is expected that increased CO_2 concentrations will modifiy the interactions between N and C. More N may be needed: for increased plant growth, for the decomposition of larger amounts of N-depleted litter and for the immobilisation by enhanced microbial activity due to C-richer root extracts. On the other hand, higher microbial activity in the soil could increase the N mineralisation over time, and so contribute to a better N supply.

The effect of increased CO_2 concentrations on trees was so far mainly assessed on potted plants or in microcosms. It could not yet be tested how older forest trees would respond. It is therefore the objective of this study to estimate the long-term effects of a CO_2 enrichment on nutrients, especially of nitrogen, in a mature forest ecosystem. For our experiments, we use the facilities of the Swiss Canopy Crane (SCC) project [2]. Here, in a mixed, 120-year-old forest, the crowns of 30-35 m high broadleaf trees are fumigated with CO_2 (500 μmol mol^{-1}) during the growing season since spring 2001. In April 2001, ceramic suction cups were installed at depths of 5 and 15 cm and attached to permanent suction systems. They form three transects through the experimental area under control and CO_2-treated trees: one transect under hornbeam (*Carpinus betulus*), one under beech (*Fagus sylvatica*) and one under oak (*Quercus petraea*, *Q. robur*). At 10 locations along each transect, soil solutions are collected approximately every 14 days and analysed for nutrients. In addition to the temporal dynamics of N in the soil solution, integrative measurements of nitrate and ammonium are made with mixed anion and cation exchange resin bags. As the CO_2 used for fumigation is depleted in ^{13}C relative to the ambient CO_2, the

isotopic abundance ($\delta^{13}C$) of dissolved organic carbon (DOC) as well as of dissolved inorganic carbon (DIC) in the soil solutions are tested as a measure for the gradient of CO_2 impact in the soil along the transects.

A strong seasonality of nutrient concentrations was observed in the soil solutions. The results obtained so far indicate an increased nitrate availability under elevated CO_2 concentrations. This effect is especially pronounced in autumn and winter and may be explained by enhanced microbial activity and higher soil moisture under CO_2 enrichement.

References:

1. Hungate B.A., Dukes J.S., Shaw M.R., Luo Y. & Field C.B., 2003: Nitrogen and climate change. *Science* 302: 1512-1513.
2. Pepin S. & Körner C., 2002: Web-Face: A new canopy free-air CO_2 enrichment system for tall trees in mature forests. *Oecologia* 133: 1-9.

Soil carbon modelling - A simple dynamic multi-scale approach

Thies Eggers, Taru Palosuo, Mikko Peltoniemi, Jari Liski

European Forest Institute, Torikatu 34, FIN - 80100 Joensuu, Finnish Forest Research Institute, Vantaa Research Centre, P.O.Box 18, FIN - 01301 Vantaa, Finnish Environment Institute, P.O.Box 140, FIN - 00251 Helsinki

thies.eggers@efi.fi

Abstract

Countries that have ratified the United Nations Framework Convention on Climate Change (UNFCCC) need to report their annual emissions of greenhouse gases, one of which is carbon dioxide. One of the sectors concerned is the sector of land use, land-use change and forestry. At present reporting methods are being developed and have to be ready in 2007 at the latest. This reporting needs to be transparent and verifiable to show how the estimates are calculated.

There are five pools in the forest sector that need to be reported, namely aboveground biomass, belowground biomass, dead wood, litter, and soil organic matter. The first four pools can be estimated with inventory-based methods, whereas the last is more difficult to monitor due to the high spatial variability in soils as well as laborious and expensive measurements. The share of soil carbon in the total forest carbon budget is, however, significant.

Modelling is an alternative approach for estimating the carbon pools and fluxes of forest soils. The simple dynamic soil carbon model Yasso provides a clear means to calculate the amount of carbon in the soil, changes in soil carbon and heterotrophic soil respiration. The model is built for regional estimates of soil carbon and therefore requires only basic information on climate as well as litter quality and litter quantity. Yasso can easily be linked to any ecosystem model or to measurements that provide estimates of litter production. For example, Yasso is already included as the soil carbon module of the CO2FIX (a stand scale modelling framework for quantifying carbon credits due to carbon sequestration in forest ecosystems and wood products), the EFISCEN (a large scale forest resource projection model), and the Motti (a Finnish empirical tree level stand growth model) models. Yasso has also been used for soil carbon estimates in Norway, Switzerland and Finland. Beside this Yasso could be used to study the effects of forest management on carbon sequestration as well as the impacts of changing climate on soil carbon stocks and fluxes at various scales.

The current version of Yasso is calibrated to describe the total carbon stock without distinction between soil layers. Parameterisation is based on litterbag experiments, total soil carbon measurements, and measurements of decaying woody debris. The approach of calibration is such that first the parameter values have been determined for climatic reference conditions and

then the effect of climate on decomposition rates is taken into account, based on litterbag experiments from across Europe.

The reliability of Yasso has been assessed using Monte Carlo sensitivity analyses. Comparisons to independent litterbag data suggest that Yasso is applicable to different litter types and widely varying climate conditions. At present, however, the application of Yasso is constrained to upland or well-drained forest soils only.

Current and future development of the Yasso model includes the uncertainty analysis of soil carbon within inventory based on carbon budgeting and an identifiability analysis of the model itself as well as further development and assessment of the temperature dependence of decomposition rates in the model. Also a version for peatland soils is under development.

Soil carbon dioxide efflux in a mixed stand of oak and beech : abiotic factors and species effects

Mathieu Jonard, Frédéric André, Quentin Ponette

University of Louvain (UCL), Forest science laboratory, Croix du Sud, 2 – box 9, B–1348 Louvain–la–Neuve (Belgium)

Jonard@efor.ucl.ac.be

Abstract

Objectives

The objectives of this research are : (1) to evaluate the contribution of the forest floor microbial activity to total soil respiration in pure oak, pure beech and mixed oak–beech stands, and (2) to quantify the species influence on this component of soil respiration using a model based on soil temperature and moisture.

Materials and methods

The study site is located in the western part of the Belgian Ardennes at 300 m elevation. The average annual rainfall is slightly below 1000 mm, and the mean annual temperature is around 8.4°C. The site consists of a 60 ha oak (*Quercus petraea* LIEBL.) and beech (*Fagus sylvatica* L.) stand, lying on an acid brown earth soil (USDA: Dystrochrepts). Three experimental plots of half an hectare were selected in sub-stands of pure oak, pure beech and in a 1:1 mixture of both species.

In each experimental plot, measurements of CO_2 efflux (portable infrared gas monitor combined with a soil respiration chamber), soil temperature (thermocouples) and volumetric soil water content (TDR-probes) were made in three different sub-plots. In the pure oak and pure beech plots, a roof of 7.5 m^2 was installed in two of the three sub-plots to broaden the range of soil water content, resulting in three kinds of zones: 'normal', 'dried', and 'moistened'.

Measurements of CO_2 efflux were taken bimonthly during one year from November 19th 2002 to November 6th 2003. In order to estimate the contribution of aboveground litter to total soil respiration, two kinds of measurements were taken at each location: one on the forest floor and the other directly on the underlying mineral horizons, after removing forest floor.

Results and discussion

The total soil CO_2 efflux (g CO_2-C m^{-2} yr^{-1}) was partitioned into two components: the flux measured on top of the A horizon (A CO_2 flux) and the flux computed by subtracting the A CO_2 flux from the corresponding total CO_2 efflux: the flux emitted by the litter (litter CO_2 flux).

The seasonal patterns of both components of soil respiration were similar to that for soil temperature. However A CO_2 flux decreased during the summer and was not related to soil temperature changes, probably in response to the simultaneous decrease of soil water content. By contrast, the litter CO_2 flux appeared relatively unaffected by the summer drought.

Soil temperature was the principal determinant of soil respiration. The components of total soil CO_2 efflux increased exponentially with soil temperature. The increase in CO_2 emission with soil temperature was however more pronounced for the A horizons than for the litter layer. It was also more marked in normal and moistened zones than in dried ones for the A layers.

Soil water content had a positive effect on the A CO_2 flux and this effect was more pronounced at increasing soil temperatures. On the contrary, the effect on the litter CO_2 flux seemed to be negative and was also stronger with increasing temperature.

Total CO_2 flux was also influenced by tree species composition. Under oak, the total and the A CO_2 fluxes were larger than under beech. The litter CO_2 flux on the two sites did not show any difference.

For each component of total soil respiration, a model based on temperature, water content and species composition was developed. The temperature dependency was described with a simple exponential equation in which the pre-exponential term was allowed to vary linearly with species composition, and the exponential coefficient considered to be water content dependent.

Based on this model, the annual A CO_2 flux computed using the pedoclimatic time series was shown to decrease when the proportion of beech increased in the stand (oak: 509g CO_2-C m^{-2} yr^{-1}; mixed stand: 427g CO_2-C m^{-2} yr^{-1}; beech: 352 g CO_2-C m^{-2} yr^{-1}). Whatever species composition, the annual litter CO_2 fluxes were equivalent : 345g C m^{-2} yr^{-1}.

Modelling of the response of forest soil respiration fluxes to the main climatic variables

Dominique Perrin, Michel Yernaux, Bernard Heinesch and Marc Aubine

Biosystem Unit – Agricultural Gembloux University – B5030 Gembloux – Belgium
Tel. : +32 81 622464 Email : perrin.d@fsagx.ac.be

Abstract

The objective of this work is to model the carbon dioxide (CO_2) efflux to the atmosphere due to soil respiration. First, we will synthesize the main components of soil respiration fluxes as found in the literature. Then, we will present a system of automatic measurements, which was set up in a beech forest stand in Vielsalm (Ardennes, Belgium). This system recorded measurements of soil efflux and of climatic variables every 30 minutes. Its spatial resolution was limited to six collars of 20 cm diameter in a two-meter diameter curve. The measurements were analyzed according to their climatic components: temperature and relative soil water content. We analyzed 22,926 cycles of soil respiration measurements, and we followed a strict procedure of data selection in order to characterize soil respiration fluxes according to the main environmental components. We developed soil temperature-dependent fluxes with a Q10 function and Arrhenius' law with temperature-adjusted activation energy, which both gave very similar results. Our best estimation for Q10 is 3.86 and for A in Arrhenius' law, 17,479. We then adjusted two line segments beneath and beyond 0.27 m3. m- 3 of water in the soil in order to describe the response of respiration fluxes to soil moisture content. The soil temperature at 4.5 cm could explain over 86 % of the soil respiration fluxes. Relative moisture content narrows this by 2 % .

Are high-elevation spruce-fir forests in the Southeastern US sources or sinks of CO2?

H. Van Miegroet[1]*, P. Moore[1], C. Tewksbury[1], and N.S. Nicholas[2]

1Utah State University, Dept. Forest, Range & Wildlife Sciences, 5230 Old Main, Logan, UT 84322-5230, U.S.A.

[2]Yosemite National Park, 5083 Forest Road, El Portal, CA 95318, U.S.A.

** E-mail: helgavm@cc.usu.edu*

Abstract

There is considerable debate about the role and contribution of old-growth and unmanaged forest ecosystems to carbon (C) sequestration in the Northern Hemisphere. In particular, it is unclear to what extent forests in National Parks and Wilderness Areas act as carbon dioxide (CO_2) sources or sinks. One such example are the high-elevation red spruce-Fraser fir forests [*Picea rubens* Sarg./ *Abies fraseri* (Pursh.) Poir] in the southern US which currently occupy about 26,600 ha, the largest contiguous area (74%) located in the Great Smoky Mountains National Park (GSMNP) of eastern Tennessee and western North Carolina. These forests are relic islands of montane spruce-fir forests that once existed in an unbroken north-south chain during the Pleistocene glaciation. The prevalence of old unglaciated landscapes combined with limited fire history has resulted in forest soils with large accumulation of organic matter and C in the forest floor (O horizon) and the upper mineral soil (A horizon). In addition, natural stand dynamics and an exotic insect infestation that has caused extensive mortality of mature fir since the 1970s, have created a heterogeneous forest structure, with large variations in forest composition, stand age, live and dead standing biomass, and coarse woody debris abundance. It is our hypothesis that the combination of geologic age, disturbance history, and the current designation as a low-management area, limits the C sequestration potential of these forests, and that their soils may constitute a large CO_2 source, especially if subjected to further atmospheric warming trends.

This analysis combines past and ongoing measurements of C pools and dynamics in the spruce-fir zone of the GSMNP using a framework of 54 20m x 20 m permanent plots located between 1525-1970 m elevation, some of which in the Noland Divide Watershed (a 17.4-ha gauged headwater catchment). Carbon pools, net growth, and C sequestration in overstory biomass were estimated from periodic stand inventories between 1993 and 2003. Carbon in the forest floor and mineral soil was determined from destructive sampling of the O horizon and incremental soil cores (on average to a depth of 50 cm) in

each plot, followed by C analysis of ground and sieved (<2mm) samples, respectively. The soil C dynamics were derived at a subset of plots from litterfall biomass and C flux measurement over one (4 plots) to five years (12 plots) and from *in situ* soil respiration measurements between 2001 and 2004 (8 plots).

The overstory represent a large but highly variable C pool within these ecosystems (average 109,000 kg C ha^{-1}; CV=40%), yet net C sequestration in living biomass is rather low (10-year average <2,000 kg C ha^{-1} yr^{-1}, range 640 to 3,200 kg C ha^{-1} yr^{-1}) mainly due to heavy conifer mortality between 1993 and 1998, especially at the higher elevations. Since then, the net C flux into living biomass has increased from an average 800 kg C ha^{-1} yr^{-1} (1993-1998) to an average 2,800 kg C ha^{-1} yr^{-1} (1998-2003), with ingrowth accounting for 20 to 60% of net overstory C at the higher elevations. The forest floor and mineral soil are more dynamic C pools and constitute significant C sources. Approximately 20,000 kg C ha^{-1} is stored in the forest floor (O horizon) with a mean residence time of around 14 yrs, corresponding to an average annual release of 1,500 kg C ha^{-1} yr^{-1} from litter turnover. Net annual CO_2 efflux from the soil is estimated at 1,400 kg C ha^{-1} yr^{-1}, but rates vary spatially and temporally in response to soil temperature. The role of understory and coarse woody debris in ecosystem C dynamics is still being determined. The belowground C dynamics in these ecosystems seem particularly sensitive to climatic changes (especially temperature) and these forest ecosystems may become net sources of CO_2 under predicted global warming scenarios.

Carbon and Greenhouse Gases: Bangladesh Perspective

Amir Hossain Chowdhury

Institute for Environment and Development Studies, 5/12-15, Eastern View (5th floor),
50, D.I.T Extension Road, GPO Box-3691, Dhaka-1000, Bangladesh.
Tel. + 880-2-935 4128 Fax:+ 880 2 831 5394 Email: iendesbk@accesstel.net

Abstract

Bangladesh is situated in the torrid climatic zone. The first survey on the climate of the country was carried out with the technical assistance of the USA. The survey was conducted mainly to prepare the following four working plans:

- Greenhouse gas emission inventory
- Vulnerability and adaptation
- Mitigation
- Awareness and dissemination

According to the survey, in 1990 carbon dioxide emission in Bangladesh caused by the primary fossil fuel burning was 13,443 giga grams. Per head yearly greenhouse gas emission in Bangladesh is 135 kg. Besides carbon dioxide, the other green house gas in Bangladesh is Methane. From the inundated rice fields and the livestock excreta 468 and 520 giga gram methane is emitted yearly respectively. The emission of other greenhouse gases in Bangladesh is very minor. In general, the condition of carbon dioxide gas emission is still not alarming in Bangladesh. The survey identified GHG (greenhouse gas) mitigation options for Bangladesh in the energy, forestry and agriculture sectors. For the energy sector, more than 60 mitigation options were identified and the least-cost options were determined through an optimization exercise. The study found the industrial sector to be the most promising in this context. Intervention in the industrial sector serves to achieve several goals at the same time, such as reducing energy consumption and reducing the cost of manufacturing. Power generation was identified as another priority area because the present technology is old and inefficient and needs to be replaced in any case, and also because it helps in using domestic gas at a negative cost to the economy. Improving the efficiency of the transport sector helps cut down energy consumption at negative cost and also reduces the foreign exchange costs of imported gasoline. Finally, the use of efficient cooling devices for refrigeration and air-conditioning is recommended; but this is associated with relatively small savings.

In the forestry sector, the ALGAS study assessed six mitigation options, with an

aggregate mitigation potential of 36.27 million tonnes carbon, and an overall mitigation cost of $1.45 per tonne carbon abated. In terms of investment cost per tonne of carbon abated and mitigation potential of individual options, the ALGAS study found artificial long rotation plantation in the hill forest area to be the least-cost option. This was followed by medium rotation artificial reforestation, medium rotation participatory coastal plantation, and the sal plantation.

Five mitigation options were proposed to reduce methane emissions from rice cultivation and livestock rearing.

The Asian Development Bank's Regional Study on Global Environmental Issues (ADB 1994) had earlier identified and assessed GHG mitigation options for Bangladesh within the context of the country's development and strategic needs. The three broad sectors in which Bangladesh has reasonable potential to reduce GHG emissions are: Energy and industry, Agriculture and Forestry.

The current scientific consensus is that with increasing atmospheric concentrations of greenhouse gases Bangladesh will become 0.5 to 2.0 degree centigrade warmer than today by the year 2030 (IPCC, 1990). Bangladesh is one of the few low-laying countries, which will be badly affected by the sea level rise. The deltaic coastal regions of Bangladesh will be most vulnerable to the adverse effects of global warming

Impact of grassland afforestation on soil carbon

M. R. Davis

Forest Research, PO Box 29237, Fendalton, Christchurch, New Zealand

murray.davis@forestresearch.co.nz

Abstract

Approximately 600,000 ha of grassland have been converted to exotic coniferous forest in New Zealand since 1990 as a result of declining agricultural product prices. To determine impacts of afforestation on soil C, data from published papers, theses, and unpublished field studies of paired adjoining grassland and afforested sites in N. Z. were assembled and compared. All forests had been planted into grassland and the mean forest stand age was 22 years (range 10–52 years). A total of 27 site pairs had both soil C concentration and bulk density information for the upper soil layer (mainly 0–0.1m), and a further 18 sites had C concentration data only.

Mean soil bulk density in the 0–0.1 m layer was unaffected by afforestation. Mean soil C in the 0–0.1m layer was lower under forests than grasslands (4.95 and 5.34% respectively, $p = 0.01$). Assuming grassland soil C was stable, soil C concentration declined by 1.03%/year under forest stands aged 10–15 years, but this rate of decline fell progressively as stand age increased, indicating C inputs to the soil exceeded outputs in older stands. There was no difference in mean soil C concentration between grassland and forest at stand age classes 21–25 yrs and 25–30 yrs, indicating early losses are balanced by inputs by about age 20 yr. Older stands (>30 years) had higher soil C concentrations than adjoining grasslands. For stands aged 10–20 years, the rate of decline in soil C concentration with afforestation was greater ($p = 0.10$) at rainfalls exceeding 1000 mm (0.83%/year) than at lower rainfalls (0.36%/year). Only 13 site pairs had data for mineral soil layers greater than 0.1 m depth. Soil C concentration in 21 upper soil layers of these 13 sites declined by 15% with afforestation ($p < 0.01$), but there was no difference in mean soil C in 19 soil layers of greater than 0.1 m depth.

The results from the paired site studies differ from those of the proposed N. Z. Carbon Accounting System which uses historical data from national soil databases to determine soil C change with land use change. Analyses using the historic data indicate that afforestation leads to a permanent reduction in soil C of approximately 5 t/ha for the 0–0.1 m layer, and 15 t/ha for the 0–0.3 m layer. The difference between the two data sets may be due to bias in the national soil data-bases arising from non-random selection of land use for farming and forestry, as forestry has traditionally been confined to poorer soils than farming.

A long-term study of soil C change has been initiated in a replicated trial with four tree densities (including a pasture control) of *Pinus nigra* planted in dry temperate grassland. Initial results at age 10 show non-significant reductions in upper (0–0.1 m) soil C mass of 0.4, 3.6 and 7.7% at tree densities of 250, 500 and 750 stems per ha respectively, but no reduction in the 0.1–0.3 m layer, supporting results from the paired site studies. Further paired site or chronosequence studies are needed to reduce uncertainties in the estimate of soil C change associated with afforestation.

Impacts of Forest Management on Soil and Forest Carbon Stocksin Central British Columbia, Canada.

Arthur L. Fredeen[1,2], Darren T. Janzen[1], Claudette H. Bois[1], Michael J. Jull[3], Roger D. Wheate[2], Paul T. Sanborn[1,2]

[1]Ecosystem Science and Management Program, [2]Faculty of Natural Resources and Environmental Studies; [3]Aleza Lake Research Forest Manager, University of Northern British Columbia (UNBC), Prince George, British Columbia, CANADA. V2N 4Z9. e-mail: fredeena@unbc.ca.

Abstract

Carbon stocks in soils and forest stands are being measured, mapped and modeled for a 7500 hectare region of the UNBC Aleza Lake Research Forest (ALRF), a sub-Boreal Interior spruce (*Picea glauca x engelmannii*) and Subalpine fir (*Abies lasiocarpa*) dominated research forest 60km east of Prince George in East-Central British Columbia. The ALRF has the longest historical record of forest management in the province, extending back to the 1920s. During this time, a wide variety of forest management activities have occurred in the forest, ranging from diameter limit logging to small and large patch clearcuts.

Extensive field sampling was performed to determine belowground and aboveground carbon stocks according to the National Forest Inventory sampling guidelines (Canadian Forest Service, 2002, version 1.1). Briefly, two belowground carbon pools were assessed from random plot centres stratified by forest cover type. Soil carbon (2 pits or cores to 50cm depth, 1 of these to 1 m depth) and forest floor (depth transects and forest floor density and core samples) were assessed in plots or along transects from the plot centres. In addition, large tree (>1.3 m in height; over 400 m^2 area), small tree (over 50m^2 area), as well as shrub and non-woody plant, and coarse woody debris in 1 m^2 subplots or along transects were also measured. Samples of all carbon stocks were finely milled and analyzed with an NA 1500 Elemental Analyzer (Fissions Instruments SPA., Milano, Italy) on 25 mg samples. Commercially available C:N standards were used to calibrate the instrument. All samples were analyzed twice, or more if agreement was not observed between 1st and 2nd samples.

LANDSAT data spanning the last 18 years (1985-2003) were acquired and related to belowground and aboveground field sample measurements and existing forest inventory and land-cover information to create maps of past and present carbon stocks as well as stock changes. Resulting 'GIS maps' of carbon stocks are related to soil type, forest cover type and forest management history

at the ALRF. We will present the most detailed picture available to date on belowground carbon stocks in sub-Boreal spruce forests of western Canada.

Spatial variability of carbon efflux from forest soils : influence of soil water table

Gaëlle Vincent, Eric Lucot, Pierre Marie Badot, Daniel Epron

Laboratoire de biologie et écophysiologie, USC INRA, Université de Franche-Comté
Place Leclerc, 25030 Besançon cedex. gaelle.vincent@univ-fcomte.fr

Abstract

Soil respiration (R_S) is known to be the main carbon efflux from ecosystems to atmosphere (Valentini et al., 2000), and forest soils contain about 40 % of the belowground carbon stock (Thuille et al., 2000). Soil carbon efflux is highly variable both in time and space. Seasonal variations of R_S are explained by soil temperature (T_S) and soil water content (W_S) (Epron et al., 1999, Janssens et al., 2001). The determinants of spatial variations of R_S have been less investigated and is thought to be more related to site dependent factors like soil or vegetation characteristics rather than climatic factors. Further investigations are required for developing spatially explicit models that would allow simulation at a regional scale.

The aim of this work is to study R_S in three contrasted sites of a mixed deciduous forest in order to identify site-dependent parameters that would account for between site variability, in relation to their difference in soil hydromorphy. These differences in soil hydromorphy were characterized by difference in the fluctuation of their water table.

The three sites are located in the state forest of Chaux (eastern France), where water tables fluctuate during the year. The three sites differed in winter depth of water table. Measurements of R_S were made on PVC collars with a portable infrared gas analyzer (EGM - PP systems), connected to a respiration chamber (SRC 1 - PP Systems). Twice a month, 36 measurements were conducted at each site. In the same time, T_S were measured near the soil surface (0-5 cm), and at 10 and 15 cm depth. W_S was recorded in the top soil (0-6 cm) with a tethaprobe (Delta T).

The data show a large variability among microsites at a given site, but also among sites, depending on the season (fig 1). An exponential function and a linear function were used respectively to account for the effect of T_S and W_S on soil respiration ($R_S = A_{SITE}.W_S \exp(B.T_S)$). These two factors explain a significant proportion of the seasonal variability of R_S ($R^2 = 0,71$) . Combining the data for all sites enable us to extract a site-dependent factor (A_{SITE}). Investigations about relationship between either soil or vegetation characteristics and A_{SITE} are in progress. A_{SITE} seems to relate to the depth of water table in winter (A_{SITE}, *cf.* fig 2).

An extrapolation to other sites within the same forest and relationships with site characteristics will be investigated in order to describe the impact of soil hydromorphy on the spatial variation on soil respiration.

References :

Epron D. *et al.* 1999. Annals of Forest Sciences 56, 221-226
Janssens *et al.* 2001 Global Change Biology 7, 269-278
Thuille A. *et al.* 2000. Tree Physiology 20, 849-857
Valentini R. *et al.* 2000. Nature 404, 861-865

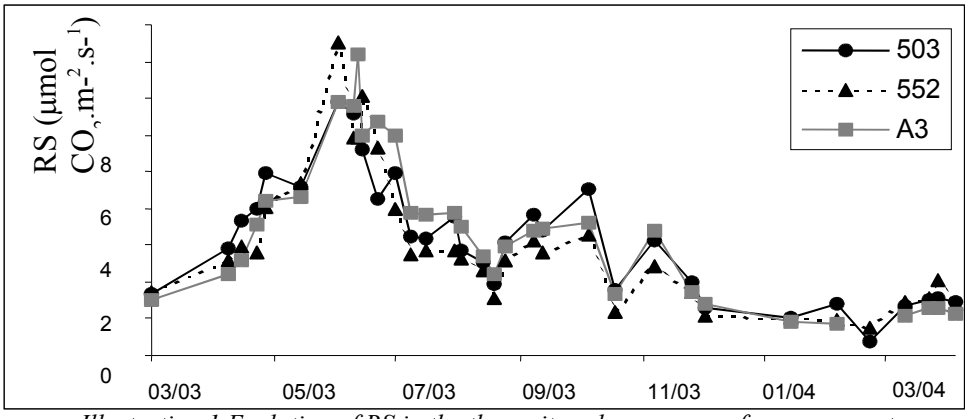

Illustration 1 Evolution of RS in the three sites along a year of measurements

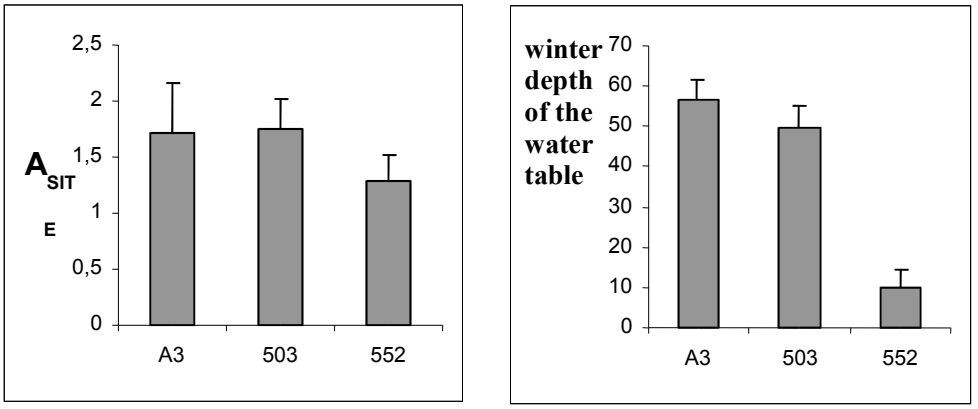

Illustration 2 ASITE and the winter-mean depth of the water table for each site, and their standard error.

Spatial variability of organic carbon stock in topsoil of forest soil in Japan

Kazuhito Morisada[1], Yasuyuki Ohno[2], Satoshi Sawata[3], Masayuki Katakura[4], Hisashi Yoshioka[5], Keiichi Nakaoka[6], Tatumi Takamiya[7]

[1] Forestry and Forest Products Research Institute, Tsukuba 305-8687, Japan, [2] Hokkaido Forestry research Institute, Bibai 079-0198, Japan, [3] Akita Prefecture Forest Technical Center, Kawabe 019-2611, Japan, [4] Nagano Forestry and Forest Products Research Center, Shiojiri 399-0711, Japan, [5] Hiroshima Prefectural Forestry Research Center, Miyoshi 728-0015, Japan, [6] Ehime Prefecture Forest Research Center, Kuma 791-1212, Japan, [7] Oita Prefectural Forest Experiment Station, Hita 877-1363, Japan

[1] morisada@ffpri.affrc.go.jp

Abstract

In order to describe a practical method for verifying the magnitude and direction of soil organic carbon (SOC) stock changes associated with forest harvesting at a field scale, we set up monitoring plots and examined spatial variability of SOC stock in the plot prior to forest harvesting.

The monitoring plots were located at six places, and they were selected from planted forests growing on the major soil types of Japan. Three plots (Hokkaido, Akita, and Ehime) were classified as Cambisols (Brown forest soils), and the others (Nagano, Hiroshima, and Oita) as Andosols (Black soils). About 100 regularly spaced grids (4m or 3m) were established at each plot before harvesting, and organic carbon density in the 0-30 cm of mineral soil was measured by gird.

Values and spatial variability of SOC in pre-harvesting samples greatly differed among soil groups. Mean value of SOC ranged from 6.2 kg m^{-2} (Ehime) to 11.5 kg m^{-2} (Akita) for Cambisols and from 15.2 kg m^{-2} (Oita) to 17.7 kg m^{-2} (Hiroshima) for Andosols group. Spatial variability of SOC expressed by the coefficient of variation (CV), ranged from 19% to 24% for Cambisols group, and it was about 10% for Andosols group. Value of SOC generally tended to increase toward lower position of slope on the grid in the plot.

The results suggested that arrangement of sampling density by soil group was practical to get a reliable estimate of SOC at the field scale. It also suggested that regular sampling along the slope is suitable for determining SOC.

Comparison of ecosystem and soil CO2 efflux in a beech forest

Jérôme Ngao, Bernard Longdoz, André Granier

UMR INRA-UHP Ecologie et Ecophysiologie Forestière, Centre INRA de Nancy, 54280 Champenoux, France

Abstract

Eddy covariance (**EC**) methodology is used for more than 15 years in net carbon ecosystem exchange (**NEE**) studies, particularly in forest and grassland ecosystems. NEE flux is measured between the canopy and the atmosphere, integrating different CO_2 fluxes. Interannual variation of NEE is commonly observed, that originates from variation of both total ecosystem CO_2 respiration ($\mathbf{R_{eco}}$) and photosynthesis. Among CO_2 sources, soil CO_2 efflux ($\mathbf{S_R}$) is considered as a major component of forest carbon balance. Partitioning the ecosystem CO_2 efflux, in particular accurate measurements of S_R, is required for analysing and modelling carbon efflux and its response to climate or perturbation, and for providing a better knowledge of carbon budgets of forest ecosystems. Using EC technique for soil respiration measurements instead of widely used closed dynamic chamber (**CDC**) technique is typically limited by low turbulences in below-canopy situations. On the other hand, the CDC technique has typically a lower temporal resolution than the EC technique. In addition, the sampling area of S_R may not correspond to the flux footprint attributed to the EC measurements, leading to substantial over or underestimations of contribution of S_R to R_{eco}.

The aim of this study is to compare R_{eco} and S_R fluxes measured at the Hesse state forest (57, France), which is a part of the CarboEurope flux-monitoring network. The flux tower is located in a 35 year-old beech (*Fagus sylvatica L.*) stand. CO_2 flux data were averaged half-hourly. Preliminary analysis has defined a footprint area oriented NE-SW, in agreement with the dominant wind direction, with a maximum extension of 300-400 m. Mean S_R flux is estimated by measuring S_R in 7 plots distributed inside the footprint area by distinguishing soil type and 3 LAI classes. Comparing temporal evolution of CO_2 fluxes in 2003, R_{eco} flux averaged 884 g $C.m^{-2}.s^{-1}$. S_R flux highlighted a correlation with soil temperature and water content, from which a model has been adjusted for annual S_R calculation. By taking account of measurements

from the 7 plots, S_R averaged 866 g $C.m^{-2}.s^{-1}$, leading to a contribution of S_R to R_{eco} of 98%. This apparent very high contribution of S_R may be due to plots exhibiting high S_R flux but not taken into account by EC measurements. A footprint analysis has been performed for each day of S_R measurements with the aim to select the plot that contributes significantly to R_{eco} measurements. Preliminary results showed that the area contributing maximum flux is mainly located in the SW situation of the flux tower. The footprint analysis would be discussed. The S_R model will be improved, particularly the response to soil water content, when considering the severe drought of summer 2003.

Activities of the GERS (Group studying the soil respiration)

Longdoz B.[1], Ngao J. [1], Perrin D.[2], Vincent G.[3], Willm F.[1], Aubinet M.[4], Granier A.[1], Epron D[5].

[1]UMR Ecologie et Ecophysiologie Forestière, INRA de Nancy, France

[2]Unité de Biologie Végétale, Faculté Universitaire des Sciences Agronomiques de Gembloux, Belgique

[3]Laboratoire de Biologie et d'Écophysiologie, Université de Franche Comté, Montbéliard, France

[4]Unité de Physique des Biosystèmes, Faculté Universitaire des Sciences Agronomiques de Gembloux, Belgique

[5]UMR Ecologie et Ecophysiologie Forestière, Université Henri Poincaré de Nancy, France

E-mail: longdoz@nancy.inra.fr

Abstract

The GERS is a group of researchers, students and technicians from France and Belgium working on the soil respiration. The aim of this group to provide an avenue to exchange idea, information or data, and where the members of the different teams can set up some experiments to share material or to compare measurement systems. This group is open to all new teams or persons interested by the topics related to soil respiration and by the exchange and sharing procedure adopted by the GERS. The poster presents four examples of research activities carried out by the GERS. The first one is a comparison of different closed dynamic systems used to measure the soil CO_2 efflux (R_s). These systems are all constituted of closed chambers placed on the soil and linked to an infrared gas analyser measuring the increase of the CO_2 concentration in the chamber, which is proportional to R_s. The comparison has been performed on a large range of R_s values in three commonly investigated forest sites by the GERS teams (in Belgium and France). This comparison shows a systematic difference of less than some 15%. This percentage is of the same order that has been presented in the most recent publications comparing other systems of measuring R_s. The second activity is a comparison of the R_s from different forest plots. Before comparison, the fluxes are corrected by accounting for differences due to measuring systems. The effects of soil temperature and water content on R_s are estimated by regression in the same way for all the plots. This procedure allows the determination of a set of parameters which are free of meteorological differences between the plots. Consequently, they can be

compared for canopy proprieties (LAI) C and N soil contents and others to achieve the R_s inter-plots variations due to the ecosystem types. Measurement of soil CO_2 concentration in the soil pores is the third activity presented. The teams of the GERS have put together CO_2 concentration sensors to obtain a vertical profile at two different forest sites. The seasonal and diurnal variations of the CO_2 concentration are analysed in relation to soil temperature, soil water content and wind turbulence only for the concentration in the litter layer. The last activity proposed by the GERS is the set up of a system measuring the CO_2 flux from wood debris on the forest soil surface. The system is able to measure the fluxes at any temperatures fixed by the experimenter. A strong dependency of CO_2 flux with the wood humidity content has been observed. The respiration rate of samples of wood debris from different classes of degradation has been measured. These values combined with the inventory of the wood debris by degradation classes and the meteorological conditions will be used to estimate the importance of the wood debris respiration in the forest carbon budget.

Changes in soil organic carbon and nitrogen following afforestation of *Cryptomeria japonica* and *Chamaecyparis obtusa* on Andisols in central Japan

Hisao Sakai[1,*], Masahiro Inagaki[2], Kyotarou Noguchi[3], Tadashi Sakata[3], Masamichi Takahashi[3], Mikhail A. Yatskov[4]

[1]Hokkaido Research Center, Forest and Forest Products Research Institute (FFPRI), Hitsujigaoka 7, Toyohira-ku, Sapporo city, 062-8516 Hokkaido, Japan [2]Japan International Research Center for Agricultural Science, Ohwashi 1-1, Tsukuba city, 305-8686 Ibaraki, Japan [3]Forestry and Forest Products Research Institute (FFPRI), Matsunosato1, Tsukuba city, 305-8087 Ibaraki, Japan [4]Department of Forest Science, Oregon State University, 321 Richardson Hall Corvallis Oregon 97331-5752, USA
sakai03@ffpri.affrc.go.jp

Abstract

Quantifying changes in soil organic carbon and nitrogen following afforestation has great relevance to the Kyoto Protocol. Recently, many reports on this issue have been published, but none have addressed Andisols. Such soils are known to accumulate organic materials in great amounts, so we hypothesized that the carbon accumulation rate of Andisols may differ from those for other soil types. We measured changes in soil organic carbon and nitrogen following afforestation of *Cryptomeria japonica* (CJ) and *Chamaecyparis obtusa* (CO) on Andisols. These species are commonly planted in Japan.

The study was carried out at the Chiyoda Experimental Station of the Forestry and Forest Products Research Institute (FFPRI), at 36˚11´N, 140˚13´E in Ibaraki Prefecture, Japan. Soil at the station was Andisols derived from volcanic ash. Soil texture was silty clay loam (SiCL). To determine the changes in carbon (C) and nitrogen (N) mass in the soil with increase in stand age, we sampled the surface organic layer and soils at 0-5, 5-15, and 15-30cm depths from stands 4, 14, and 23 years old for CJ, and from stands 4, 12, and 25 years old for CO. At these stands, the soil was ploughed to 30cm depth and coarse woody materials were cleared away. Before tree planting, the sites had been managed as lawns for several years. We took samples from an adjacent lawn as a control. At each stand, tree height and DBH (diameter at breast height) were measured. To correct for differences in initial C and N values at the stands, we assumed that a subsoil layer (15-30cm) maintains the soil in each stand in its initial condition, and consider it as a reference layer for the purpose of correction. The changes in C and N mass in the soil at 0-15cm depth were estimated from the reference layer.

At the CJ stands and the CO stands, the changes in C and N mass with stand age were mostly confined to the organic layer and the soil at 0-5cm depth. They were negligible for the soils at 5-15cm depth. In the 4-year-old stands, C mass in the surface soil at 0-5cm depth decreased by 1.4 g C m^{-2} at the CJ stands and 1.7 g C m^{-2} at the CO stands. Except at the 4-year-old stands, C and N mass at the CJ and CO stands were higher than those at the lawn site. The rates of soil C accumulation with stand age in the soil of 0-15cm depth were roughly constant: 44.8 g C m^{-2} yr^{-1} for CJ stands, and 21.1 g C m^{-2} yr^{-1} for CO stands. The amounts of nitrogen at the depth of 0-5cm in the 4-year-old CJ stands and the 12-year-old CO stands remained unchanged. Subsequently N mass increased by 0.3 g N m^{-2} in CJ stands of 23 years old and by 0.2 g N m^{-2} in CO stands of 25 years old. Nitrogen in the soil at 5-15cm depth did not differ with stand age. C and N in the surface organic layers increased linearly with stand age for CJ. At CO stands, C and N in the organic layer increased until 12 years old, and subsequently plateaued.

In this study, C accumulated at a faster rate at CJ stands than at CO stands. This resulted from relatively small input of C from aboveground due to the small forest biomass and the low litterfall rate at CO stands. The rate of increase in aboveground biomass was estimated to be 468 g C m^{-2} yr^{-1} in CJ stands and 333 g C m^{-2} yr^{-1} in CO stands. This suggested that 1/10 or less of the biomass accumulated in the trees accumulated in the soil at the CJ and CO sites. In conclusion, the accumulation rates of soil organic matter in the Andisols we studied were within the range of those found in other soil types (Post and Kwon, 2000). Any increase in labile organic matter after afforestation seems to be constrained by the characteristics of the planted species and not by the soil type.

Dual potential of increasing CO2 efflux from forest soils in high latitude area in Japan

Shigehiro Ishizuka[1], Tadashi Sakata[2], Satoshi Sawata[3], Shigeto Ikeda[2], Chisato Takenaka[4], Nobuaki Tamai[4,5], Takanori Shimizu[6], Kensaku Kan-na[7], Nagaharu Tanaka[1], and Masamichi Takahashi[2]

[1]Hokkaido Research Center, Forestry and Forest Products Research Institute, Sapporo, Hokkaido Japan [2]Forestry and Forest Products Research Institute, Tsukuba, Ibaraki, Japan [3]Akita Prefecture Forest Technical Center, Kawabe-gun, Akita, Japan [4]Graduate School of Bioagricultural Sciences, Nagoya University, Nagoya, Aichi, Japan [5]Now at: Fuji Research Institute Corporation, Tokyo, Japan, [6]Kyushu Research Center, Forestry and Forest Products Research Institute, Kumamoto, Kumamoto, Japan [7]Okinawa Prefecture Forestry Experiment Station, Nago, Okinawa, Japan
e-mail: ishiz03@ffpri.affrc.go.jp

Abstract

In order to evaluate the variation of CO_2 efflux from forest floor in Japan, we have made a network for the flux measurement, which consisted of 25 sites stretched from the latitude of 26 °N to 44 °N, and monitored CO_2 flux monthly by closed chamber method. We also took intact soil samples with a 100 mL cylindrical stainless tube, and incubated them to evaluate the CO_2 emission potentials of the soils. We analyzed the relationship between these potentials and soil physical, chemical and biochemical properties.

The CO_2 efflux from forest floor in each site was seasonally fluctuated, mainly controlled by the soil temperature. The CO_2 fluxes were exponentially correlated with soil temperatures.

The CO_2 emission rate at the same soil temperature, for example 15 °C, was gradually increasing from south to north. The annual rate of carbon emission from forest floor, which was estimated by the soil temperature and the correlation equation mentioned above, ranged from 3.6 to 10.6 Mg C ha^{-1}. Annual soil respirations estimated by the result of soil incubation analysis had a high correlation with the annual-integrated soil temperatures. Soil respiration rate had a high correlation with the CMCase (one of the cellulases) activity in the soil, this result suggesting that the temperature effect for microorganisms' activity is directly responsible for the temperature effect for soil respiration.

The ratio of the contribution of organic layer and/or root respiration to the total CO_2 flux from soil in northern regions was larger than that of southern regions. Additionally the content of sugars in the soil in northern regions was higher than that in the southern regions. These results indicate that the regions in high latitude in Japan have dual potential (both high organic layer content and easily-degradable soil organic matter) of increasing CO_2 efflux from forest floor with an increase in soil temperature.

Plenary session 2 « SOIL BIOLOGY»

Soil biota:Global change and the function of forest soils as a habitat for soil organisms

Martin Potthoff and Friedrich Beese

Institute of Soil Science and Forest Nutrition, University of Göttingen, Büsgenweg 2, D-37077 Göttingen, Germany

Abstract

Environmental conditions influence the quality of soil as habitat for soil biota (soil fauna, soil microbiota, and epigeic organisms). Habitat conditions cause global and local changes to the environment through their effect on abundance and biomass of species, community structure, diversity and genetic shifts in populations (Fig 1).

Soil functions e.g., nutrient uptake and cycling, water uptake and hydrology, decomposition and mineralization, and acidification and detoxification are strongly related to the activity of soil organisms. For forest management and landscape conservation practices appropriate soil functions are essential and they may be endangered by environmental changes. Global forces that drive changes in habitat conditions include temperature and rainfall, shifts in substrate composition due to CO_2 enrichment, altered land use practices, and invasion by exotic plant or animal species. Soil pollution, eutrophication and salinization are examples of strongly changed habitat conditions on regional and local levels

Both the intensity of perturbation and the tolerance of species and/or communities to changes in habitat conditions have to be in the focus of forest soil research and management to predict ecosystem responses to global and local changes (Figure 1).

This keynote will give a brief overview of the current research by providing a variety of relevant examples (case studies) describing the effects of global climate change on forest floor biota and their activities, while focusing on functional groups like decomposers, ecosystem engineers, predators as regulators, symbiotic organisms, and nutrient transformers.

A wide range of scenarios can be listed for soil biota under global change. CO_2 enrichment of the atmosphere is known to affect substrate quality and is likely to cause changes in the decomposer food web.

The extinction of earthworms from forest floors in central Europe by acidification of soils is considered as an important reason for forest soil degradation. However, in North America exotic earthworms act as invasive species are considered as pest. They are very effective consumers of the humus layers in northern hardwood forests destroying the typical plant communities in

these areas. It seems to be very important to take also the human angle into account when assessing any changes in ecosystem performance.

Evaluation of the present research activities will be used to suggest future directions in soil biological research which may include:

- Linking community structures to functions
- Identifying factors that put key functions at risk
- Management of soil biota of forest floors that are degrading or damaged
- Resistance and resilience of soil communities and soil functions to disturbance
- Identifying indicators to assess soil quality in terms of habitat conditions

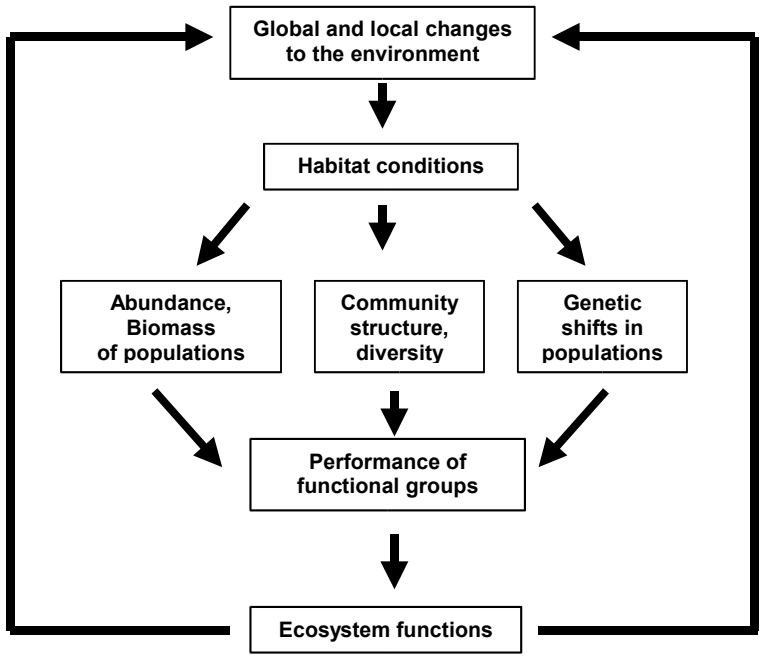

Figure 1: A schematic representation of the central role of soil as a habitat for soil biota in affecting ecosystem functions in relation to global, regional and site specific changes.

How are the saprophagous macrofauna likely to respond to global change in temperate forest soils?

J. F. David & D. Gillon

Centre d'Ecologie Fonctionnelle & Evolutive, CNRS,
1919 route de Mende,
F-34293 Montpellier cedex 5, France
e-mail: david@cefe.cnrs-mop.fr

Abstract

Saprophagous macrofauna organisms (earthworms, macroarthropods) are important regulators of the decomposition processes in mull-type forest soils. They have been classified into four functional groups (epigeic, epi-anecic, anecic, endogeic), depending on their role in the fragmentation of leaf litter, incorporation of organic matter deep in the soil, and organomineral mixing.

Using data from the literature, the biomass of the four functional groups was compared between mull sites located either at various latitudes in northwestern Europe, or in the Mediterranean region. The long-term mean air temperature ranged from 5.5°C in Sweden to 13.9°C in southern France. In comparison with the cool temperate soils, the Mediterranean soils represented extreme scenarios of global change for the macrofauna, with a mean annual temperature at least 3.3°C higher, a marked drought in summer, and leaf litter of lower quality due to high C:N ratios and the occurrence of sclerophyllous plant species.

The results showed that (1) the total biomass of saprophagous macrofauna was significantly higher in the Mediterranean soils. (2) All the functional groups were well represented in the Mediterranean soils. However, the epigeic group comprised only macroarthropods, and the activity period of anecic and epi-anecic earthworms was shifted towards the winter. (3) Although endemic species accounted for a substantial proportion of the animal biomass in the Mediterranean soils, all functional groups also included species widespread in northwestern Europe, which were acclimatized or adapted to Mediterranean conditions. When the Mediterranean endemic species were left out, the total biomass of saprophagous macrofauna did not vary significantly from Sweden to the Mediterranean.

These results suggest that, in the temperate regions of northwestern Europe, the saprophagous macrofauna of forest soils are unlikely to be greatly affected by global change. All the functional groups that take part in the formation of forest mull comprise some species that can easily withstand an average temperature up to *ca.* 14°C, a marked drought in summer, and a substantial decrease in litter quality. These species could constitute efficient

saprophagous communities in the event of a further increase in temperature and atmospheric CO_2 concentration.

Control of the nitrogen mineralising activity of micro-organisms by vegetation is a key-parameter to be taken into account by managers whatever the ecosystem function considered

Jacques Ranger, Jean-de-Dieu Nzila, Bernd Zeller, Jean-Paul Laclau, Jean-Pierre Bouillet, Philippe Deleporte, Judicaël Moukoumi, Jean-Hugues Jussy, Jean-Noël Marien.

(1) INRA Centre de Nancy, Biogéochimie des Ecosystèmes Forestiers 54280 Champenoux France ranger@nancy.inra.fr ; (2) UR2PI Pointe-Noire Congo ; (3) ESALQ-Piracicaba University of Sao Paulo - Brazil

Abstract

The role of vegetation in ecosystem functions was recognised from the very beginning of soil science. Nevertheless, this role is not yet fully understood because of its multiple effects. Vegetation affects the physical cover of the soil and thus its pedoclimate and physical and chemical erosion. It controls the carbon cycle, *i.e.* fixation, restitution by litterfall, root exudates, organic matter biodegradation, and the nutrient cycles by the way of uptake, returns, and mineralisation.

Vegetation, both trees and herbaceous species, exerts a particular control on N-mineralising organisms. This effect could promote or inhibit the activity of soil-nitrifiers which will potentially affect all the soil functions. These ecological relationships indicate the potentially strong impact of forest ecosystem management on the sustainability of all the soil functions.

The objectives are to present several examples taken from experimental investigations in temperate and tropical forests where changes in the plant cover led to changes in N-mineralisation. Consequences of such changes for soil sustainability will be addressed.

Material and methods

Observations made in three experiments monitored for medium term period were used here: results concerning soil solid phase and solutions, the main fluxes of the biogeochemical cycle of nutrients, and nitrogen mineralisation patterns.

1- A chronosequence of a Douglas-fir studied for nutrient dynamics during stand development and clear-cutting. The stand was planted on acid soil previously cultivated in the Beaujolais (France); elevation was 750 m; rainfall 1100 mm and mean annual temperature 7°C.

2- A 30-year old experiment comparing broadleaved and coniferous species planted after clear-cutting of the native stand in the Breuil-Chenue forest in Morvan (France). The soil was highly acid; elevation was 650 m; rainfall 1400 mm and mean annual temperature 7°C.

3- A short rotation plantation of clonal Eucalyptus introduced on a native savanna in the coastal plain of Congo (Africa). The soil was weakly acid; elevation was 40 m; rainfall 1200 mm and mean annual temperature 27°C.

Results and discussion

In the Beaujolais site, mineralisation and nitrification were very high in the acidic soil conditions. Excess nitrates led to large losses in seepage waters. In contrast to what was expected, nitrification decreased when the 70-year old stand was clearcut. It was hypothesised that past land use was responsible for high mineralisation rates, and that Douglas-fir rhizosphere promoted nitrification, contrarily to ground vegetation, which tends to inhibit it.

In the Morvan site, no nitrification occurred in the native broadleaved forest, while it appeared at different degrees in the plantations: some species had a strong promoting effect on nitrification, higher than nutrient uptake leading to excess nitrates which led to very different soil solution chemistry. Under fertilised treatment, the stand production was increased and nitrates and accompanying cations were strongly reduced in soil solutions.

In the Congo site, replacement of savanna by Eucalyptus plantations immediately promoted nitrification. More precisely, eliminating grasses by glyphosate under intensively managed Eucalyptus plantations, immediately caused nitrification.

Our results show that vegetation ‘controlled’ the N-mineralising activity of soil microbes. Important ecological consequences appear on soil function due to excess nitrates and interesting or noxious cations. Environmental constraints could also be identified, especially the risk of N and cation leaching. Fertilisation can have positive effects, increasing nutrient uptake and limiting the secondary effects of nitrification. Weed control and forest species changes can play a significant role on the sustainability of all the soil functions.

Conclusions

- The mechanisms underlying these observations have to be elucidated by further ecological investigations, and more investigations are required to identify the generality of these observations.

- The methodology used for ecological investigations needs to take into account the numerous interactions and feed-backs observed *in situ*. It is not sure that a lot of the key factors are not eliminated in purely controlled

measurements, limiting their interest for determining the mineralising soil capacity.

- Forest management could potentially affect the ecosystem function and sustainability through vegetation control: weed control or forest species changes.

Soil carbon and nutrient pools, microbial properties and gross nitrogen transformations in adjacent natural forest and hoop pine plantations of subtropical Australia

Zhihong Xu, Sally Ward, Chengrong Chen, Tim Blumfield and Nina Prasolova

Faculty of Environmental Sciences, Griffith University, and CRC for Sustainable Production Forestry, Nathan, Queensland 4111, Australia (author for correspondences: zhihong.xu@griffith.edu.au)

Abstract

An improved understanding of important soil carbon (C) and nutrient pools as well as microbial activities in forest ecosystems is required for developing effective forest management regimes, which underpin forest productivity and sustainability. The objectives of this study were to: (1) quantify the impacts of forest types (natural forest dominated by eucalypt species *vs* hoop pine plantations) and management practices (harvesting and conversion from the first rotation to second rotation hoop plantation) on soil C and nutrient pools in adjacent natural forest and hoop pine plantations of ca. 50-year-old first rotation (1R) and 1-year-old second rotation (2R) (with harvest residues windrowed and about 5 m between the 2 windrows); and assess microbial properties and gross nitrogen (N) transformations in top 10 cm soil under the adjacent natural forest, 1R and 2R hoop pine plantations (26°52' S, 151°51' E) located in southeast Queensland, Australia.

Five transects spaced 3 m apart with 9 sampling points along each transect (1.2 m between 2 adjacent sampling points) were selected for each of the 3 forest plots (9.6 m x 12.0 m), with 45 20-cm soil cores (ca. using an auger with 7.5 cm in diameter) taken from the relevant sampling points and separated into 0-10 and 10-20 cm soil depths. There were 90 soil samples from each forest site for determining soil total C, total N, stable C isotope composition ($\delta^{13}C$) and N isotope composition ($\delta^{15}N$), which were also used to estimate appropriate sample size or number required for detecting differences in these soil variables between the forest sites. Soil total C and N, $\delta^{13}C$ and $\delta^{15}N$ were determined using an Isoprime isotope ratio mass spectrometer (Isoprime-EuroEA 3000). Five 0-10 cm soil samples (9 soil samples in each transect were bulked to make such a sample) from each site were used to determine soil pH, CEC, exchangeable cations (K, Ca, Mg and Mn), total P and total K. For assessing soil microbial properties and gross N transformations, each (about 30 m by 100 m) of the research areas under the adjacent natural forest, 1R and 2R hoop pine plantations, which covered the above 3 forest plots used for the transect soil

sampling, was divided into 5 subplots for soil sampling. A total of 25 soil cores (0-10 cm) were randomly collected with an auger from each subplot and bulked (well mixed). In the 2R hoop pine plantation, the soil was sampled from areas between the windrows of harvest residues. Field-moist soil samples were sieved (<2 mm) and stored at 4 ^{o}C before assaying for soil microbial biomass C and N, soil respiration and metabolic quotient. Potential N mineralization (PMN), gross N mineralization and immobilization were determined on air-dried soil samples with ^{15}N isotope dilution method.

Total C and N in 0-10 cm soil samples were significantly higher in the natural forest and 1R hoop pine plantation than those in the 2R hoop pine plantation, while total C and N in 10-20 cm soil samples were highest in the natural forest, followed by the 1R and then 2R hoop pine plantations (Table 1). The δ^{13}C values in the 0-10 and 10-20 cm soil samples were significantly lower in the natural forest than those in the hoop pine plantations, while δ^{15}N values were significantly higher in the natural forest than in the hoop pine plantations. The sample sizes required for detecting differences in soil δ^{13}C and δ^{15}N were relatively lower (2-3 for δ^{13}C and 4-23 for δ^{15}N), compared with those (6-48 for soil total C and 5-31 for total N) as shown in Table 2. Soil total P was the highest in the natural forest, followed by the 1R and then 2R hoop pine plantations, while soil total K was significantly higher in the 2R hoop pine plantation than in the natural forest and 1R hoop pine plantation (Table 3). There were no significant differences in soil pH, CEC and exchangeable cations among the 3 forest sites. There were little differences in soil microbial C and N, respiration and metabolic quotient among the 3 forest sites (Table 4). The PMN and gross N mineralization were significantly higher in the natural forest, while gross N immobilization was highest in the 2R hoop plantation, followed by the natural forest and then 1R hoop pine plantation.

[a]***Table 1*** *Soil total carbon (C) and nitrogen (N), and stable C and N isotope composition ($\delta^{13}C$ and $\delta^{15}N$) in 3 adjacent forest ecosystems (means of 43-45 samples collected by soil auger of 7.5 cm in diameter from each forest plot of 9.6m x 12m)*[a]

Forest type	Total C (%)	Total N (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)
		0-10 cm soil		
Natural forest	6.3ab[b]	0.55a	-25.89b	10.02a
First rotation hoop pine plantation	6.4a	0.58a	-25.36a	8.32b
Second rotation hoop pine plantation	5.8b	0.49b	-25.53a	8.03b
		10-20 cm soil		
Natural forest	4.7a	0.42a	-25.32b	10.20a
First rotation hoop pine plantation	3.7b	0.37b	-24.54a	9.04b
Second rotation hoop pine plantation	3.0c	0.29c	-24.67a	8.72b

There are no significant differences in soil bulk density (BD) among the 3 forest plots (mean BD = 0.717 g cm^{-3}) for 0-10 cm soil depth; [b]*Means within a column for a given soil depth followed by the same letter are not different from each other at 5% level of significance.*

Table 2 *Sample size required for estimation of mean soil total carbon (C) and nitrogen (N), and stable C and N isotope composition ($\delta^{13}C$ and $\delta^{15}N$) in 3 adjacent forest ecosystems (9.6m x 12m for each of the 3 forest plots) with the sample mean relative error at 10% ($P_{\alpha}^{10\%}$) and 20% ($P_{\alpha}^{20\%}$) with 95% confidence*[a]

Forest Type	Total C (%)		Total N (%)		$\delta^{13}C$ (‰)		$\delta^{15}N$ (‰)	
	$P_{\alpha}^{10\%}$	$P_{\alpha}^{20\%}$	$P_{\alpha}^{10\%}$	P_{α}^{2}	P	P	P_{α}^{1}	P_{α}^{2}
				0-10 cm soil				
NF	13	6	12	5	3	3	2.3	8
1R	24	9	16	7	3	3	1.7	7
2R	39	13	20	7	3	3	8	4
				10-20 cm soil				
NF	13	6	11	5	3	2	9	5
1R	48	15	31	10	3	3	1.0	5
2R	30	10	20	7	3	2	6	4

[a]*Forest type: NF – natural forest; 1R – first rotation hoop pine plantation; and 2R – second rotation hoop pine plantation.*

Table 3 *Other chemical properties in 0-10 cm soil in 3 adjacent forest ecosystems (means of 5 representative samples collected from each forest plot of 9.6m x 12m)*[a]

Forest Type	pH (1:5 H_2O)	CEC (cmol kg^{-1})	Exchangeable cation (cmol kg^{-1})				Total P (mg kg^{-1})	Total K (mg kg^{-1})
			K	Ca	Mg	Mn		
NF	5.0a[b]	3.5.7a	0.49a	3.85a	0.76a	0.046a	1.477a	701b
1R	6.0a	3.8.7a	0.67a	6.85a	1.55a	0.018a	1.116b	1191b
2R	5.4a	2.8.5a	0.52a	3.96a	1.13a	0.082a	7.48c	5588a

Forest type: NF – natural forest; 1R – first rotation hoop pine plantation; and 2R – second rotation hoop pine plantation; and CEC – cation exchange capacity; Means within a column followed by the same letter are not different from each other at 5% level of significance.

Table 4 *Microbial properties and gross nitrogen transformations in 0-10 cm soil in 3 adjacent forest ecosystems (means of 5 representative samples collected from each forest plot)*[a]

Forest Type	MBC (mg kg^{-1})	MBN (mg kg^{-1})	CO_2-C respired (mg kg^{-1} h^{-1})	qCO_2-C (µg mg^{-1} MBC h^{-1})	5 g soil incubated with 5 µg $^{15}NH_4$-N in 50 ml solution (99% ^{15}N excess)		
					PMN (mg kg^{-1})	*M* (mg kg^{-1})	*I* (mg kg^{-1})
NF	951a[b]	113.1a	0.503a	0.552a	114.6a	140.2a	25.6b
1R	686a	102.3b	0.414a	0.672a	62.6b	78.3b	15.8c
2R	930a	142.6a	0.571a	0.626a	58.7a	95.9b	37.2a

[a]*Forest type: NF – natural forest; 1R – first rotation hoop pine plantation; and 2R – second rotation hoop pine plantation; MBC – microbial biomass carbon (C); MBN – microbial biomass nitrogen (N); qCO_2-C – metabolic quotient; and potential mineralizable N (PMN), gross N mineralization (M) and gross N immobilization (I) obtained by the 5 g soil incubated for a week at 40 °C with 5 µg $^{15}NH_4$-N in 50 ml solution (99% ^{15}N excess), are closely related to the corresponding values incubated with 10 µg $^{15}NH_4$-N in 50 ml solution (99% ^{15}N excess) (data not shown); bMeans within a column followed by the same letter are not different from each other at 5% level of significance.*

Litter layer influence on the thermal regime of a sandy soil under a pine forest

J. A. Andrade, F. G. Abreu

Departamento de Geociências, Universidade de Évora, Évora, Portugal
zalex@uevora.pt
Departamento de Ciências do Ambiente, Instituto Superior de Agronomia, Lisboa Portugal
fgabreu@isa.utl.pt

Abstract

Soil temperature determines the rates and directions of energy and mass exchange with the lower layer of the atmosphere and strongly influences soil microbial activity.

Temperature profiles of a sandy soil (Podzol) under a pine forest were measured at several depths down to 40 cm, with and without litter layer. Daily and annual temperature cycles were analysed by means of Fourier series. Daily cycles were studied based on data for four days defined according to soil water content.

The daily periodic variations of soil temperature follow closely the time-course of solar irradiance. Daily course of soil temperature was well described by the two first Fourier harmonics. The litter layer acts as a thermal insulator, reducing soil temperature gradients and amplitudes and increasing damping depth, particularly in dry soil.

Impacts of harvest residue management on soil carbon and nitrogen pools and microbial properties in a slash pine plantation of subtropical Australia

Chengrong Chen and Zhihong Xu

Co-operative Research Centre for Sustainable Production Forestry and Faculty of Environmental Sciences, Griffith University, Nathan, Qld 4111, Australia
E-mail: c.chen@griffith.edu.au

Abstract

Harvest residue management can affect the dynamics of soil carbon (C) and nutrient pools and associated soil microbial processes. A field experiment was conducted to investigate the impacts of harvest residue management practices on soil C and nitrogen (N) pools in a 6-year-old slash pine plantation grown on a sandy soil in southeast Queensland, Australia. This trial comprised 4 treatments using a complete randomised block design with 4 replications: 1) No slash (0S) – removed both litter and logging debris from 1st rotation harvest (29.4 years old); 2) Single slash (1S) – retained and evenly distributed both litter and logging debris from 1st rotation harvest; 3) Single slash plus complete weed control (1S+WC); and 4) Double slash (2S) – retained litter and logging debris from 1st rotation harvest and added harvest residues from no slash plots. Results showed that harvest residue retention significantly enhanced accumulation of soil total C and N compared with residue removal (Table 1). The NH_4-N was the predominant form of soil mineral N, and residue management practices did not affect concentrations of NH_4-N in soil. Concentrations of water soluble and hot water extractable organic C and total N tended to be higher in soil with residue retention compared with residue removal, but this trend was only significant for hot water extractable organic C (HWEOC) in surface soil (0-10 cm). Residue retention also tended to increase soil microbial biomass C and N, but did not significantly affect soil respiration and metabolic quotient (qCO_2) (Table 2). Direct C and N inputs into soil from the residue layer and moderation of the variation of soil moisture and temperature over the seasons by harvest residue cover might have contributed to the accumulation of soil C and N and microbial biomass with the residue retention treatments. The lack of statistically significant differences in some of soil microbial properties (e.g. MBC, respiration etc.) might have been related to a large spatial variability among replicate plots at the experimental site.

Table 1 *Surface soil (0-10 cm) total C (TC), total N (TN), NH_4-N, Water soluble organic C (WSOC) and total N (WSTN) and hot water extractable organic C (HWEOC) and total N (HWETN) in relation to harvest residues management in a second rotation slash pine plantation at Toorala State Forest, southeast Queensland, Australia. OS harvest residue removal; 1S single slash retention; 1S+WC single slash retention plus complete weed control; 2S double slash retention with both on-site harvest residues and those from the OS plots. Data are means (n = 4); data in parentheses are standard deviations. Means within a column of the corresponding depth followed by the same letter are not different at the 5% level of significance*

Treatment	MBC (μg g^{-1})	MBN (μg g^{-1})	Soil respiration (μg CO_2-C g^{-1} 7 $days^{-1}$)	qCO_2 (μg CO_2-C mg^{-1} microbial C h^{-1})
0S	291 (126)a	43.6 (7)b	79 (10)a	1.8 (0.7)a
1S	354 (115)a	45.9 (2.7)ab	99 (10)a	1.8 (0.6)a
1S+WC	291 (73)a	34.8 (14.5)b	102 (31)a	2.8 (2.3)a
2S	430 (201)a	54.5 (4.2)a	94 (12)a	1.6 (0.8)a

Table 2 *Soil (0-10 cm) microbial biomass and activity in relation to harvest residues management in a second rotation slash pine plantation at Toorala State Forest, southeast Queensland, Australia. OS harvest residue removal; 1S single slash retention; 1S+WC single slash retention plus complete weed control; 2S double slash retention with both on-site harvest residues and those from the OS plots. MBC microbial biomass C, MBN microbial biomass N, qCO_2 metabolic quotient. Data are means (n = 4); data in parentheses are standard deviation. Means within a column of the corresponding depth followed by the same letter are not different at the 5% level of significance*

Treatment	T C (%)	T N (%)	N H_4-N (μg g^{-1})	W SOC (μg g^{-1})	W STN (μg g^{-1})	HW EOC (μg g^{-1})	HWETN (μg g^{-1})
0S	1.078b (0.238)	0.034b (0.005)	2 (4)a	120a (55)	4.4a (0.3)	320 (17)bc	7.2 (1.5)a
1S	1.677a (0.247)	0.052a (0.009)	2 6 (6)a	150a (54)	4.0a (0.8)	359 (67)ab	7.2 (1.4)a
1S+WC	1.454ab (0.387)	0.045ab (0.011)	2 4 (4)a	147a (70)	5.1a (2.0)	288 (18)c	8.6 (3.0)a
2S	1.922a (0.204)	0.057a (0.005)	2 4 (3)a	140a (24)	5.0a (0.5)	425 (50)a	9.8 (0.7)a

Diversity of saprophytic fungi degrading model organic materials in different forest sites: a PCR-TGGE approach

Ariana Kulhankova [1, 2], Jacques Ranger [1], Thierry Beguiristain [2], Judicael Moukoumi [1, 2]

[1] INRA, Centre de Nancy, Unité Biogéochimie des Ecosystèmes Forestiers, Champenoux, 54 280, France

[2] LIMOS, CNRS UHP UMR 7137, Université Henri Poincaré, BP 239, Vandoeuvre-les-Nancy, 54 506, France

e-mail: arikul@centrum.cz

Abstract

In forest ecosystems, decomposition of litter is an important factor controlling nutrient cycling and soil organic matter formation. It is mainly carried out by microorganisms, particularly fungi. They play an important role in the process because they can attack the lignocellulose matrix in the litter. Studies on fungal ingrowth and succession during the decay are necessary for better understanding of the biological aspects of litter decomposition.

The decay rate as well as the diversity of microbial population may vary both with soil properties (such as pH or microclimate) and with litter composition (e.g. nutrient status and biochemical compounds). These factors are influenced among others by vegetation and conversely.

Recent applications of molecular biology techniques provide cultivation-independent options for analysis of fungal communities. These methods are expected to give a more realistic view of species richness and distribution, because only a few fractions (about 5%) of fungi can be cultured

Polymerase chain reaction (PCR) technique allows to amplify selected DNA section *in vitro* by simulating *in vivo* replication. Temperature gradient gel electrophoresis (TGGE) is a simple method to determinate genetic diversity of the community by separation PCR-amplified rDNA fragments of different species. It is based on the decreasing electrophoretic mobility of partially melted double-stranded DNA molecules in polyacrylamide gel containing a linear temperature gradient.

The aim of this study was to identify the distribution of saprophyte fungi degrading organic materials in five forest sites in the same area but with different dominant tree species. The sites are situated at altitude 650m in Breuil research site, Morvan, France. The classical litter-bag method was used to decompose two main litter compounds, cellulose and lignin. Then the fungal species richness in incubated samples was studied by molecular based technique. We have applied PCR of rDNA using internal transcribed spacer

(ITS1F and ITS2) primer pairs followed by TGGE of PCR products. Some separated DNA fragments were re-amplified and sequenced. The nucleotic sequences were compared to sequences from the GenBank database using Blast program of National Centre for Biotechnology Information (NCBI). Banding patterns analysis were based on presence/absence and relative abundance of species.

There were significant differences in decay fungi composition among forest types. Duration of the sample exposition had a major effect and the succession of fungal species can be found during the decomposition. Mass loss of samples, site properties and substrate composition are also discussed.

Influence of different kinds of Cerrado land development (pastures vs eucalyptus silviculture) on soil organic matter stocks (C and N) in Brazil

Maquère V., Laclau J.P.L., Bernoux M., Gonçalves J.L.M., Cerri C., Moreira M.Z., Ranger J.

Institut National des Recherches Agronomiques
UR Biogeochimie des ecosystèmes forestiers, INRA, Champenoux

Abstract

Introduction:

Most of the eucalyptus stands of Brazil have been planted on Cerrado (tree and bush savannas) or on Cerrado converted to pastures. To study the influence of tree plantations on the atmospheric CO_2 sequestration, case studies are needed to assess the influence of land use (eucalyptus, pasture, cerrado) and land use change, especially afforestation, on soil organic matter stocks (C and N). Moreover, the study of the influence of very contrasting silvicultural practices on soil carbon storage may help to assess whether a shift in the common practice silviculture may enhance soil organic matter stocks.

Objectives:

In this study, the influence of different kinds of Cerrado land developments (pastures vs eucalyptus silviculture) on soil organic matter stocks is assessed 20 and 60 years after land-use change. Moreover, the influence of very contrasting silvicultural practices over a 60 year period (short rotation silviculture vs no clear cutting) on soil organic matter storage is assessed.

The aims of this study are: (i) to quantify, at the one hectare scale, the influence of different kinds of Cerrado land developments (pastures vs eucalyptus silviculture) on soil organic matter stocks, 20 and 60 years after land use change; (ii) to assess the influence of very contrasting silvicultural practices (no clear cutting or short rotation silviculture during 60 years) on soil organic matter storage in ecologically comparable situations.

Material and methods :

The study was conducted at the Itatinga experimental station of Sao Paulo University (Brazil). The climate is Cfa according to the Köppen classification (annual mean precipitations = 1300mm, annual mean temperature = 18,35°C,

minimum temperature of 1,3°C in may, maximum temperature of 35,4°C in mars, for year 2003).

The soils were sampled in different plant communities situated in identical ecological conditions. The five situations studied are: a shrub and tree prevailing Cerrado, a pasture planted on this Cerrado 20 years ago, a pasture planted on this Cerrado 80 years ago, an eucalyptus stand managed in short term rotations for 60 years, a 60 year old eucalyptus stand where no clear cutting has been realised. Both eucalyptus stands were first planted around 1940 on 20 years pastures, initially planted on the same cerrado.

In each situation, three blocks were positioned along a transect going down the slope in order to integrate spatial variability. Each block was composed of five pits 40cm deep and of one soil pit 100cm deep. In each pit, soils were sampled with a 10cm diameter corer at depths 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, plus 40-60 cm, 60-80 cm, and 80-100 cm for the soil pits 100cm deep. Sampling was done at fixed depth because the soils presented no clear layer limit but progressive gradients. Soils were dried at 40° C, passed through a 2mm sieve, separating the roots, and an aliquot was crushed through a 0,150mm sieve for carbon and nitrogen determination (LECO). Moreover, a soil aliquot was dried at 105°C for residual humidity reference and bulk density determination.

Litter was sampled in each situation thanks to a 30cm diameter metal ring near each of the 18 pits. Litter and roots were dried at 65°C, then ground for C and N determination (LECO).

For the calculation of carbon and nitrogen stocks, results obtained by summing available values down to 1 meter or by using a model of organic carbon vertical distribution in soils were compared. The comparison between soil organic matter stocks of the different situations was processed using statistical analyses.

Results and discussion :

The parent material homogeneity between the five situations was assessed by particle size analysis and X-ray diffraction of the deepest layers of the soil pits. The particle size analysis showed homogenous results, especially for the deepest horizons (mean clay rate = 18.4%, coefficient of variation = 2.9, the clay rate is a diagnostic rate in this kind of soils). The X-ray analysis is in progress.

At any given depth, bulk densities were homogenous in each situation, the variances corresponding to the mean density for a fixed depth in a fixed situation varying from 0.00 to 0.05. The density profile shape is the same for all situations showing increasing densities with depth. The values range from 0.86 (EUC) to 1.24 (PAS) for the 0-5cm layer, and from 1.37 (EUC60) to 1.45 (PAS)

for the 0-80cm layer. The highest density values are observed in the 60 year old pasture, due to cattle stamping.

The carbon and nitrogen analyses are in progress. These data will enable the calculation of the storage of C and N in this soil for different vegetation and site management, as well as defining soil organic matter quality via index parameters such as C/N ratio.

An evaluation of the contribution of roots and deeper soil horizons in the global C and N storage will also be done. These may be considerable, since these ferralitic soils are very deep.

Riparian hatitats influence on soil organic carbon content

Teodora Martínez, María Félix Martínez, Yolanda Díaz y M. Carmen Lobo

Instituto Madrileño de Investigación Agraria (IMIA). Comunidad de Madrid, Apdo.127. 28800 Alcalá de Henares. Madrid. España. e-mail: teodora.martinez@imia.madrid.org

Abstract

Introduction and objectives

The concept of carbon sequestration is related to the carbon storage in soils, forest or other vegetation system. Establishment of new forest plantation and degraded forest restoration increase carbon storage. Maintenance of stands, reforestation and an optimum management of the forest system are the principal methods to increase carbon sequestration. In this context, we are carrying out a research project aimed to study the capacity of riparian systems to capture and storage carbon. Forest soils capacity to storage carbon is well known (Kyong Hark Lee 1997, Brown 1997) and soil mineralization and humification processes, and other soil and the climate parameters are important factors. The objective of this paper is evaluate and compare in four riparian areas the forest soil capacity to storage carbon.

Material and methods

Experimental area is located in Alcalá de Henares (Central Spain). Four riparian habitats with different floristic composition and history managements practices were evaluated: Zone A, Native gallery forest, homogenous in composition and structure; Zone B, Riparian plantation, as a result of a restoration process during 1994; Zone C, Riparian plantation in 1999 and Zone D, riparian deforested area, with herbaceous vegetation. Soils were sampled at four dephts: 4, 20, 40 and 100 cm, according to the different horizons in the soil profile. Samples were collected in autumn 2001 and spring 2002. Soils were characterized according to Official Spanish Soil Methodology. Soil organic carbon content was determined by Walkey-Black method.

Results and conclusions

In the soils samples from autumn 2001, organic carbon content was higher in Zone A (native forest) in the surface layer (4cm). The lower percentages were observed in restoration area from 1999. Significant differences were observed in the first and second soil layer between native forest and restoration areas. When

soils were sampled at 40 and 100 cm, no differences were observed in organic carbon content. Soil samples collected during spring 2002 showed higher carbon percentages in comparison with those sampled in autumn, especially in more recent plantation. Significant differences were not observed in the deepest soil samples between plantations areas, but showed significant differences between native forest and deforested area.

Soil under native forest showed higher organic carbon content at 0-20 cm layer due to organic fresh residues accumulation and microclimate conditions (humidity and shadow). Plantation areas showed less contribution to carbon storage, and similar percentages to the deforested area. However in deep layers (more than 40 cm) in spring samples, higher values of organic carbon were found in zones B, C and D than in native forest (A). This fact may be related to organic matter accumulation from high production of herbaceous vegetation and different floristic composition within these systems. Changes in soil C in deep layers in planted and deforested areas could be consider as a indicator of carbon sequestration.

References

Brown, S. (1997). *Los bosques y el cambio climático : El papel de los terrenos forestales como sumideros de carbono.* XI Congreso Forestal Mundial. Vol.1, Tema 4. Antalya, Turquía.

Kyeong Hak Lee (1997). *Acumulación y flujo del carbono en los bosques de Corea*. XI Congreso Forestal Mundial. Vol.1, Tema 4. Antalya, Turquía.

Influence and contribution of the vegetable organic matter (Vicia faba) on the development of the micro-organisms in the soil

Mekkaoui Ali

FSB/ USTHB B.P. 133 Biological soil laboratory Bab Ezzouar Algiers Algeria.
E-mail: alimek0560@hotmail.fr

Abstract

The surface soil of bush-hammer is different from deeper (bed rock) soil and has active biochemical reactions in relation to degradation of the organic matter (Alexander 1982).

Methodology

The experimental soil comes from the I T G C (Institut Technologique des Grandes Cultures) station, Oued Smar. It is characterized by its sub humid climate and its argillaceous texture. After removing surface of bush-hammering containing the vegetable remains (approximately 5 cm), we took the soil to 20 cm depth (area with most root system). The organic matter from broad bean (Vicia faba) was used as most important leguminous crop in Algeria.

The vegetable material is taken from the similar area as the studied soil. Plants were collected without roots, after harvest of the pods were separated and they were fast dried by splitting at ambient temperature, to avoid decomposition at high temperatures. Once dry, the leaves and the stems are crushed separately. Three series of 33 flasks erlens of 600ml of volume received each one dry soil 100g. The 1st serie (A) is amended with 10g of the powder of sheets in each erlen, the 2nd serie (B) is amended with 10g of the powder of stems in each erlen, the 3rd serie (C) not amended. To each erlen 32ml of sterile distilled water was added. 30 erlens of each series are stopped with knitting machine in order to allow good split, the three other remainders received molecular nitrogen, and then stopped with rubber in order to create anaerobic conditions. The various flasks were incubated at 28°C during one to 52 days period and various physico-chemical and microbiological analyses were tested. The organic matter was analysed by incineration with 500°C; 5g of the sample for 3 hours (Myskow 1974). Carbon total was proportioned according to the Anne method, CO_2 respired under aerobic and anaerobic conditions, by absorbing in baryta Ba $(OH)_2$, according to the method of Petersen amended by Rashid and Shaeffer (1985). Total Nitrogen determined by the method of Kjeldhal, ammoniacal, nitrous and nitric nitrogen according to Drouineau and Gouny, the fractions of

fulvic acid, and humic acid (Duchauffour1982), and of total sugars by the method with the anthrone (Up-Degraff, 1962).

Microbiological analyses:

Total microflora was measured by incubation at 28°C for 3 days for bacteria and one week for the fungi, Streptomycin were used to select the fungi flora and actidione for the bacteria at 40µ g/ml, the reading was done per counting one limp containing number of ranging colonia between 30 and 300.

Functional groups of carbon:

Organic matter decomposition and fertility of the soil were assessed by micro-organisms involved in the carbon cycle; according to the methods described by Pochon and Tardieux (1962) Cellulolytic bacteria (aerobic and anaerobic), with bacteria Amylolytic and Pectinolytic. The probable number are determined according to the table of Mc Grady in three repetitions. The incubation of each done for a number of days.

Interpretations:

Factors affecting decomposition are: split, moisture, the pH and especially C/N fraction. Our study one the respirometry of the soil confirmed by Bacherlier G. 1968, which this phenomenon edge be due to air drying before amendment and humidification. This release appears to depend, not only of the percentage of carbon immediately mineralizable, aim also of the total percentage of carbon likely to become easily mineralisable (Dommergues & Al. 1978). By comparing the two samples discussed by the sheets and the stems it could be explained by the structure and content of organic matter in the various left of the plant, because one observes clear contribution to the respirometry by the stems, that is to say in aerobe or anaerobe, which confirms the assumption of the content cellulose at the stems that at the sheets. Organic matter and natural conditions, additional carbon disappears initially more quickly than the carbon of accumulation, then there would exist has some parallelism between the phenomenon of decomposition and synthesis on different levels (Demelon 1966). The range of C/N affected decomposition and synthesis in the soil (with the state of balances, C/N is appreciably equal to 10). In comparison the treatments between them we note that the amendment by the stems gives has favourable medium to mineralization that to the sheets (Poirson and al. 1986).

Microbiology:

It should be noticed that the methods currently suggested to the researchers highlight the zymogenic micro-organisms which cuts has growth

misses higher than that of the germs autochthons and consequently tightens to dominate them (Boulard and Morreau, 1962; Ladle and Tchan, 1948). In general after immediate re-humidification spored bacteria and the cocci occurred; towards the 2nd however 3rd day the actinomycetes occurred, this succession correspond to the increasing phase of ammonia outburst; then the moulds invade the culture. Towards the 4th day generally correspond to the beginning of the decreasing phase (Duchauffour1973).

Conclusion:

This reveals that the cellulolysis is much more significant in the substrates containing stems than in the substrates containing sheets. This would be explained by has content higher cellulose in the stems than in the sheets and conversely for the mineral nitrogen content.

Tree diversity and soil biology a new research program in French Guyana with preliminary data on nutrient foliar resorption

Roy Jacques [(1)] , Bonal Damien [(2)] , Bréchet Laetitia[(1) (2)], Coûteaux Marie-Madeleine[(1)], Domenach Anne-Marie[(2)], Hättenschwiler Stephan[(1)]

[(1)] Centre d'Ecologie Fonctionnelle et Evolutive, CNRS, 34293 Montpellier Cedex 5
[(2)] UMR Ecofog, BP 709, 97387 Kourou Cedex, Guyane Française
roy@cefe.cnrs-mop.fr

Abstract

The interactions between soil fertility and biology of primary producers have been studied in several ecosystems. A major result is the positive feedback between soil fertility and plant chemical characteristics. Plants in unfertile habitats are slow growing and produce low quality leaves (high C/N and phenol content) with slow turn-over and low decomposition rate which reinforce the low fertility. The opposite occurs in fertile habitat. In this comparison of contrasted ecosystems, the effects of soil fertility and species characteristics are combined. In the context of global atmospheric and biodiversity changes as well of forestry and agriculture, it is necessary to specifically identify the impact of species identity and diversity on soil biology and ecosystem physiology.

Using a collection of 16 species of local trees established as monocultures 20 years ago in the humid tropical forest of French Guyana, we are setting up a program to analyse i) the ecological and physiological determinant of litter quality, ii) the impact of litter chemistry on decomposition, iii) the response of faunal and microbial communities and activities and iv) the consequences on soil functions. Specific experimental and modelling approaches will attempt to link trophic interactions, species diversity and biogeochemical cycles. The relatively high number of species in the experimental design will allow to derive functional types of primary producers independently of species identity. Specific experiments will also be set up to study the relationship between the diversity of species mixtures on soil functioning.

Using preliminary data to characterize leaf and litter quality, we calculated leaf nutrient resorption and its impact on litter chemistry. Resorption is the withdrawal of nutrients from mature leaves as they age before abscission. It is generally found that interspecific variation in litter quality is primarily determined by interspecific differences in mature leaf chemistry. The underlying assumption is that nutrient foliar resorption (although it represents a high

proportion of leaf nutrients) is not very different from one species to the other. We measured nitrogen, phosphorus and carbon concentration in mature and recently fallen leaves and calculated C/N ratio as well as N and P resorption. Chemical composition varied widely between species both for mature and senescent leaves: mature leaf N and P concentration varied between 1.0 % and 2.7 % and between 0.04 % and 0.12 % respectively. The N concentration in senescent leaves varied between 0.7 % and 2.0 % and P concentration between 0.01 % and 0.07 %. C/N ratio of senescent leaves was not correlated with C/N ratio of mature leaves. Resorption efficiency, calculated on a mass basis, varied greatly among species. For N it varied from –9 % to 57 % (mean=30) and for P from –15 % to 79 % (mean=48 %). Amount of resorption of N and P were positively correlated. Across species, a strong positive relationship was found between C/N ratio of the litter and N resorption, suggesting that the latter is a main determinant of litter quality. These results need to be confirmed on more representative leaf samples and using a better measurement of resorption. If confirmed, they suggest that a low litter quality is not to be always associated with poor recycling of nutriments. On the contrary, if it is the consequence of a high resorption, overall recycling is very efficient since resorption is a large recycling pathway which is fast and also prevents leaching and taking away of nutrients through competition in the soil.

Effects of slash management on soil microarthropods from a *Eucalyptus globulus* Labill. plantation in Óbidos, Central Portugal

C. Seabra Ferreira[1], Teresa M. Vasconcelos[1], Neusa Nazaré[1] and Manuel Madeira[2]

[1] Escola Superior Agrária de Coimbra, DCEA-SBE, Bencanta 3040-316 Coimbra, Portugal;
Tel.: + 351 239 802 975; Fax: + 351 239 802 979; E-mail: cseabra@mail.esac.pt
[2] Instituto Superior de Agronomia, Dep. de Ciências do Ambiente, Tapada da Ajuda, 1349-017 Lisboa, Portugal

Abstract

Soil possesses a complex habitat systems, but its biological systems are poorly understood. Soil invertebrates are determinants and indicators of soil quality and, therefore, key elements in the development of a sustainable agriculture and forestry.

In Portugal, *Eucalyptus globulu*s (Labill.) is currently of major importance in both industrial and non-industrial private forestry, for its use in paper pulp production. Different management practices on these plantations can lead to changes in habitat configuration, particularly in the organic horizon and vegetation cover levels, which are vitally important to the existence of favourable ecological conditions (namely in terms of food and moisture) for soil microarthropds (Sousa *et al*). Thus, it is expected that different slash management practices will have some impact on soil arthropod communities (mainly Collembola and Acarina), which, in turn, may affect microbial biomass and activity (regulated by soil microarthropods), decomposition, nutrient turnover rates, and other soil processes.

An experimental trial was set up in 1993 to assess the effects of different options of slash management on the populations of soil microarthropods from a *E. globulus* plantation located in Quinta do Furadouro (Óbidos, Portugal). The treatments were: (R) removal of forest floor litter layer and harvesting debris of the previous plantation; (S): distribution of these debris on the soil surface and (I): incorporation of all organic debris in the soil through a 15 cm depth harrowing.

Here the results of samples taken in January and May 2003 are presented. At both sampling dates three soil samples for microarthropods were collected in each treatment plot, using a metal cylindrical core sampler (8 cm in diameter, 5 cm in depth and about 250 cc in volume), making a total number of 36 samples. Soil samples for determination of soil moisture content were also taken and soil temperature was measured, *in situ,* up to a depth of 10 cm in each plot. Soil

mesofauna was extracted by means of Berleese-Tullgren funnels and soil microarthropods were sorted and quantified under binocular microscope, being springtails, *i.e.* Collembola (Insecta: Apterygota) identified to species level under light microscope.

In January 2003 the total number of arthropods were: in R plots - 492, in S plots - 1266, and in I plots - 354 individuals. Total number of springtails were: R – 171, S – 277, and I – 50, species diversity and richness being also higher in S plots. Mean abundance of arthropods was higher and significantly different in treatment S in relation to R and I treatments. Although no statistically significant differences were observed in mean number of arthropods *taxa,* or mean abundance and mean number of collembolan species, these were higher in S and lower in I. These data from January 2003 point out to a separation of S plots from R and I plots, as previously seen in Autumn 1998, Spring 1999 and Spring 2000.

Nevertheless, data from May 2003 do not show clear differences among treatments. Preliminary results show that samples from R plots had 2132 individuals, from S plots 2110 and I plots 1810, the total number of taxa being 11 in R and S samples, and 13 in I samples. This may be related resilience in the system since 10 years had already elapsed after the application of the treatments.

As season variability should be considered in abundance, number of *taxa* and diversity, and changes in the composition of collembolan populations, in terms of dominant species (Ferreira *et al.*, 2001). Therefore, the available results at the moment do not allow us to draw a definite conclusion on the effects of slash management practices on soil mesofauna. They seem to indicate, however, that organic debris management plays an important role in the structure of soil microarthropods populations. It is necessary to continue these studies in order to better understand the effects of forest stands management on soil invertebrate communities.

Referances

Ferreira, C. S.; Vasconcelos, T. M. and Madeira, M. (2001). Estudo das comunidades de artrópodes edáficos de um povoamento de *Eucalyptus globulus* (Labill.) submetido a diferentes opções de gestão de resíduos orgânicos *Revta Ciênc. Agrárias*, **24 (3/4):** 257-270.

Sousa, J. P.; Vingada, J. V; Barrocas, H. and Gama, M. M. (1997). Effects of introduced exotic tree species on Collembola communities: the importance of management techniques. *Pedobiologia*. **41:** 145-153.

Role of Climate in Soil Organic Carbon Dynamics in a High-Elevation Spruce-Fir Forest in the Southeastern United States

C.E. Tewksbury[1], and H. Van Miegroet[1]

[1] *Utah State University, Dept. of Forest, Range, and Wildlife Sciences, 5230 Old Main Hill, Logan, UT 84322-5230, U.S.A.*
ctewksbury@cc.usu.edu

Abstract

Quantifying and understanding the factors controlling the major pools and fluxes of carbon (C) in forest ecosystems is critical for estimating their role in climate change scenarios. Soil organic carbon (SOC) in the forest floor and mineral horizons of forests can be large and highly dynamic. Our study focuses on high-elevation red spruce-Fraser fir [*Picea rubens* Sarg./ *Abies fraseri* (Pursh.) Poir] forests in the southeastern United States, where large pools of SOC have accumulated in the forest floor and mineral horizons due to lack of glaciation, fire disturbance, and limited management. The most recent disturbance in these forests has been insect-induced mortality of Fraser fir, which has caused heterogeneity in stand structure and site microclimate. We hypothesize that the combination of decreased net ecosystem productivity and changes in SOC dynamics and microclimate may cause these spruce-fir forests to become a net C source rather than a C sink. Additionally, predicted regional warming may exacerbate existing drivers of decomposition and result in a positive feedback to climate change.

Sixteen 20m x 20m permanent plots were established in the Great Smoky Mountains National Park of Tennessee and North Carolina (35º30'N, 83º30'W) along an elevation gradient between 1525 and 1980 m, with climate as a covariate. The objective of this study was to quantify the influence of climate on SOC dynamics by measuring: organic and mineral horizon C pools; litterfall C inputs; mean residence time (MRT) of the O-horizon; needle litter decomposition rates; and *in situ* soil respiration. Climatic variability among plots was determined by degree days above 5ºC (DD) based on soil temperature measurements using data-loggers at 15 cm depth. C pools in the forest floor and mineral soil were measured from a destructive sampling of the O-horizon and incremental soil cores, followed by C analyses on ground and sieved samples. Litterfall C return was estimated from periodic litterfall collections using four 0.07m^2 traps per plot (3 years for 12 plots; 2 years for 4 plots). Litterfall was dried, sorted, weighed, and analyzed for C. The MRT of C in the O-horizon was calculated as: O-horizon mass/ annual litterfall flux. Litter

decomposition rates were estimated by measuring weight loss in mesh litterbags (n=4 per plot). *In situ* soil respiration measurements were conducted at 8 plots during the summer and fall of 2 years using the static chamber technique with NaOH as a trapping agent.

The plots in the study represented a climate gradient. Soil temperatures at lowest elevation were on average 3°C higher than at higher elevation with a corresponding difference in annual DD. These differences in site microclimate resulted in spatial and temporal variations C pools, MRT, litter decomposition rates, and soil respiration. The forest floor C pools ranged from 11,000 to 29,000 kg/ha with an average of 19,000 kg/ha and were positively correlated with annual DD (r^2=0.83). Litterfall C ranged from 1,200 to 4,000 kg $ha^{-1}yr^{-1}$ and were also positively correlated with annual DD (r^2= 0.79) Calculated MRT ranged from 6 to 21 years with an average of 14 years and was negatively correlated with annual DD (r^2=0.79). Annual respiration rates were highly variable among plots (990-1900 CO2-C $ha^{-1}yr^{-1}$), and were positively correlated with annual DD (r^2=0.40). There were also seasonal differences with rates generally higher in the summer than the fall (Summer 510 CO2-C/ha per 30 days vs. Fall 390 CO2-C/ha per 30 days). Litter decomposition rates were lower in cooler sites especially during the summer (r^2=0.47).

Our study indicates that SOC dynamics of spruce-fir ecosystem are particularly sensitive to site microclimate (soil temperature). A changing climate may therefore be another important disturbance mechanism in determining whether these forests function as net sources or sinks of atmospheric CO_2. A relatively small change of forest SOC dynamics could have important implications for the global C budget.

Plenary session 3 « PRODUCTIVITY AND NUTRITION »

Water and Nutrient Interplay and Forest Productivity in the tropics

José Leonardo de Moraes Gonçalves[1], Jose Luiz Stape[1], Jean-Paul Laclau[2] and Marcos Cesar Passos Wichert[1]

1 Department of Forest Sciences, University of São Paulo, Piracicaba, SP, Brazil (jlmgonca@esalq.usp.br, jolstape@esalq.usp.br; ptsm@esalq.usp.br);
[2] CIRAD-Forêt/USP-ESALQ (jplaclau@esalq.usp.br)

Abstract

Intensively-managed plantations are a major source of raw material for fuelwood, charcoal, wood-based industry, pulp and paper industry and poles in the tropics and subtropics. These plantations are managed to produce high yields. The climate and the productive capacity of soils under plantations vary enormously at the site level, but at a regional scale, differences in plantation productivity can be partly attributed to climatic, soil and geomorphological variations leading to differences in the supply of water and nutrients. In most cases soils under plantations are deep with variable texture, have low to good water storage capacity, and are usually poor in nutrients. Plantations are usually established in regions where dry seasons can last for more than two months. On average, water stress limits plant growth for periods ranging from 8 to 12 months each year in 42% of tropical land and from 4 to 6 months in 30% of the land, while the remaining 28% is not subject to long dry periods.

Water stress is frequently the main constraint to plantation growth, and nutrient deficiencies are usually the second limiting factor. Under water stress, the strong interaction between rainfall and soil types on productivity at a regional level has often been observed. Usually, under similar conditions of rainfall, on deep and clayey soils, less water stress and consequently, high productivity are observed.

Nutrient transfer processes in the soil and uptake by trees, regardless of the soil fertility, are strongly affected by the soil texture and soil moisture regime. Within certain limits, the rate of nutrient uptake by plants is a function of these characteristics and can predispose the plants to nutrient constraints. The response of eucalypt stands to fertilizer applications in savanna areas of Brazil is commonly much higher than that obtained in coastal areas (udic regime), despite the general similarity of soil fertility on both areas. This difference in response has been attributed mainly to better nutrient transport in the soil solution to the plant roots in the coastal area, where despite the low soil fertility larger amounts of nutrients reach the root surface. It is also common to observe symptoms of nutrient deficiency in plantations during the dry season, especially if dry conditions last more than 3 months. Two prominent examples are P and B

deficiencies which are increasingly common in eucalypt plantations and aggravated by the occurrence of seasonal drought. Deficiencies of other nutrients, such as N and S, for which the soil organic pool is the main source, have frequently been observed in soils with the ustic moisture regime (slow mineralization).

Several soil and forest management practices can influence the interaction of water and nutrients in the soil, affecting their uptake for successful plantation forestry. To partially overcome the constraints on growth due to water and nutrient limitations, selection of suitable genotype is of paramount importance.

Growth, distribution and configuration of tree roots in the soil are other important factors influencing water and nutrient uptake. Dense fine root system favours the uptake of poorly mobile nutrients that move by diffusion. Therefore, it may be expected that species which have abundant fine roots or can establish symbiotic associations with mycorrhizal fungi will have an advantage in the field, especially during the establishment phase, because they will be better competitors for water and nutrients.

The choice of soil and nutrient management strategies (including the estimated monetary return from fertilizer application), and the intensity of weed control required to minimize competition for soil water and nutrients, is dependent on understanding the effects of water x nutrient interaction on productivity in these environments. The amount of available water is to be taken into account in deciding on strategies for site management and nutrient application. For that reason, minimum soil cultivation as an inter-rotation practice has proved very useful.

Large areas of intensively-managed plantations had several rotation crops with research and management now addressing the question of sustained productivity. The potential constraints on long-term high productivity and the principles underlying various management practices to overcome the water and nutrient constraints will be discussed.

Above and belowground biomass and nutrient contents of four even-aged *Quercus robur* L. stands in NW Spain

Balboa, M. A.[1]; Álvarez González, J. G. [1]; Merino, A.[2].; Rojo Alboreca, A.[1]

[1]Departamento de Ingeniería Agroforestal. Escuela Politécnica Superior de Lugo. Campus Universitario s/n, E-27002, Lugo. Tfno: +34982252303. Fax: +34982285926. e-mail: mibalboa@lugo.usc.es

[2]Departamento de Edafología y Química Agrícola. Escuela Politécnica Superior de Lugo. Campus Universitario s/n, E-27002, Lugo.

Abstract

Pedunculate oak (*Quercus robur* L.) stands account for 9.4 % of the forest area and for 6.5 % of the land area in Northwestern Spain, and they have been identified as highly efficient carbon sinks. In this study, tree biomass modelling and soil data were used to characterize the amount of carbon accumulated in the system and to assess the nutritional status of four even-aged pedunculate oak stands in NW Spain.

The relationships between biomass and nutrient concentrations can be used by forestry researchers to quantify the carbon and nutrients fluxes in relation to both silvicultural management practices and harvesting operations, and to calculate the nutrient budgets. The logging residues left on the site will slowly release available elements to naturally regenerated stands.

For tree biomass models, a total of 32 trees (DBH from 9.0 to 67.5 cm) were destructively sampled to develop biomass prediction equations for tree components: stem, bark, branches, twigs, leaves and roots. Regression equations relating the dry weight of each tree component to tree level variables (diameter at breast height, total height) and stand level variables (basal area, dominant height, dominant diameter, average diameter), were fitted simultaneously by using seemingly unrelated regression.

The use of these equations, along with the data from chemical analyses allowed us to estimate the biomass, as well as the carbon and nutrients accumulated for each component at stand level. Total and available element storage in the soil was calculated from the depth of each horizon, bulk density, the mean nutrient concentration and that adjusted for gravel content. Element storage in the litterfall was also determined for each stand.

Root biomass represented 20 % of the total tree biomass. Stem wood accumulated 61 % of the aboveground biomass, whereas leaves only represented 2 %. Litterfall biomass ranged from 54 to 125 Mg ha^{-1}, and

constituted an important reservoir for all elements, particularly for Mg and Ca, with average amounts of 143 and 274 kg ha^{-1} respectively.

For most nutrients, the following pattern of decreasing concentration from stem to higher order branches was obtained: leaves > twigs> branches > stem wood. Although leaves, bark and twigs only represented 2 %, 9 % and 1.5 % respectively of the total aboveground biomass, they contained the highest amounts of Mg and Ca.

Genotype x environment interactions and their impact on assessments of site quality - a national view for New Zealand

Peter W. Clinton[1], Beets, P.N[2]., Coker, G[1]., Davis, M.R[1]., Garret, L[2]., Olykan, S.T[1]., Parfitt, R.L[3]., Payn, T.W[2]., Smaill, S[4]., Simcock, R. C[5]., Watt, M.S[1].

[1]Forest Research, PO Box 29237, Christchurch, New Zealand

[2] Forest Research, Private Bag 3020, Rotorua, New Zealand.

[3] Landcare Research, Private Bag 11052, Palmerston North, New Zealand

[4]School of Biological Sciences, Univeristy of Canterbury, Private Bag 4800, Christchurch New Zealand

[5] Landcare Research, Private Bag 92170, Auckland, New Zealand

Abstract

Understanding of productive capacity is generally poor and there is often little information about how site quality influences forest productive capacity. Even less is known about how species interact with environmental factors and how such interactions may affect assessment of site quality. Since forest species and genotypes may differ in response to the environment or have different resource requirements, understanding genotype x environment interactions is important since forests in New Zealand contain different species and genotypes and are planted across wide range of edaphic and climatic conditions. Further, by understanding the biological activity of forest tree symbionts and other microflora associated with tree crops and the impact of management practices on them we will broaden our interpretation of site quality and also our ability to maintain the productive capacity of soils.

Research on a series of the national long-term site productivity trials (LTSP 2) aims to define the biophysical indicators of site quality and forest productive capacity using a unique experimental format of highly stocked mini plantations of two contrasting species. In another national trial series (LTSP3), initiated in 2001, 15 sites covering a wide range of edaphic and climatic conditions were selected to examine the utility of plants as indicators of site quality. This trial series uses genotypes of three forest species with different physiological characteristics to define sites in terms of water and nutrient supply. This paper reviews relevant results from these recent trials and New Zealand's previous experience of species performance and uses the findings to address the question of how choice of species affects assessments of site quality.

How land use determines soil nutrient content and nutritional status of holm-oaks in dehesas of C-W Spain

Gerardo Moreno and José Jesús Obrador

Universidad de Extremadura. Avda. Virgen del Puerto. 10600 Plasencia, Cáceres, Spain.

gmoreno@unex.es

Abstract

Several studies have shown the general low soil fertility of dehesa soils and a major role of the holm-oak trees in the improvement of soil fertility (Escudero, 1985; Gallardo *et al*., 2000; Joffre, 1987). However, no study has focused on importance of dehesa land use for soil fertility and tree functioning and productivity.

We have studied the content of several nutrients in soils and trees in dehesas with three types of vegetation structure, to assess the effects of land use on soil fertility and nutritional status of holm-oak, which may improve our knowledge for a more sustainable dehesa management.

The study was carried out in three dehesas of Central-Western Spain (34° 4'N, 6°13'W), which consisted of three types of vegetation structure resulting from different land uses: intercropped dehesa (cereal + holm-oak; *C*), grazed dehesa (native grasses + holm oak; *G*) and shrubby dehesa (several shrub species + holm oaks; *S*). We randomly selected six oak trees per farm (*SO*, *CL* and *DB*) and land use (*C*, *G* and *S*). We took soil samples (0-20 cm) at five distances to the trunk (2, 5, 10, 15 and 20 m). In addition, foliar samples were collected from 9 trees (combining 4 buds, one per direction) for consecutive years (2002 and 2003). Soil samples were analysed for total-N, available-P (Olsen) and exchangeable Ca^{2+}, Mg^{2+} and K^{+}. The total content of these nutrients were also determined in foliar samples.

The nutrient content of the soils studied can be described as moderately low (Table 1), considering all European soils (Vanmechelen *et al*., 1997). Cropped plots showed higher contents of all nutrients, but differences were only significant for Mg^{2+}. It seems that periodical fertilization (dehesa is cropped and fertilized every 4 years, on average) did not improve soil fertility, and soil cultivation did not impoverish the soil. By contrast, a certain abandonment of dehesa, which contributes to the encroachment (*S* plots) of vegetation, had higher values of total-N and available Ca^{2+} and K^{+} in soils (Table 1). An improved cation exchange capacity resulting from a higher organic matter accumulation in *S* plots than in *C* and *G* plots (Obrador *et al*., 2004), and the nutrient accumulation by the heterogeneous woody vegetation (Fisher and Binkley, 2000), could explain the increment of nutrient in soils of shrubby plots.

Dehesa encroachment favoured a significantly better nutritional status of trees for P, possible due to a better P mobilization by roots of different shrub species (Table 1). Conversely, dehesa encroachment worsened the nutritional status of holm-oaks for N and Ca. Trees showed higher content of N and K in *C* plots than in *G* ones (Table 1), possibly due to fertilizers applied to crops. Cropping did not affect negatively the trees for any nutrient, indicating lack of any competition for nutrients between cereal plants and trees when compared to the competition between trees and native grasses. This lack of competition may be explained by the spatial separation of the root system of crop and tree in dehesas studied (Obrador *et al*., 2003).

Table 1. Nutrient content in soil and holm-oak leaves in dehesas of CW Spain, considering three types of land uses or vegetation structure. The relation between soil and tree nutrient content is expressed by means of correlation coefficient (r) and the level of signification (p).

		Cropped	Grazed	Shrubby	Correlation r and p
N	Soil (mg g^{-1})	1,05 a	0,99 a	1,40 b	-0,63 and 0,071
	Plant (mg g^{-1})	11,3 a	10,6 b	9,35 c	
P	Soil (mg kg^{-1})	10,9 a	9,86 a	9,38 a	0,21 and 0,595
	Plant (mg g^{-1})	0,48 a	0,54 a	0,65 b	
Ca	Soil (cmolc kg^{-1})	2,09 a	1,63 a	3,08 b	-0,73 and 0,260
	Plant (mg g^{-1})	9,32 a	8,92 a	6,97 b	
Mg	Soil (cmolc kg^{-1})	0,83 a	0,54 b	0,98 a	-0,20 and 0,598
	Plant (mg g^{-1})	1,58 a	1,75 a	1,56 a	
K	Soil (cmolc kg^{-1})	0,15 a	0,14 a	0,24 b	0,30 and 0,440
	Plant (mg g^{-1})	4,72 a	4,23 b	4,70 a	

Acknowledgement

This study was supported by E.U. (SAFE project) and Spanish government (MICASA project, MCyT). Jesús Obrador was awarded a grant by Colegio de Posgraduados and ANUIES (Mexico).

Reference

Escudero, A. (1985): Efectos de árboles aislados sobre las propiedades químicas del suelo. Rev. Ecol. Biol. Sol 22: 149-159.

Fisher RH and Binkley D (2000) Ecology and management of forest soils. John Wiley & Sons, Inc, NY. 489 pp.

Gallardo, A. Rodríguez-Saucedo, J.J., Covelo, F. And Fernández-Alés, R. (2000): Soil nitrogen heterogeneity in a dehesa ecosystem. Plant and Soil 222: 71-82.

Joffre R (1987) Contraites du milieu et réponses de la végétation herbacée dans les dehesas de la Sierra Norte (Andalouisie, Espagne). Thèse doctorat. CNRS-CEPE, Montpellier, 201 pp.

Obrador J.J., Bordet, M., García, E. and Moreno, G. (2003): Root distribution in intercropped dehesas of Central-Western Spain. International Symposium on Sustainability of Dehesas, Montados and other agrosilvopastoral systems. European Soil Science Society. Cáceres, Spain.

Obrador, J.J., García López, E., Moreno, G. (2004): Consequences of dehesa management on nutritional status of vegetation in Cuatro Lugares, Central-Western, Spain. Advances in Geoecology , 37 (in press).

Vanmechelen, L., Groenemans, R. and Van Ranst, E. (1997): Forest soil condition, Results of a large-scale soil survey. Forest Soil Coordinating Centre, Belgium. 261 pp.

Nitrogen nutrition of *Picea abies* in a mountain forest ecosystem subjected to experimentally increased N deposition.

Patrick Schleppi*, Matthias Saurer**, Rolf Siegwolf**

** Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), CH-8903 Birmensdorf, Switzerland*

*** Paul Scherrer Institute (PSI), CH-5232 Villigen, Switzerland*

Abstract

As compared to nitrogen (N) fertilisation, N from atmospheric deposition appears to be less taken up by trees and to be preferentially immobilised in the soil. Forest N fertilisation experiments are thus of limited use for assessing the effects of N deposition. On the other hand, forest monitoring under changing N inputs has its own methodological limitations: because of the lack of a control, all environmental variables interact and their effects can often not be statistically properly separated.

Within the European project NITREX, conifer forest ecosystems were subjected to experimentally changed N deposition. The effects of chronically increased or reduced N inputs were studied on soil, water and vegetation. Within a few years of treatment, the N deposition barely affected the nutrition and growth of the trees. Through ^{15}N labellings, this could be attributed to limited uptake of the deposited N by the trees: typically only 20 % of the recent N inputs.

Since 10 years, the effects of chronical N addition have been studied in a paired-catchment experiment at the NITREX site Alptal (central Switzerland). The site lies 1200 m above sea level and has a cool, wet climate (6°C; 2300 mm/year). The bulk deposition of $NO_3^- + NH_4^+$ is 12 kg N/ha/year. On a Flysch substratum, the soils are umbric Gleysols. The trees are predominantly Norway spruce (*Picea abies*), with 15 % silver fir (*Abies alba*). The tree canopy is not very dense (LAI = 4.1) and the ground vegetation is well developed. Two forested catchments (approx. 1500 m^2 each) have been delimited by trenches. NH_4NO_3 is added to rainwater during precipitation events and applied by sprinklers to one of the catchments. The effects of the treatment (26 kg N/ha/year) were assessed after one year of pre-treatment measurements. During the first year, the added N was labelled with ^{15}N (both NH_4^+ and NO_3^-).

Nitrate leaching increased within a few weeks of adding N, which could indicate a N saturation of the ecosystem. Most of the added N, however, remained in the soil. After 7 years of N addition, as a consequence, the C/N ratio of the topsoil decreased from 20.2 to 17.8 %. Tree needles, however, still show relatively low N concentrations, 12 mg/g on average. No effect of the

added N could be measured until the 6th year. On average of the last 5 years, the N concentration in the needles was then 0.7 mg/g higher under increased deposition. The dry weight per needle was identical in the first 5 years, but then 16 % higher in the treated plot. However, these changes in the needles did not yet affect the growth in diameter or in height of the trees. So far, the leaf area index (measured by light absorption) remains unaffected.

Every year, 5 age classes of needles were analysed for both total N and ^{15}N. Wood cores (tree rings) and twigs were also analysed on two occasions. This enabled us to follow the uptake of recently deposited N and its redistribution between tissues of different ages within the tree. Labelled N proved to be very mobile and also entered into old needles or old sapwood. It was further taken up during several years after its deposition. Previous estimates of the allocation of deposited N will thus have to be revised when considering the long term, with some more N taken up by the trees. A tracer redistribution model could be adapted to our data and will give predictions for time scales exceeding the decade covered by our experiment.

The role of climate in phosphorus cyclingin forest soils: a comparative study in California and Washington.

B.J. Cade-Menun1,2, J.G. McColl2, E.E.Y. Moghaddas2 and R.L. Edmonds3

1Department of Geological and Environmental Science, Stanford University
2Department of Environmental Science, Policy and Management, University of California at Berkeley
3College of Forest Resources, University of Washington

Abstract

Nutrients bound in forest litter are an important part of the forest nutrient cycle. This is especially true for phosphorus (P), which is predominantly in organic forms in forests in both litter and soil. Due to its influence on decomposition rates, climate can influence P cycling in forest floor material, and future climate change may alter P cycling. To understand the impact of climate on P cycling, we collected forest floor samples from two climatic regimes: the Sierra Nevada, California (CA), with a Mediterranean climate of hot dry summers and cool wet winters; and the Olympic Peninsula, Washington (WA), a temperate rainforest with cooler temperatures and year-round rainfall. Our objective was to determine if the forms and concentrations of nutrients in this forest floor material would change if incubated in a different climate type for two years.

At each location, partially decomposed litter (H or O2 horizon) was collected from stands of Douglas fir or cedar, with 12 stands total (3 each for Douglas fir or cedar in Washington and California). This litter was air-dried, combined to produce 4 litter types (CA Douglas fir, CA cedar, WA Douglas fir and WA cedar), and packed into litterbags. Paired litterbags were placed at the mineral soil surface below the forest floor in forests in both locations: 10 pairs of CA litter and WA litter at each location for each species, with Douglas fir returned to Douglas fir forests, and cedar to cedar forests. After two years, the litterbags were collected, air-dried, sorted to remove roots and fungi, and ground, and analyzed for total P, organic P, Bray P, pH, total C, N, Al, Ca, Fe, K, Mg, Mn, Zn, LOI, mass loss and P-NMR.

For both species, litter pH was lower in WA material than CA material, and the pH in the transplanted litter changed to resemble the destination. Mass loss was highest in CA material in WA, and lowest in WA material in WA. Concentrations of K, Mg and Mn resembled original material rather than destination material.

For cedar litter, total P and organic P were highest in CA litter than WA litter, and remained unchanged after transplanting. Bray P was highest in WA

litter than CA litter, and remained unchanged after transplanting. Concentrations of Ca resembled that of destination material, while Al and Fe were increased and Zn was decreased relative to original material in both Ca and WA. The C concentration decreased and N concentration increased after transplantation for both CA and WA litter.

For Douglas fir, Bray P, total P and organic P were highest in the WA to WA samples, and lowest in CA to CA samples. Concentrations of Bray, total and organic P decreased in WA material transplanted to CA, and increased in CA material in WA. Concentrations of Al, Ca, Fe and Zn also resembled destination, not origin. The CA litter gained C and N after transplantation to WA. The C concentration of WA litter was unchanged after transplantation, but N concentrations had decreased.

P-NMR spectroscopy of Douglas fir and cedar litterbags from CA and WA show that many different P compounds are present, and most P is in organic form. Aromatic diesters are present only in Cedar litterbags. Polyphosphates and phosphonates are present in samples from WA (WA to WA and WA to CA) but not samples from CA, for both species.

Principal component analysis (PCA) for all data collected for the Douglas fir litterbags shows that the original CA and WA samples are separated along PC1. The transplanted litters are separated from the original material along PC1, but are close to one another along PC1 and separated from each other along PC2. For the cedar litterbags, original and transplanted CA litters remain close together, as do original and transplanted WA litters.

Our results show that, for the Douglas fir material, the concentrations of most nutrients changed after two years, and resembled the concentrations of litter at the destination sites. In contrast, for the cedar material, the concentrations of nutrients remained unchanged after two years, and resembled those of the source material more than the destination, both for CA-to-WA and WA-to-CA. Thus, changing climate may alter nutrient cycling, but the effects appear to be species specific.

Decomposition and nutrient release from root litter of Eucalyptus globulus and Pinus pinaster in Mediterranean conditions

C. Ribeiro[1] & M. Madeira[2]

[1]Escola Superior Agrária de Coimbra, Bencanta, P-3040-316 Coimbra, Portugal, e-mail: cribeiromail@esac.pt;

[2]Instituto Superior de Agronomia, Departamento de Ciências do Ambiente, Tapada da Ajuda, 1349-017 Lisboa, Portugal, email: aa15309@isa.utl.pt

Abstract

The amounts of nutrients released through decomposition of annual litterfall are of utmost importance for sustainable forest production. Decomposition of above ground residues (mostly harvesting residues) has been widely studied for the last decade. However, less is known about the process of root decomposition and its contribution to the dynamics of nutrients in the soil and carbon balance. Few studies have been done in this field, most of them in northern latitude, which have different climatic conditions to those of mediterranean region. For this reason, the decomposition of root litter, and nutrient dynamics, of widely planted forest species in Portugal (*Pinus pinaster* and *Eucalyptus globulus*) was assessed.

The study took place in Central Portugal (Quinta do Furadouro, Óbidos) (30º 20' N, 9º 13' W, 50 m a. s. l.), in *P. pinaster* and *E. globulus* 30 years old plantations, planted at a 3 x 3 m spacing. Mean (1950-1980) annual rainfall was about 600 mm, 75 % of which occurred from November to April; mean annual temperature was about 15.2 ºC. The climate is of the Mediterranean type, tempered by oceanic influence, and the soils are Dystric Arenosols. The following root litters from *P. pinaster* and *E. globulus* were used: (M) very fine roots, <1 mm diameter; (F) fine roots, 1-2 mm diameter; (T) medium roots, 2-5 mm diameter; and (G) coarse roots, 5-10 mm diameter. The litterbag technique was used; litterbags were placed in the Ah horizon, about 5 cm below the soil surface, and were sampled every 3-4 months. At each sampling occasion root litter of each bag was dried (85º C), weighed individually and then pooled for each treatment to make one composite sample for chemical analysis.

The chemical composition of the initial root litter of both species was similar. Nitrogen content was greater in fine roots than in coarse roots. The same pattern was observed for lignin content. Conversely, extractables and cellulose contents were greater in coarse than in fine roots.

The pattern of weight loss was similar for both root litter species. The coarse root litter decomposed faster than the fine root litter. The annual

decomposition rate, at the end of the experiment (three and half years), varied between -0.25 yr^{-1} (G root litter) and -0.13 yr^{-1} (M root litter) in *E. globulus*. This difference was more pronounced for the *P. pinaster* root litter, whose annual decomposition rate varied between -0.30 yr^{-1} (G root litter) and -0.11 yr^{-1} (M root litter). Annual decomposition rates were positively correlated with increasing both diameter class and carbohydrate content, but these rates were not correlated with C/N and lignin/N ratios.

Net release of N from the root litter did not occur during the first 100 days of decomposition; conversely, immobilization of N was observed in all root litter diameter classes. On the contrary, net release of P during the same period occurred, and it was more pronounced for root litter of *P. pinaster* (ranged from 31% to 81%) than for root litter of *E. globulus* (ranged from 15% to 54%). Phosphorous losses were positively correlated with increasing diameter classes and increasing decomposition rates. After the early decomposition stage, another phase was observed between 100 days and 600-700 days of decomposition process in both forest species root litter. During this period, both N immobilization and P release still occurred, but at slower rates. After this period and till the end of the study, release or immobilization of N or P were not observed.

During the study period, net release of K, Mg and Ca was observed from root litter. This release was however not correlated with the root diameter classes of both forest species. Calcium was released steadily along the experiment period, whereas K was mostly released during the early decomposition phase, e.g. during the first 100 days

In conclusion, the decomposition process of root litter of *E. globulus* and *P. pinaster* was similar. Despite the small N content and the great C/N or lignin/N ratios, in both cases coarse roots decomposed faster then fine roots. Roots were a source of P, Ca, Mg and K, but a sink for N.

Fertility of soils and nutritional measurement of native forest species in Costa Rica.

Amelia Paniagua-Vásquez

Institute of Investigation and Forest Services INISEFOR-UNA, Heredia- Costa Rica

Abstract

Institute of Research and Forest Services of the National University of Costa Rica has investigated the nutritional factors limiting forest productivity. It has legal requirements to teach the population about the necessities of preserving and maintaining a balance in the biodiversity on the forest land.

This report will present results of investigation with objective to determine nutritional requirements of the most important forest species in Costa Rica and to group them according to the regions so as to offer recommendations for application of amendments and fertilizers.

The methodology included the chemical analysis of soils and plants, pot experiments in the greenhouse and field based research. The common analytic techniques are useed in the laboratories of Costa Rica.

The results demonstrated that the area can be divided into two distinct regions: (a) high acid soils where mainly native forest species are planted. (b) High fertility soils of the region Chorotega and Atlantic Huetar where species like *Tectona grandis* are planted. *Gmelina arborea*, 25 years old showed good growth. The Central region due to the influence of volcanic soils contains the best soils for planting *Cupressus lusitánica*.

Root growth within eucalyptus plantations in Congo : effect of stand age and soil humidity.

Armel Thongo-M'Bou[1], Christophe Jourdan[2], Philippe Deleporte[1,3], Yann Nouvellon[1,3], Jean Pierre Bouillet[3], Daniel Epron[4], Laurent Saint André[3], Fidèle Mialoundama[5], Guy Kazotti[6].

1UR2PI, BP 1291 Pointe-Noire, Congo
[2] Perennial Crop Department, CIRAD, Avenue Agropolis, 34398 Montpellier Cedex 5, France
3 Forest Department, CIRAD, TA 10/D, Avenue Agropolis, 34398 Montpellier cedex 5, France
8 Ecology and Ecophysiology Dep., University of Henri POINCARE – Nancy 1, BP 239, 54506 Vandoeuvre, France
5 Faculty of sciences, University of Brazzaville, BP 69 Brazzaville
6 SNR , BP 839 Pointe-Noire, Congo

Abstract

Structure, physiology and mortality of the root system are essential factors of forest stand functioning, because of their role in anchorage, tree nutrition and nutrients cycle.

In tropical zone, many studies deal with the above-ground part of the tree system. In contrast, knowledge on the root system remained limited mainly because of the cost and the complexity of the employed methods.

Root growth was studied across an age series (9-months, 2- and 4-years old stands) of one eucalyptus hybrid clone in Congo. The study was performed between January 2001 and May 2002. In each stand, 3 to 4 trees were chosen representing different basal area classes in order to cover the full variation of root growth within each stand. Root growth was monitored using rhizotron (a standard in-situ method to study the root dynamics). Two rhizotrons were set up around each tree: the first one in a nearly-vertical position and the second one in a nearly-horizontal position. These rhizotrons were monitored initially, once and then twice a week.

The main results showed a diversity of root types in eucalyptus plantations, each of these presenting specific morphological (growth rate, average root-length, lifespan) and physiological characteristics. For some root types, root growth decreased with the stand age. The young trees (9-months and 2-years old) presented a faster growth than the old ones (4-years old).

Dry and rainy seasons induced a seasonal variation of root growth in the three stands (soil humidity was the main driving factor).

In addition to the understanding of eucalyptus root growth, this study provided some practical applications in fertilization management and technical practices.

Soil acidification as influenced by natural and manipulated environmental conditions: implications for productivity and nutrition

E.I. Vanguelova [1,2], A.J. Moffat [2], S. Nortcliff [1] and F. Kennedy[2]

1. Department of Soil Science, PO Box 233, The University of Reading, RG6 6DW United Kingdom

2. Environmental Research Branch, Forest Research, Alice Holt Lodge, Farnham, Surrey, GU10 4LH, United Kingdom

email: elena.vanguelova@forestry.gsi.gov.uk

Abstract

Introduction

Forest soil quality and productivity are essential elements in the maintenance and development of a sustainable forest. Acid deposition is associated with an increase in soil acidification, reduction in essential nutrients and Al mobilisation, which are believed to be threats to forest vitality through its effects on the fine roots and nutrient uptake. This can also lead to ground and surface water contamination. Soil acidification may also change the ratio of NO_3-N to NH_4-N in the soil solution in favour of the ammonium ion, which may cause acidification at the soil-root interface. Soil sensitivity to acid deposition depends on its properties. Acid sandy forest soils are usually sensitive to an increase in the acid load due to their low base saturation, high Al saturation and high leaching potential and changes in such soils may be irreversible. Thus, insight into the dissolution and transfer of Al and essential nutrients is crucial for our understanding of the impact of acid deposition on the acidification of soil and water.

Natural ecosystem changes are as important as these influenced by pollution due to the evolution of environmental conditions in a changing climate. Many natural processes, including nitrification and cation uptake, result in a natural acidification of poorly buffered soils, even in the absence of acidic deposition. Seasonal changes in the soil water regime can change soil solution chemistry. Nevertheless, it is necessary to differentiate to what extent such changes could result from effects of air pollutants and to what extent these are induced by the natural processes occurring in the soil environment.

Objectives

The study aimed first to follow the seasonal fluctuations of the soil solution chemistry and then to evaluate the changes in the soil and soil solution chemistry as influenced by manipulated increase in acid deposition under field conditions.

Material and Methods

The experimental area was located at Headley Park, near Alice Holt Forest Research Station, Hampshire, UK. The soils are humo-ferric podzol, under 40-years Scots pine (*Pinus sylvestris*) plantation. Soil solution chemistry was monitored once a week for 2 years (2000 and 2001) by the means of porous cups. Soil solution pH was measured by conventional pH meter and solutions analysed for: Al, Ca, Mg, K, Na, Mn, Fe, P, S and Si by ICP/OES, mineral anions: NO_3^-, SO_4^{2-}, Cl and F by ion chromatography (Dionex DX-500), NH4-N colorimetrically by flow injection analyser and DOC by carbon analyser (Shumatzu 500, TC analyser, Osaka, Japan). Speciation of Al was modelled by the chemical equilibrium program MINEQL+ (Version 4.0 for Windows, Environmental Research software, Edgewater, MD, USA). Soil moisture was measured by Theta probes (Delta-T Devices Ltd., Cambridge, England) and temperature using thermocouples.

During the second year of investigation, acidification treatments (simulating 15 kg S ha^{-1} a^{-1} applied as H_2SO_4) were carried out directly into the soil in a randomised block experimental design and the effects on the soil and soil solution chemistry were assessed.

Results and Discussion

Naturally occurring soil acidification

Soil moisture and soil solution chemistry changed considerably during the two years of observations. Soil moisture content was significantly higher ($p< 0.001$) in the whole profile during the second year, which was a result of the intensive rainfall during the previous autumn and winter. Soil solution pH decreased significantly in 2001 compared with the previous summer and this was accompanied by a significant ($p<0.01$) increase in soil solution Al, Ca and Mg. Soil solution NO_3-N, NH_4-N and DOC also increased significantly ($p<0.001$) during 2001 possibly as a result of increased nitrification and decomposition due to the higher soil moisture content. The changes in Al were most likely to be caused by changes in soil solution pH. However, the seasonal variation of Al was also related to NO_3 ($n=150$, $r^2=0.79$, $p<0.001$), but not to

SO_4^{2-}, suggesting the importance of the nitrification in the mobilisation of Al. Soil solution Al^{3+} has also increased significantly in 2001 compared with 2000. The changes in soil solution chemistry have been related entirely to naturally occurring processes since the precipitation chemistry in the area did not differ between the two years of observation.

Induced soil acidification

A manipulated increase in acid deposition of 15 kg S ha^{-1} a^{-1} under field conditions acidified the soil solution in a podzol and increased the soil solution Al and base cations. These phenomena were likely to be caused by exchange processes in the upper soil and by increase in weathering and dissolution of aluminium secondary compounds at the subsoil as indicated by the Si in the soil solution. There was an increase of soil solution NH_4-N, suggesting that the acid input inhibited the microbial activity, including the nitrification rate. The results suggested that the podzol might retain sulphate, which is a crucial factor that regulates acidification of soils and drainage waters. Sulphate was significantly positively correlated with most base cations ($p<0.01$) in the soil solution from the Acidification plots. This suggests that the decrease of sulphate would reduce the loss of cations, particularly Ca and Mg, and thereby reduce the rate of soil acidification. However, there was no correlation between soil solution sulphate and pH, suggesting that a decrease in sulphate in the precipitation does not necessarily lead to a reduction in H^+ in the soil solution, at least in the short term. Consequently, there was also no correlation observed between SO_4^{2-} and Al in the soil solution.

The soil exchange properties were unaffected by the increased acid input with the exception of the decrease in base saturation due to lower exchangeable Ca and Mg in the organic layer. They were brought into solution and leached down the soil profile. In this respect, the organic layer may act as a barrier confronting the acidity input and protecting the mineral soil from acidification.

Conclusions

- Changes in soil moisture regime will change the chemistry of the soil solution of poorly buffered soils significantly and detrimentally
- Both naturally occurring and induced soil acidification could increase monomeric Al in the soil solution to reach critical values associated with damage to fine roots of trees and decreased tree nutrient uptake.
- An increase in acid deposition of 15 kg S ha^{-1} a^{-1}, as H_2SO_4 reduced significantly the exchangeable Ca and Mg in the organic layer.

- The organic layer functions as a barrier confronting the acid load and protecting the mineral soil from acidification, but this is only true in the short term
- The acid input also increased the NH_4: NO_3 ratio in the upper mineral soil, so the greater NH_4 available for uptake can acidify the soil in the rhizosphere

Plenary session 4 « SUSTAINABLE FOREST AND SOIL MANAGEMENT »

Sustainability of the Multifunctional Forest

E.P. Farrell

Forest Ecosystem Research Group,
Department of Environmental Resource management, Faculty of Agriculture,
University College Dublin, Belfield, Dublin 4, Ireland.
Ted.Farrell@ucd.ie

Abstract

The sustainable management of forests has, for centuries been embodied in the principle of sustained yield. According to this principle, the forest should be managed in such a way as to ensure that its productivity, in terms of timber yield is not compromised. The harvest of one generation should not be taken at the expense of the next. In recent decades, this principle has been applied to virtually all aspects of human activity. Contemporaneously, society's view of the forest has changed. People look to the forest for the conservation of soil and water resources, as a store of carbon, a filter removing pollutants from the atmosphere and very-importantly as society becomes increasingly urbanised, a place where people can go to play and to relax. These multiple functions are being demanded not only of natural forests, but even of plantation forests, which were established, for the most part, with one purpose in mind, usually the production of timber. The concept of sustainable forest management, which has replaced the long-established principle of sustained yield management, represents an extension of that principle to the multifunctional forest.

Criteria of sustainable forest management have been developed to assist the implementation of the principle. Indicators have been formulated in order to ensure that the forest is managed in a sustainable manner. This process is proceeding rapidly, but perhaps there is a need to slow down and to ask ourselves "What does 'sustainable forest management' really mean?" If it has a meaning that we can define, can we really measure it? If we are prepared to try, what sort of measurements, what sort of indicators might make sense? The paper will explore the concept of sustainability in the context of forest management and forest soils and suggest quantitative measures of progress towards the sustainable management of forests and forest soils.

Impact of clearcutting on organic matter repartition and spatial occurrence of litter decay in a Douglas fir plantation(Beaujolais, France)

G. Bally[1]*, F. Andreux2, F. Roux[2], J. Leveque[2].

[1] Laboratoire de Géologie - UMR CNRS 6143 " M2C " - Université des sciences de Rouen – 76821 Mont Saint Aignan Cedex.

2 Laboratoire GéoSol - Équipe de l'UMR INRA 1229 "MGS" - (Microbiologie & Géochimie des Sols) -Centre des Sciences de la Terre, Porte 3-14 - 6, Boulevard Gabriel - 21000 Dijon, France.

** Coresponding author : gabriel.bally@univ-rouen.fr*

Abstract

Introduction and study aim

In France, the Douglas fir (*Pseudotsuga menseizii*) has become the second tree species used for reforestation, covering an area of 341 000 ha (National French Inventory, 2003). Planting is associated with disturbing forestry practices, especially clearcutting when soil surface is scrapped off and residues are removed. This practice induces new biological and microclimatic constraints on the soil organic matter equilibria. The mineral biogeochemical cycle of a Douglas fir plantation from the young growing stage to clearcutting has been investigated in the Beaujolais Mounts in an area managed by the CRF-INRA of Nancy. The experimental plantation included an area where the impact of clearcutting has been monitored. While the CRF-INRA studied the mineral functioning of this clearcutting, the present study focused on the soil organic matter (SOM) changes.

In a 64 years old Douglas fir plantation, the trees were cut and the small size litter residues were left on the soil surface, resulting in an heterogeneous distribution of these residues, consequently in the surface soil organic matter content. This purpose will be achieved by: (i) studying the spatial distribution of the organic matter content in the litter and the soil at different periods of time after the clearcutting, (ii) establishing the spatial and temporal relationships between the litter and the surface SOM.

Methods

A spatial and temporal measurements of organic matter content and soil physico-chemical properties were done from April 1999 to May 2001. The litter and the surface soil (0-5, 5-10 and 10-15 cm) were sampled according to a systematic 32 nodes grid, at different time and analysed for organic carbon, organic nitrogen, pH, bulk density, and humidity. Maps of temporal variations

were constructed by subtracting the values of each variable, using that of April 1999 as time reference for each sampling location. The maps were obtained from the sampling points by interpolating with a linear krigging method. In addition, a survey of the litter weight and composition was investigated. The litter decay and the SOM evolution were surveyed and compared with each other.

Preliminary results and conclusion

Considering the whole experimental-plot, the mean stocks of soil organic carbon (SOC) and soil organic nitrogen (SON) in the 0-5 cm layer increased significantly from 2.5 ± 0.2 kg C m^{-2} and 0.15 ± 0.05 kg N m^{-2} 6 months after the clearcutting to maximal values around 4 ± 0.5 kg C m^{-2} and 0.22 ± 0.07 kg N m^{-2} 8 months later. The layers 5-10 and 10-15 cm which contained lower stocks of SOC and SON showed no significant changes with time. The total weight of litter decreased strongly from its maximum (6.1 ± 1.6 kg m^{-2}) in April 1999 to a minimum (2.0 ± 0.2 kg m^{-2}) in May 2000. The same tendencies were also observed for the fine (<2cm) and coarse litter (>2 cm) fractions.

The maps of SOC and SON in the layer 0-5 cm revealed a peculiar spatial distribution, with an enrichment in the northern part of the plot, with respect to the southern part. The variability of SOC and SON was more pronounced after 6 months than after 19 months and 25 months following cleacutting.

Maps of the total litter stocks revealed a sharp decay with time, with a high variability, especially in August 1999. This variability seems to be more pronounced in the northern part than in the southern part, as for the SOM. From August 1999, the litter decomposed fast and its spatial variability was less pronounced.

The comparison between the spatial distribution of the litter and SOM contents in the soil layer 0-5cm revealed a close relationship between these two variables during the time of the experiment. Such relationship was no longer evidenced in the 5-10 and 10-15 cm soil layers. Further works, based on correlation studies should confirm the impact of such heterogeneous distribution of the litter left on the soil after clearcutting, on the spatial distribution of SOM in the surface soil .

Assessing long-term change in forest soils fertility by mean of stable Sr isotope dendrochemistry

Th. Drouet, D. Demaiffe, and J. Herbauts

Laboratoire de Génétique et d'Ecologie végétales, Université Libre de Bruxelles, chaussée de Wavre 1850 ,
B 1160 Bruxelles, Belgium. Tel : +32 2 650 91 60 ; Fax : +32 2 650 91 70 ; e-mail : tdrouetd@ulb.ac.be

Abstract

Acidification of forest soils by atmospheric deposition involving leaching of nutrient cations is still an active subject of research. Many studies made in Europe and North America have shown that an increasing depletion of exchangeable base cation may cause tree nutritional deficiencies in some sensitive soils. Vegetation takes up nutrients from the soil exchange complex and in the soil solution, which can be replenished by mineral weathering or atmospheric input. Strontium isotope dendrochemical analysis uses radial variation of Sr isotopic composition in tree-rings to monitor possible change of tree source of nutrient. Strontium can be used as a proxy of Ca because these ions have similar chemical structure and behave similarly in the soil and plant compartments.

Measurement were undertaken in 3 forest stands on ochreous brown earth in High Belgium and on acid leached soil in Central Belgium. Strontium isotope ratio ($^{87}Sr/^{86}Sr$) was measured in beechwood (*Fagus sylvatica* L.) growth rings in all sites and in pedunculate oak (*Quercus robur* L.) tree-rings in one site of High Belgium.

We observe a gradual decrease in Sr isotope ratio as from mid 19^{th} century to present. Assuming the contribution of atmospheric deposition (low $^{87}Sr/^{86}Sr$ ratio) to the soil to be constant during this period, a change toward a lower Sr isotope ratio in younger wood must result from a decreased contribution of Sr from the soil pool (high $^{87}Sr/^{86}Sr$ ratio). This may occur when cations are displaced from the soil by acidic deposition at a rate faster than they can be replenished by the slow mineral weathering. As a result, the Sr isotope ratio in the soil water taken up by tree, moves towards that of atmospheric source.

Similar patterns of decrease in Sr ratio over time in stemwood of different tree species found by other authors in Scandinavia and France may indicate that this process is a general feature in Europe.

Deterioration of the peaty soils of the humid complex of EL-Kala, NE Algeria

Benslama M.* and Zanache H.*

** Laboratoire de Biologie Végétale et Environnement, faculté des Sciences Université Badji Mokhtar Annaba. B.P12, 23000 Annaba Algérie Tel/Fax : 00 213 38 87 27 55 E-mail : Bensmohand@ yahoo.fr*

Abstract

The humid zones in the world represent 6% of the land surface, but contain high plant diversity. This biodiversity is related to the quality and the availability of food in the region.

In Algeria, due to lack of access and the danger presented by risks of the malaria national and international knowledge on their dynamics is not appropriately understood. At the end of the seventies an inventory of peat-bog in Algeria indicated that out of 1400 acres of peat areas 900 acres were located in North east, and corresponded to the different humid zones of the El-Kala region. The presence of the peat (soil rich in organic matter) and the availability of surface water encouraged the development of agriculture causing fast consumption of water and loss of organic matter due to drainage and the use of soil. Many factors deteriorate the landscape: pumping of water, fires, labours of borders and stake in cultures.

The Nechaa Righia is the biggest active peat-bog of the region and of the Maghreb, it probably currently covers 300 acres (500 acres on map), but it is exposed to an intense exploitation and a fast and total destruction of its biodiversity (soil, vegetation). Through exploitation, Algerian humid area loses 50 to 60 acres/year, which limits its life span of 20 to 30 years, and no protective and back-up measure is being taken.

Formation, organization and evolution of the forest soils of El-Kala humid complex (N.E. Algeria)

Benslama M.* and Zanache H.*

** Laboratoire de Biologie Végétale et Environnement, faculté des Sciences Université Badji Mokhtar Annaba. B.P12, 23000 Annaba Algérie Tel/Fax : 00 213 38 87 27 55 E-mail : Bensmohand@ yahoo.fr*

Abstract

Situated to the Northeast of Algeria, the humid complex of EL-Kala is part of a particular geographical unit characterized by:

An acidic substratum formed on the one hand by the alternative deposits of sandstone and clay of Numidy and by the presence of zones of materials which is poor in limestone. A humid climate (1000 to 1200 mm / year) occurs with a strong winter rainfall (3/4 of precipitations) and a strong warm summer. A dense and varied plant cover occurs which can be grouped into five stands: *Quercus suber, Quercus fagénéa, Quercus coccifera, Pinus pinaster and Alnus glutinosa.*

Pedogenesis caused **brunification** and is at the beginning of **podzolisation** and has an organic matter accumulation in the swampy zones. Four soil orders have been recognized and they are: Alfisols, Histosols, Inseptisols and Mollisols.

Comparison of chemical soil properties under Black locust and oak forests in Hungary - Will soil inventories at the landscape level provide valid information?

Dirk Berthold

Institute of Soil Science and Forest Nutrition, University of Göttingen, Germany; e-mail: dbertho@gwdg.de

Abstract

The areas under Black locust (*Robinia pseudoacacia L.*) have increased in recent decades and are about 3 Mio. ha worldwide, only exceeded by Eucalyptus and Poplar. In Hungary the area under Black locust stands has increased from 201.000 ha in 1958 to 320.000 ha in 1994 and may increase by another 40.000 ha in the next twenty years (Molnár 1994). Reasons for cultivating Black locust are: its tolerance against drought, its excellent wood properties and its ability to fix atmospheric nitrogen. It is easy to regenerate from root suckers, grows efficiently on poor sites and improves nitrogen supply and element turnover. There are however other issues which may cause concern. For example, the amount of N fixed during long-term growth of Black locust may exceed the demand for tree nutrition causing excess nitrogen to either accumulate in the stand and the organic layer or leach causing loss of base cations and high soil acidification. The growth of Black locust may decline when planted for several generations on the same site, due to changes of chemical soil parameters (acidification, nutrient losses) and enhanced occurrence of soil-borne pathogens.

To investigate the impact of Black locust on soil fertility, soils from five regional areas in Hungary were compared. Each regional area had a number (mean = 4) of paired sites under Black locust and oak on adjacent area. At each site chemical parameters of organic layer and mineral soil (pH; C, N, P; exchangeable cations) were compared. As the smallest spatial unit adjacent stands of Black locust and oak were used (paired stands) by assuming that the differences in chemical soil characteristics were mostly related to the influence of tree species. As a next step stands were compared for the whole regional area. For a defined area of similar soil and climatic conditions, it was possible to illustrate the influence of Black locust on soils. However the sites had to be grouped into calcareous and non-calcareous soils before the effects of Black locust could be compared with other tree species at the landscape level.

The comparison of adjacent (paired) stands of Black locust and oak indicated that cultivation of this legume led to soil acidification and the loss of nutrient cations of non-calcareous sites. However an increase in soil nitrogen content under Robinia stands could not be conclusively observed. Smaller C/N

ratios in soils under Robinia indicated the effects of N_2-fixation, probably reflecting in elevated nitrogen supply and faster mineralization. As expected soil acidification effects were not observed on sites with the calcareous soils.

Chemical soil parameters of stands with different tree species within a single regional area did not differ significantly. This was clearly related to the long distance between stands leading to high heterogeneity in soil parameters indicating that the differences in pH or concentration of nutrient cations between stands of Black locust and oak became weaker, when a complete forest region was under consideration. For example at a forest site in the middle of Hungary two pairs of Black locust and oak stands were compared, which were approximately 5km remote from each other. At the first site pH in the mineral soil (0-50cm) under Black locust decreased up to 0.8 units and cation exchange capacity was dominated by acid cations (60% compared to 35% under the adjacent oak stand). At the other site of this region pH under Black locust also decreased compared to the oak stand, but only in the deeper part of the mineral soil (30-50cm). No difference in base exchange capacity values were measured.

In order to assess soil acidification by Black locust where it is compared with non N_2-fixing tree species, it is necessary to observe several paired and adjacent stands representing different forest regions and different chemical soil characteristics. A regional scale comparison may lead to erroneous results due to high spatial heterogeneity in soil properties.

A regional approach based on the "IPCC Good Practice Guidance for LULUCF" for estimating carbon balance in Andalusian forest soils (Spain)

José Castillo

Unidad de Desarrollo Técnico (jdelpino@egmasa.es)
Empresa de Gestión Medioambiental, Consejería de Medio Ambiente.
C/ Johan G. Gutenberg, s/n. Isla de la Cartuja. 41092 Seville (Spain)

Abstract

Introduction

Soil organic carbon (SOC) is the main terrestrial carbon reservoir interacting with the atmosphere. Important factors affecting the carbon change between soil and atmosphere are: (1) land use and vegetation cover; (2) climatic variables as temperature and humidity; and, (3) soil properties as texture, pH and kind and amount of clay particles. Soil and climate are long-term decisive factors, while land-use change and vegetation cover management are short-term key variables influencing carbon dynamics. The Intergovernmental Panel on Climate Change (IPCC) considered these factors and proposed a methodology for calculating carbon balance on forests soils, as shown in the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (herein IPCC GPG for LULUCF).

Objectives

This paper aims to show preliminary conclusions on the implementation of the IPCC recommendations regarding the estimation of both the magnitude and the trend of carbon stock changes in mineral forest soils. Consequently, a regional approach and initial results for Andalusia region (Spain) are presented below.

Material and methods

After estimating forest land category and sub-categories areas in Andalusia by applying GIS, forest soil areas for each soil category and within each forest land use sub-category were calculated, as well as parameters for each soil category within each forest land use sub-category to use in equation 3.2.14 from IPCC GPG for LULUCF:

$$\Delta C_{MINERAL} = \sum_{ij}[(SOC_j - SOC_i)\cdot A_{ij}]/T_{ij}$$

where:

$\Delta C_{MINERAL}$ = annual change in carbon stocks in mineral soils, tonnes C · yr^{-1};

SOC_i; SOC_j = stable soil organic carbon stock, under current «j» or previous «i» state, tonnes C · ha^{-1}; and being $SOC_i = SOC_{ref} \cdot f_{foresttype(i)} \cdot f_{manintensity(i)} \cdot f_{distregime(i)}$;

SOC_{ref} = the reference carbon stock, under native, unmanaged forest, tonnes C · ha^{-1};

$f_{foresttype(i)}$; $f_{manintensity(i)}$; $f_{distregime(i)}$ = adjustment factors reflecting the effect of a change from the native forest to forest type «i», management intensity «i» on forest type «i», or a change in the disturbance regime to «i» with respect to the native forest, in that order, dimensionless;

A_{ij} = forest area undergoing a transition from state «i» to «j», ha;

T_{ij} = time period of the transition from SOC_i to SOC_j, yr (the default is 20 years).

Results and discussion

Table 1 shows the first results obtained using the IPCC GPG for LULUCF methodology, where the SOC global stock in Andalusia is calculated as more than 90 million tonnes C:

Table 1 – Preliminary results for Andalusia	Annual Change (tonnes C · yr^{-1})
Forest Land that remained as Forest Land	7.297,05
Land Converted To Forest Land	920,22
TOTAL FOREST LAND	8.217,27

Results indicate that annually more than 30 Gg CO_2 could be sequestered from the atmosphere by Andalusian forest soils due to land use, land use change and silviculture. These first estimates do not could seem to be significant, but they should be compared with other estimates to assess the significance of forest soils in carbon dynamics in Andalusia.

Conclusions

Further research is required to obtain valid estimates of changes in carbon stock in mineral forest soils of Andalusia. The techniques provided by IPPC GPG for LULUCF offer a sound way to handle this issue.

Assessment of nutrient cycling in an *Eucalyptus globulus* plantation in Southern Portugal as a tool for sustainable management

Nuno Cortez & Manuel Madeira

Instituto Superior de Agronomia, Tapada da Ajuda, 1349-017 Lisboa, Portugal, phone +351213653293, fax +351213635031, e-mail nunocortez@isa.utl.pt

Abstract

Demand for raw material for the paper pulp industry has led in Portugal, as in other Mediterranean areas, to the increase of *Eucalyptus globulus* plantations, which have been intensively exploited as short rotation coppiced stands. Such exploitation has led to soil nutrient depletion and consequently to the modification of soil characteristics in forest land (Fisher & Binkley, 2000). Effects of *E. globulus* plantations on soil nutrient status were assessed through nutrient cycling approach (Cortez, 1996) to provide guidelines toward a more sustainable forestry management.

The study was carried out in a flat area with Mediterranean type of climate and a mean annual rainfall of 700 mm. The soils are Dystric Cambisols derived from Cretacic sandstones. The sample plot area was 50 m x 50 m. The stand age varied between 7 to 9 years during the study, with a 3 m x 3 m spacing. The aboveground tree biomass was measured from 9 individual sample trees. Sixteen samples (0.50 m x 0.50 m) were taken to determine the forest floor litter layer mass. The soil beneath forest floor was sampled (16 points) with a soil corer up to 80 cm depth. Collectors were set up at the top of a tower, 26 m high (some meters above tree canopy) for bulk rain, at ground level for throughfall and at the base of the trunk for stemflow. Nutrient losses due to drainage water were determined collecting soil solution samples by lysimeters at two different depths. Samples of bulk rain, throughfall, stemflow and soil solution, and samples of aboveground tree components, forest floor litter layer and mineral soil were analysed to assess concentrations and amounts of nutrients.

Annual nutrient balance along the study period showed that nutrient losses from soil through water drainage (less than 0.1 kg P ha^{-1} $year^{-1}$ and 1-3 kg ha^{-1} $year^{-1}$ for the other nutrients) were similar or even lower than the total inputs from weathering of similar rocks (values from Attiwill & Leeper, 1987) and gross rainfall (the amounts of N and Ca added were, respectively, 4 and 3 kg ha^{-1} $year^{-1}$). Thus, data suggest that the nutrient geochemical balance was positive.

Nutrient requirements for tree growth were partially supplied by internal redistribution (*sensu* Attiwil & Leeper, 1987) (26% of N and 15-16% of P and K needs), and by litterfall (35% of Ca, 21% of Mg and 24 % of K needs), which was the dominant transfer of nutrients from the tree to the soil. Throughfall and

stemflow had a negligible influence in the tree nutrient supply. Therefore, during the study period, accumulation of nutrients in the aboveground tree biomass was strongly dependent on soil reserves (more than 60% of N, Ca, Mg and P, and about 46% of K).

Despite their low content of organic carbon, extractable P and exchangeable base cations, the mineral soil layers stored large proportions of N (94%) and Ca (54%) in the system. The amount of extractable Ca in the mineral soil was similar to that accumulated in tree aboveground biomass and forest floor litter layer, but the amount of extractable P was about 2.2 times less.

This pattern leads to the conclusion that removal of total aboveground biomass would provoke the loss of 36 % of Ca and 63 % of P from the system. Nevertheless, these losses may be negligible if only the stem is removed. The whole tree harvesting corresponds to an export of N, P K, Ca and Mg which amounts to 24.7, 3.6, 25.9, 69.5 and 11.6 kg ha^{-1} $year^{-1}$, whereas harvesting only the bole-tree reduces such export by 76%, 44%, 58%, 85% and 63%, respectively.

Results underline that *E. globulus* plantations promote a high transfer of nutrients from soil to aboveground biomass, reducing nutrient stocks in soil. Such a transfer is of paramount importance especially in sites whose soils have a low nutrient status. Intensity of biomass removal and application of fertilisers are key tools to ensure that long-term productivity is not jeopardised.

References:

Attiwill, P. M. & Leeper, G.W. (1987). *Forest Soils and Nutrient Cycles*. Melbourne University Press, Victoria.

Cortez, N. R. S. (1996). *Compartimentos e Ciclos de Nutrientes em Plantações de Eucalyptus globulus Labill. ssp globulus e Pinus pinaster Aiton*. Ph.D. thesis. Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Lisboa.

Fisher, R. F. & Binkley, D. (2000). *Ecology and Management of Forest Soils*. Third Edition. John Wiley & Sons, Inc. New York.

The impact of tree harvesting operations on forest floor density and moisture

Robert A. Douglas, Matt Wood, Roger Sands

NZ School of Forestry
University of Canterbury
Christchurch, New Zealand

Abstract

Tree harvesting operations can lead to adverse impacts on forest soil quality, and thus the prospects for growth for the subsequent crop. Trials were undertaken in New Zealand's Southland to observe the effects of season of work, machine type and trafficking intensity on the physical properties of a clay soil of stony silt-loam texture. The depth of wheel or track ruts was observed, and soil sampling and testing including nuclear density testing, cone penetration testing, TDR moisture testing, and coring were performed to determine soil moisture and density as a function of the independent input variables. A unique feature of the field research programme was the inclusion of thin wall Shelby tube sampling. While common in geotechnical engineering, the authors are not aware of its previous use for forest floor compaction studies. Mean values of soil cone penetration resistance for trafficked test sites were generally greater than those for the untrafficked test sites, and often significant at $P = 0.05$. Values of soil dry density showed little difference between the untrafficked and trafficked test sites. Overall, no trends were observed for soil disturbance according to either machine type or trafficking intensity, although the effectiveness of tillage (soil ripping) as a means of improving soil quality was clearly demonstrated. The results of the study were considered in relation to (a) generic soil physical thresholds where root and/or tree growth may be affected and (b) the management of future harvesting operations in the region.

NOTE: aspects of the work (comparison of methods of density determination) have so far been presented in:

References

Wood, M.J., Sands, R., and Douglas, R.A. 2004. A comparison of three methods for measuring the density of a forest soil in New Zealand. International Journal of Forest Engineering 15(1):71-80.

Monitoring the dynamics of soil organic carbon in cleared temperate maritime pine forest

Claudy Jolivet[a], Fabien Bourhis[a], Dominique Arrouays[a], Francis Andreux[b] and Pierre Trichet[c]

a INRA, Unités Infosol et Science du Sol, Avenue de la Pomme de Pin, BP 20619, 45166 OLIVET cedex, France

[b] UMR 1229 INRA-Université de Bourgogne, Microbiologie et Géochimie des Sols, Centre des Sciences de la Terre, Université de Bourgogne, 6 Boulevard Gabriel, 21000 DIJON, France

[c] INRA, Unité de Recherches Forestières, Domaine de l'Hermitage, Pierroton, 33610 CESTAS, France

Correspondence to: claudy.jolivet@orleans.inra.fr

Abstract

Soil organic matter represents a large reservoir of organic carbon and a main soil constituent. Natural or human disturbance of terrestrial ecosystems can lead to significant evolution of soil organic properties which is of prime interest in term of global change and sustainable management of natural soil resources. Gascony is covered with the greatest forest area in Western Europe (about 1 million hectares) mainly composed of maritime pine. The soils are hydromorphic sandy Spodosols, developed from Quaternary coarse sandy aeolian deposits. The vegetation, the profile development and the storage of organic matter vary spatially, in relation to the microrelief and to the seasonal variations of the water table. Contrasting with the natural infertile characteristic of these podzolic sandy soils, intensification of silvicultural management (soil drainage, mechanization and fertilization) has resulted in highly productive artificial forests. The objective of this work was to evaluate the effect of clear-cutting on organic matter properties by *in situ* monitoring of organic carbon contents in whole soil and particle-size separates.

Two adjacent intensively managed maritime pine stands of one hectare each have been monitored for 6 years from 1997 to 2003. One has been used as control (IF) and the second (CC) has been clear-cut in the first year of the monitoring. Clear-felling was associated to several silvicultural practices involving chopping, stumping, fertilization and ploughing to 50 cm depth. In this area, the interactions of relief and water table level result in contrasted drainage situations which spatially govern the properties of soils and organic carbon contents. This factor was considered to define the sampling design to monitor the spatial and temporal development of soil organic matter attributable to clear-cutting.

In the undisturbed soil of the IF stand no changes were observed in the soil organic carbon stocks during the experiment. Before clear-cutting, the soil organic carbon content of the CC stand was 32 g C kg^{-1} in the 0-30 cm layer. Clear-cutting and associated silvicultural practices had considerable impact on organic carbon content and stocks, and were associated to immediate opposite effects. The incorporation of organic material into soil with chopping (understory vegetation, forest floor and timber residues) showed an immediate increase of organic carbon content. On the contrary, stumping and ploughing caused a sharp decrease in organic carbon content mainly due to mechanical dilution of organic carbon-rich A horizon with organic carbon-poor E horizon. All these silvicultural operations finally resulted to a net loss of soil organic carbon content of about 10 g C kg^{-1}. Simultaneously, an equivalent amount of carbon was incorporated in soil as raw material which could have made up the loss of soil organic carbon.

Monitoring of the particle-size separates provided the dynamics of soil organic carbon. Clear-cutting have a contrasted impact on fine (0-50 μm) and coarse (50-2000 μm) fractions of soil. Clear-felling decreased organic carbon content in the two particle size separates. Incorporation of fresh organic matter with chopping temporary supplied the decay of the organic carbon pool contained in the coarse fraction. After ploughing the fine fraction is progressively supplied by the decomposition of organic matter of the coarse fraction.

These results showed that clear-cutting have a dramatic impact on soil organic carbon. Six years after clear-cutting, the sharp decrease in SOM observed just after clear-felling and ploughing has stabilized. Organic carbon loss was partly made up by the incorporation in soil of fresh organic matter, but the initial level of soil organic carbon was not recovered, questioning the sustainability of this kind of forest management.

Longterm monitoring of litterfall under some European beech stands: consequences for productivity and nutrient cycling in relation to atmospheric depositions

P.K. Khanna1, K.J. Meiwes2, and J. Eichhorn3

[1]Institute of Soil Science and Forest Nutrition, Buesgenweg 2, 37077 Goettingen, Germany

[2]Forest Research Institute of Lower Saxony, Graetzelstr. 2, 37079 Goettingen, Germany,

[3]Hessische Landesanstalt für Forsteinrichtung, Waldforschung und Waldökologie, Hann. Muenden Germany

Abstract

Litterfall is an important factor for assessing the role of C turnover and nutrient cycling processes in affecting the productivity and health of forest stands, but the amount of various litterfall components (leaves, twigs, buds, florescence, fruits, woody parts and others) can vary during the year and from year to year. Most studies in the past have been confined to measurements of short periods of less than 5 years and in most cases of leaf fall component mainly. However many changes in the soil and stand characteristics due to atmospheric inputs and management practices are of long term nature and require long-term measurements to understand their impacts on forest stands. We present here litterfall data from three European beech stands which have been measured continuously for the last 12 years and periodically for the last 30 years. All the three stands (SO - Solling, GW – Goettinger Wald, and ZB -Zierenberg) are mature forests dominated by European beech, which were located in the middle of Germany. Forest sites vary in their soil properties (different parent materials (SO – Loess overlying Triassic red sandstone, GW – limestone, ZB – Basalt), chemical characteristics and proton buffering, biological processes and climatic conditions (altitude, annual precipitation).

The atmospheric inputs of nutrients and heavy metals have changed during the last 10 years (low acidity, low S, low Ca and other cations) and the last 20 years (low Pb, Cd and other heavy metals), whereas those of N have not changed in a significant manner. The climatic changes (warm and dry summers, and warm and wet winters) on the sites cannot be easily quantified. The productivities of most stands have increased in the last few decades. Frequency of heavy mast years has increased probably in relation to changes in productivity, climate conditions and atmospheric inputs, though their occurrence remains infrequent and unpredictable. Every mast event brings with it huge additions of C and nutrients in the annual litterfall and their effects on

the tree physiology and nutrient turnover have not received due attention. Our data indicated that mast events did not show a significant affect on the amount of leaf litter. Most probably climatic factors determine the annual variability in the leaf litter.

Contents of S and a number of heavy metals have shown major decreases in the leaf litter and green leaves during the last decade on all the three sites, indicating the effectiveness of Clean-Air policies. For example, concentration of Pb in the leaf litter decreased from 7.5 mg/kg in 1991 to 1.7 mg/kg in 2001. The annual pattern and the amount of leaf fall on the three sites varied very little (leaf fall values ranged from 2.3 t/ha to 3.9 t/ha). Concentrations of N (mean values on sites SO 12.3 g/kg, GW 11.1 g/kg and ZB 12.9 g/kg respectively) and S in the leaf litter were also similar (mostly determined by atmospheric inputs), but those of other elements differed depending mostly on soil characteristics. For example, the three sites followed the order: P (ZB>SO>GW), Mg (ZB>GW>SO) and Ca (GW>ZB>SO), indicating high P and Mg in ZB soils developed from basalt and high Ca in GW soil developed from lime stone.

Due to continual changing input conditions and climatic factors, their interactions between site factors and stand parameters strongly and differently affect forest productivity and nutrient cycling processes. In order to manage such ecosystems in a landscape context, it is essential to develop suitable knowledge base on such interactions e.g., on the role of litter fall parameters which may enable one to extend site specific information to landscape level.

Organic carbon stock and soil erodibility in forest andosols of the Canary Islands

A. Rodríguez Rodríguez, C.D. Arbelo, J.A. Guerra, J.L. Mora and C.M. Armas

Department of Soil Science and Geology, Faculty of Biology, University of La Laguna, Avda. Astrofísico Francisco Sánchez s/n, 38204 La Laguna, Tenerife, Canary Islands, SPAIN

e-mail: antororo@ull.es

Abstract

Volcanic ash soils and, more specifically Andosols, are characterized by a high organic carbon (SOC) content that produces very dark-coloured humic surface horizons. This high SOC content is attributed to the fact that the organic matter in these soils is stabilized by short-range ordered minerals or by the formation of Al-humus complexes.

Andosols are soils with a large potential to sequester carbon (C), although little is yet known about the dynamics of C in these soils and the mechanisms governing stabilization of organic compounds.

Organic carbon is known to play an important role in the structural stability and resistance of soils to erosion. However, little is known about these mechanisms and processes in andic soils and about the influence of the different types of SOC on aggregate stability and on SOC losses by interrill erosion in these soils.

The objectives of this paper were, therefore:

-to determine the content and forms of SOC in Andosols under evergreen forest vegetation (laurel and heather forest), and

-to determine the role of organic matter in aggregate stability and resistance of Andosols to sheet water erosion.

The study was carried out in a sampling area of around 40 km^2 in the Garajonay National Park (La Gomera, Canary Is.) characterized by a thermomediterranean mesophytic subhumid bioclimate, with annual precipitation ranging between 650 and 900 mm, a mean annual temperature of 14-16ºC and a potential evapotranspiration of 750-800 mm/yr. These conditions give place to a udic soil moisture regime and a thermic soil temperature regime. The natural potential vegetation corresponds to the laurel and heather forest (*Lauro-Perseeto indicae* and *Myrico-Ericetum arboreae*).

Predominant Andosols in this area (Melanudands, Fulvudands and Hapludands) have been grouped, after laboratory analysis, into two main categories: allophanic and non-allophanic (or organomineral) Andosols. This division has been applied according to the "binary composition", by which the

Alp/Alo ratio indicates the occurrence of allophanic or non-allophanic properties, such that Alp/Alo values of less than 0.5 point to a soil mineralogy dominated by allophane and allophane-like minerals (imogolite, ferrihydrite), otherwise occurring the active Al mainly as Al-humus complexes.

Soil sampling was performed in a 500m x 1000m grid over the entire surface (88 sampling points), intensifying sampling density in areas showing the greatest evidence of degradation both of vegetation and soils, where samples were collected on the basis of an additional grid measuring 250m x 250m (75 samples).

A total of 163 sampling sites were studied and soil samples were collected at each in the first 30 cm at 3 randomly distributed sampling points. In the soil samples sieved through 2 mm-mesh, the following parameters were determined: Walkley-Black SOC, pyrophosphate extractable SOC, Fe and Al, potassium sulphate extractable SOC, dissolved SOC and acid oxalate extractable Fe, Al and Si. Also, the following analyses were performed: fulvic and humic acids, K-factor of USLE and aggregate stability by wet-sieving and water-drop tests.

The Andosols studied present high concentrations of SOC (60-280 g C kg^{-1}) and the stocks in the first 30 cm from the soil surface oscillate between 8 and 32 kg C m^{-2}. The dissolved organic carbon in these soils is around 112.4±44.7 gL^{-1}.

There was no significant difference between allophanic and non-allophanic Andosols, with a separation limit of $Al_p/Al_o = 0.5$. The percentage of SOC adsorbed to the mineral fraction (extractable pyrophosphate -C_p-) represents 43-45% of the total SOC.

All the Andosols present a high stability both to slaking and to raindrop impact (wet-sieving and water-drop tests). Raindrop impact is a mechanism of aggregate breakdown that seems to be related with Fe_p and C_p in both types of soils. Disaggregation due to aggregate slaking is related with Fe_p, Al_p and C_p in allophanic Andosols, but not in non- allophanic ones.

A comparison of methods to predict the potential area of forest types in Southern Spain

M. Anaya-Romero, A. Jordán, L. Martínez-Zavala, N. Bellinfante Crocci

Departamento de Cristalografía, Mineralogía y Química Agrícola (Universidad de Sevilla)
C/ Profesor García González, 1. 41012 – Sevilla (Spain).
E-mail: manaya@us.es

Abstract

Models to evaluate forest systems using environmental parameters have been used by different authors in diverse ways. Nevertheless, the validity of the model calculations is influenced by the quality and number of variables used, as also by the mathematical – statistical method used.

More accurate prediction model was used in the present work, as proposed by Anaya-Romero (2003). The objective of this evaluation was to predict the potential distribution of several forest types in Aracena Mountains (Sierra de Aracena Natural Park) and Western Andévalo (Huelva, Spain). Selected models relate to the presence/absence of each forest type due to the main parameters of distribution of forest species depending on the environmental conditions of the study area. Three models were selected for their predictive and explanatory capacities: logistic regression (LR), artificial neuronal network (ANN) and decision tree (DT).

The forest types in the area are oak (Quercus suber and *Q. rotundifolia*), pine (*Pinus pinaster* and *P. pinea*) , eucalyptus (*Eucalyptus globulus* and *E. camaldulensis*) and deciduous forest. The selected environmental variables were grouped in several categories: litology (type of rock, acidity and consolidation), geomorphology (erosive processes, mass movements, sedimentation processes and morphogenesis), physiography, relief (elevation, slope and hillslope facing), soil (pH, nutrients, organic matter, CEC and clay content) and climate (average summer precipitation, annual average temperature, average temperature of the warmest month and average temperature of the coldest month).

After the exploratory analysis of the data, sites were for using the three selected models of prediction. With the objective of studying the behaviour of each prediction analysis when new data were used, the whole information was divided in calibration and validation (test) data. The division was made randomly, so that 75% of the samples were classified as calibration set, and 25% as test. The results obtained by the three prediction models were compared using the Kleinbaum confusion matrix.

The LR and the DT models obtained similar results, and both had an index of error smaller than the ANN for the four studied forest types. The average index of estimation error was calculated for the four formation types and for each model of evaluation used. Again, the LR model had better results for the test-data than ANN and DT models, so it was selected for the analysis of potential distribution of the forest types in Aracena Mountains and Andevalo. The results were extrapolated to the whole study area.

References

Anaya-Romero, M. (2003). Modelo de distribución Potencial de Usos Forestales en Sierra de Aracena y Andévalo Occidental (Huelva). PhD. Universidad de Sevilla (Sevilla).

Effect of forest tree species on distribution and biodegradability of organic matter in soil aggregate fractions

Moukoumi. J (1) (2)*, Munier-Lamy. C (1), Mallouhi. N (1), Berthelin. J (1), Andreux. F (3), Ranger. J (2),

(1)Laboratoire des Interactions Microorganismes Minéraux Matières Organiques dans les Sols (LIMOS), UMR 7137, CNRS-UHP Nancy I, Faculté des Sciences, BP 239, 54506 Vandoeuvre Lès Nancy cedex, (France).

(2)Laboratoire de Biogéochimie des Ecosystèmes Forestiers (BEF-INRA) 54280 Champenoux (France).

(3)Laboratoire de Microbiologie et Géochimie des Sols (GéoSol), UMR 1229, INRA-Université de Bourgogne, Centre des Sciences de la Terre, 6 Boulevard Gabriel 21000 Dijon (France).

(*)Judicael.moukoumi@limos.uhp-nancy.fr

Abstract

This study was a part of a general project looking at the effects of changing the forest tree species on the biological and biogeochemical behaviour of the ecosystem, more specifically the soils. Soil organic matter represents a key-constituent for both biological and non biological reactions in soils. Changing native forest species by alien ones leads to important changes in the ecosystem, which in return can alter the C and N cycles.

Soil organic matter behaviour was mainly investigated using several qualitative and quantitative analyses e.g. the carbon stock in the forest floor, restitution by litterfall, organic matter content in soil solution, bulk and net N-mineralization, and organic matter biodegradability. The specific objective of the present work was to determine the changes in the potential of soil organic matter biodegradation.

Soil samples from a 30-year old experiment comparing broad-leaved and coniferous species planted after clear-cutting of the native stand in the Breuil-Chenue forest in Morvan (France) were used. The area has an elevation of 650 m and receives 1400 mm of rainfall, along with average temperature of 7°C. The soil is strongly acidic.

Soil samples were collected in May 2003 from the A1 organo-mineral layer (0 – 5 cm) under three forest species (two plantations of European beech (pB) (*Fagus sylvatica L.)*, and Norway spruce (pS) (*Picea abies Karst.)*, and under the native forest (nF), a 150-year-old coppice with standards dominated by beech. Soil aggregate fractions (< 50 µm, 50 – 200 µm, 200 – 2000 µm and 0 – 2000 µm) were incubated in the laboratory for 30 days under controlled temperature (15°C) and moisture (80% of WHC) conditions.

In the three cases (i.e., nF, pB, pS), fractioning of soil samples showed that the fine (< 50 µm) and the coarser (200 – 2000 µm) fractions were the more abundant, whereas total organic carbon content was the highest in the fractions

50 – 200 µm and < 50 µm fractions. The incubation of the total fine earth (0 – 2000 µm) showed that the carbon mineralization rate was always significantly higher for the samples from the spruce plantation and decreased as follows: nS > nF > nB. The incubation of separate aggregate fractions indicated that the biological activity varied with species, and was systematically lower for beech.

The biodegradation of organic matter was also expressed by a decrease of total dissolved organic carbon (DOC) with time. The amount of organic components, such as polysaccharides and phenols, varied with the different fractions species, but the highest quantities of these compounds was always more important for spruce.

For all tree species, mineral water soluble elements (Ca, Mg, Na, K, Mn, Fe, Al,) were more abundant in the < 50 µm fraction. In addition, the mineral content decreased with incubation time.

In conclusion, this study showed that forest species, age and probably disturbance during plantation were some of the important factors influencing soil organic matter biodegradability. Thirty years after plantation establishment, the soil organic matter has undergone considerable changes, including the more stable fractions of the organo-mineral layer. These data indicate the potential impact of forest management on soil properties and sustainability.

Stand Effects on Surface Layer Base Condition in Humic Andosols in Eastern Japan.

Satoshi Sawata[1], Hidemasa Kato[2], Don Nilson[3]

1Akita Prefecture Forest Technical Center, Kawabe-gun, Akita, Japan Graduate School of Agricultural Sciences, Utsunomiya University, Utsunomiya, Tochigi, Japan 3Akita International University, Kawabe-gun, Akita, Japan
e-mail: satosawa.@pref.akita.lg.jp

Abstract

Research was conducted in stands of Japanese Cedar (*Cryptomeria japonica*), Japanese Cypress (*Chamaesiparis obtus*a) and mixed stands of Japanese Cedar and Beech (*Fagus crenata***)** on similar thick humic Andosols in eastern Japan.

In the Japanese Cedar stands, the mass of O horizons remained constant after stands reached 18 years of age. Exchangeable Ca and other bases supplied through the decomposition of tree litter increased rapidly in the surface layer of stands aged 35 years and above. The accumulation rate of exchangeable Ca attained and then maintained a constant level in the soil under stands aged 45 years and above. This increased soil pH and base saturation in the surface layers.

In Japanese Cypress stands, the mass of O horizons also held constant after stands reached 18 years of age. However in Japanese Cypress stands, exchangeable Ca did not accumulate, and soil pH and base saturation were much lower than those in the Cedar stands.

In mixed stands, differences were noted in the amount of Ca accumulated in the soil surface under tree crowns of Japanese Cedar and Beech trees, respectively. Soil pH in the surface layers changed in relation to the base accumulation of the soil. The amount of litter from the Japanese Cedar trees increased at places of higher tree density and both the base saturation of the soil surface and the soil pH also increased likewise. Compared to the case of Japanese Cedar, the soil pH under the tree crowns of Beech trees was found to be strongly acidic. Although there was much organic material supplied to the soil from tree litter, the level of base saturation was not found to increase as much as expected under these conditions.

Stand composition proved to have significant effect on the base condition of surface soil, and the surface soil beneath Japanese Cedar tended to accumulate exchangeable bases.

Differences in phosphorus forms depending on land use and related carbon and nitrogen in two different plateau soils of Palencia (Spain)

Turrión, M. B. [1], Aroca, M. J. [2], López, O. [1] , Lafuente, F. [1], Ruipérez, C. [1] & Mulas, R. [1]

1 Escuela Técnica Superior de Ingenierías Agrarias de Palencia, Avda. de Madrid 57, 34004 Palencia, España – Tel: 34-979-108429 – Fax: 34-979-108301 – email: bturrion@agro.uva.es

[2] Universidad Politécnica de Madrid, Escuela Universitaria de Ingeniería Técnica Forestal.

Abstract

Introduction

Phosphorus may be a limiting nutrient in some forest soils. P availability depends on hydrolysis of organic forms and solubility of inorganic ones. In order to enhance the understanding about P dynamic in two soils of low P levels, characterization of P forms was performed using ^{31}P nuclear magnetic resonance (NMR).

Materials and methods

Two soil types with very different characteristics were selected from Palencia province (central north of Spain). One of them, was a "raña" soil from "acid plateau" at north. The acid soils are classified as ultisols, pH 4.6–5.6 with an argilic horizon, where different sampling points were selected under more frequent agricultural and forestry uses: natural oak forest (*Quercus pyrenaica)*, pine plantation (*Pinus pinaster*), bushwood and rye crop. The other soil from Cerrato calcareous plateaux is characterized by the presence of entisols, pH 7.8-8.4. Samples were from soils under different land uses: natural oak forest (*Quercus ilex)*, pine plantation (*Pinus halepensis*) and agricultural land: barley. Soils were sampled at 2-5cm, 10-15, 20-25 and 30-35 cm depths.

To characterize soil phosphorus ^{31}P NMR was used, after NaOH-EDTA extraction (Cade-Menum and Preston, 1996), with peaks assignments according to Turner *et al.* (2003). This technique is used to obtain quantitative and qualitative information about different forms of inorganic and organic phosphorus: orthophosphate, pyrophosphate, monoester, phospholipids, nucleic acids and phosphonates.

Results

Amount of organic C, as average values of different uses and depths, had similar values in both soils. But N percentages were higher in Cerrato than in Raña soils, so C/N values were higher in Raña soils. In both soils amount of N and C was highest in oaks, but not statistically significant except for agricultural land. C/N values were higher in pine and increased clearly with depth in Raña than in Cerrato soils.

P-NMR forms of the alkaline extract differed between both soils. All P-NMR forms were higher in Raña soils, except phospholipids with similar values in both soils. As percentage, inorganic forms predominate in Raña soils (55%) as against Cerrato soils (23%). This was marked by orthophosphate P and monoester P as main forms. Raña soils had higher inorganic pyrophosphate P percentages than Cerrato soils (4.9 / 2.5) and lower phospholipids P % (1.1 / 4.0) but higher nucleic acids P % (5.6 / 4.0). These differences were high when compared to monoester P.

Ortho-P/monoester-P ratio was higher in pine than in oak soils of Raña, but there was no difference between them on Cerrato soils. In Raña soils nucleic acids P/monoester P ratio was highest for pine and no differences were found among rest of uses. These higher values for the acid soils and for pine sites could be due to low mineralization of organic compounds and at the same time faster stabilization as less mobile inorganic forms may occur. In Cerrato soils this ratio was higher for pine than oak soil but it was not statistically significant.

No significant differences were found between P forms with depth, except in Ortho P/monoester P ratio for Cerrato soil where it decreased with depth.

Conclusions

Soil phosphorus analysis by ^{31}P nuclear magnetic resonance was found useful to detect differences in dynamics of P cycle of different soils and land uses. These differences could be better explained involving other soil properties and nutrients.

References

Cade-Menum, B.J. and Preston, C.M. (1996). A comparison of soil extraction procedures for ^{31}P NMR spectroscopy. Soil Science 161: 770-785.

Turner B.L., Mahieu, N. and Condron, L.M. (2003). Phosphorus-31 nuclear magnetic resonance assignments of phosphorus compounds in soil NaOH-EDTA extracts. Soil Sci. Soc. Am. J. 67: 497-510.

Quality of forest soils from Ponte Vedra Provence (Spain)

Vega, F.A., Covelo, E.F., Andrade, L., Marcet, P.

Departamento de Biología Vegetal y Ciencia del Suelo. Universidad de Vigo. Las Lagoas. Marcosende 36200 Vigo. España. Tel: 986 812630; Fax: 998812556. e-mail:florav@uvigo.es.

Abstract

Environmental degradation caused by unsuitable land use is a worldwide problem that has revived the issue of sustainability (Pierce and Larson, 1993; Hebel, 1998). During the last decade, a **soil quality** concept has emerged that considers the **soil**'s capacity to carry out its functions of biological production, environmental protection, and human health sustenance (Doran and Parkin, 1994; Herrick, 2000). Several studies have assessed **soil quality** indicators in forest **soil**s**.** Pennock and van Kessel (1997) evaluated the effect of clear-cut harvest practices on forest **soil**s and established that although there was a decline in **soil quality** attributes, the values were within the natural or undisturbed range, except for soil organic matter, which had declined below the natural range.

The research sites were in the south of the Pontevedra province (Galicia, Spain). This zone has various natural environments containing managed forest **soil**s. The objective of this study is to examine from an environmental perspective the **soil quality** under the various land uses in this zone. It is our hope that this approach will provide information concerning the effects of land use on **soil** properties and processes whereby land use distribution can be optimised for improving ecological **soil** functions.

A field judgement sampling was performed. Twenty-one sample points were selected from a previous **soil** survey to represent different land uses, soils, vegetation, and parent matter with similar relief, and climate. The **soil**s were Humic umbrisols (12 samples), Dystric regosols (3 samples), Humic Acrisols (3 samples), and Eutric regosols (3 samples). At each sample point, a **soil** pit was dug to determine the depth of the **soil** horizons and to carry out discrete depth sampling by natural horizons. Intact cores in density cylinders and bulked samples were collected. **Soil** horizon samples were air dried, and, in the case of bulked samples, crumbled and sieved through a 2-mm screen and homogenized in a vibratory homogeniser for solid samples and five subsamples from the composed sample were taken for the analyses. **Soil** analysis was carried out on the sieved fraction. The samples were analysed for particle size distribution,

density, porosity, pH, nitrogen, organic carbon, effective cationic exchange capacity (CECe), exchangeable cations, and iron, aluminium and manganese oxides. A mineralogical analysis of the fraction <2 μm has also been performed.

Because of our special interest (Henderson, 1995), the **soil** organic matter was studied by the humid sieving procedure proposed by Andriulo et al. (1990) and Galantini et al. (1994), which facilitates the obtaining of humified organic matter, and non-humified organic matter contents. In each case, measurements were made in triplicate at each sampling area; results presented are the means of the values obtained for each area. The data obtained in the analytical determinations was treated statistically using the programme SPSS version 10.1 for Windows. ANOVA and test of least significant difference (LSD) were made.

Several common quantitative **soil** characteristics directly related to the ecological functions of environmental protection of the **soil** were used as indicators to infer **soil quality** (Doran and Parkin, 1996; Brejda et al., 2000; Singer and Ewing, 2000). For selected A horizon samples, the texture and porosity, the **quality** of the **soil** organic matter, the soil acidity, aluminium saturation percentage, nitrogen content, and exchange bases were considered.

Humic Umbrsols soils, under *Quercus robur* L.*,* and *Castanea sativa* Mill. *,* lacked any nutrient limitation due to the acidity, since the aluminium saturation percentage was less than 50%. All other soils had low N, K; Mg and Ca contents mainly Dystric regosols and Eutric regosols those in addition, had the lowest organic matter contents of all studied soils (9.3 to 32.3 mg kg^{-1}).

The most important factors determining the quality of the studied soils were the parent matter and their management, mainly the vegetation developed on these soils. The soils under *Pinus pinaster* Ait., and *Eucaliptus globules* Labill., have lower quality than those under *Castanea sativa* Mill*.,* and *Quercus robur* L.

The soils developed on alluvial quaternary sediments and on granite have low quality, according to the used indicators.

References

Brejda, J.J., T.B. Moorman, D.L. Karlen, T.H. Dao. 2000. Soil Sci. Soc. Am. J. 64:2115–2124.

Doran, J.W., and T.B. Parkin. 1996. *In* J.W. Doran and A.J. Jones (Ed.). SSSA Spec. Publ. 49. SSSA ASA, Madison, WI. 25–37

Doran, J.W., T.B. Parkin. 1994. *In* J.W. Doran et al. (Ed.) SSSA Spec. Publ. 35. SSSA ASA, Madison, WI, 3–21.

Hebel, A. 1998. *In* H.P. Blume. (ed.) Adv. GeoEcol. 31. Catena Verlag, Reiskirchen, Germany. 1–2

Henderson, G.S. 1995. *In* McFee, W.W., Kelly, J.M. (Eds.). Soil Sci. Soc. Am., Madison, WI, 419–535.

Herrick, J.E. 2000. **A**ppl. Soil Ecology 15:75–83.

Pennock, D.J., C. v**a**n Kessel. 1997. Geoderm**a** 75:13–32

Pierce, F.J., W.E. L**a**rson. 1993. *In* J.M. Kimble (ed.) USD**A**, Soil Conserv **at**ion Service, N**at**ion**a**l Soil Survey Cen**t**er, Lincoln, NE. 7–14

Singer, M.J., S.**A**. Ewing. 2000. *In* M.E. Sumner (ed.). CRC Press Inc., Boc**a** R**at**on, FL.

Assessement and characterization of the forest litter in the region of El-Kala (N. E. Algeria)

Zanache H. and Benslama M.*

** Laboratoire de Biologie Végétale et Environnement, faculté des Sciences Université Badji Mokhtar Annaba. B.P12, 23000 Annaba Algérie Tel/Fax : 00 213 38 87 27 55 E-mail : Zanachabiba@ yahoo.fr*

Abstract

For the assessment and the characterization of the seasonal production of the litter, we selected three forest stands (cork oak, maritime pine, glutinous alder), situated in the region of EL-KALA. Distribution of sampling sites covered all geomorphologic situations, geological and especially the plant formations. The quantitative assessment of the seasonal production of the litter collected at different sites showed that the maximum amount of fall was observed in winter for cork oak and glutinous alder, whereas for maritime pine it was in summer. The rate of decomposition in the three stands was influenced by the old litter. Quality of the litter fall on the three sites differed affecting their decomposition.

The mineral composition of the litter varied depending upon litter component and season, total litter production, shrub stratum and an intense biological activity. These are preliminary results due to the absence of any reference stands in this region.

Plenary session 5 « HYDROLOGICAL CYCLES »

Forest Management and its Impact upon Hydrological Processes and Water Quality

Herbert Hager

Department of Forest and Soil Sciences; University of Natural Resources and Applied Life Sciences;
BOKU Wien; Austria

Abstract

For more than a century the influence of forests on the water cycle in a landscape was the focus of hydrological research and the topic of many, sometimes controversial, discussions. The classical forest hydrological research of Engler and later Burger in the Swiss Emmental region at the beginning of the 20th century elucidated the influence of forests upon seasonal as well as event based runoff response of watersheds. Since then many research efforts have contributed to the understanding of the hydrological processes, their interaction with forest vegetation, and especially, how the management of forest vegetation may influence the routing, the consumption and storage of water in the forest ecosystem.

All forest management decisions, starting from the selection of site specific tree species to the thinning and harvesting practices, influence interception storage and evaporation from the canopy and from the forest floor layer. There is a clear relationship between leaf area index (LAI) and interception loss, and also the pattern of canopy throughfall, which is dependent upon tree species and their architecture. Since the depth of the forest floor, and thus humus type, is also important for water infiltration, soil water recharge and seepage, any forest management practice affecting forest floor will influence these processes and their magnitude. Water extracting root systems differ with site conditions and tree species, suggesting that species selection influence the recharge of soil water and its extraction pattern and the magnitude of the water storage system in forest soils. Moreover tree species vary in their water utilization efficiency, also called transpiration coefficients. Thus tree species, forest operations and engineering measures have definite impacts upon the hydrological processes.

Thinning and harvesting operations, where heavy machinery is involved would diminish infiltration capacity and increase overland flow. Forest road system also effect hydrological processes, e.g.; the packed road surface increases surface runoff; forest roads in sloping terrain dissect slopes hydrology and especially the interflow. Sites close to the cutoff bank as well as the refill on the valleyside are usually drier than the sites further upslope or downslope.

Biogeochemical cycles in forests, which are also dependent upon tree species, and consequently upon species selection on a site, influence solute chemistry and seepage water quality. Conifers may influence the acid/base balance in soils and thus water quality depending upon the proton buffering of the soil system. Treatments of forest stands like clearcutting or heavy thinning may mobilize nutrients from the forest floor increasing the ionic loads in the soil solution. Similarly fertilization will affect soil solution composition. Selection of N-fixing tree species or the breakdown of nitrophilous vegetation on the forest floor may cause significant acidic pulses in the soil solution and high ionic loads. Simlar effects may be also observed when hardwood sites with deep rooted broadleaf species are changed to shallow rooted conifers. In a polluted environment, a rough and evergreen forest canopy causes high depositions of atmospheric constituents and may result in acidification and enhanced leaching of cations from forest soils. Forest operations, like road building, logging and skidding may produce significant loads of suspended solids in surface waters and thus decrease water quality and the quality of the aquatic environment. Data from case studies will be presented to elucidate some of these issues.

Hydrogeochemical profile balance of forest umbrisols (Sierra de Gata mountais, CW Spain)

Menéndez1, J.F. Gallardo2, J. Saavedra2, and G. Moreno3

(1) Dpto. Física, University Las Palmas, Gran Canaria (Spain), <imenendez@dfis.ulpgc.es>

(2) Consejo Superior de Investigaciones Científicas, Ap.257, Salamanca 37071 (Spain)

(3) University Extremadura, E. I. T. Forestal, Campus Plasencia 10300 (Spain)

Abstract

Three techniques for obtaining soil water (gravitational water with zero-tension lysimeters, and matrix water extracted with both, *in situ* tension lysimeters and *in vitro* pressure chambers) were used to determine the chemical composition of gravitational and matrix water, from the *Ah* and the *BwC* or *C* soil horizons. The study was carried out in three *Quercus pyrenaica* and *Castanea sativa* deciduous forests, located in the "*Sierra de Gata*" (40º2'40'', N; 3º0'50'', W, Spain), with sub-humid Mediterranean climate. Soils are predominantly *Umbrisols*, with a typical *AhBwC* profile. They are moderately acid because of the Paleozoic, acid substrate (greywackes and shales). Relatively high pluviometry and moderate temperatures favour the soil organic matter accumulation. Water samples were analysed for pH, electric conductivity, DOC (TOCA, *Bekman*-315A), major cations (by AAS, *Varian*-1475), minor cations and silica (by IPC, *Perkin Elmer Plasma-II*), and major anions (by ion chromatography, *Dionex* 350). Tension (0.2 MPa) and zero tension lysimeters were collected from the soil horizons during two complete hydrological cycles (1992-1994), every two-weeks. Furthermore, matrix water was extracted from soil samples in duplicate *in vitro* with pressure chambers (1.5 Mpa).

An increase of Si $(OH)_4$ (87 %) and of Al^{3+} (57 %) was found in the drained waters from the *Ah* horizon in relation to the water entering to the soil. This leaching of $Si(OH)_4$ proceeds even in the *Bw* (67 %), but an adsorption of Al^{3+} is observed (-52 %) when the gravitational water cross the latter soil horizon, similarly to that found by Marschner & Kalbitz (2003). This fact explains, at least partially, the formation of gibbsite at this depth in these soils. Macías (1981) considered that Al^{3+} is sequestered by fulvic acids, which later are mineralised and then the Al^{3+} precipitated, giving gibbsite as a result. The water deeply drained has also a noticeable increment in Mn^{2+} (82 %), as a consequence of the reduction in O_2 tension; in fact, small black dots of MnO_2 were visualised at the *Bw* horizons. Also a slight increase of Na^+ and Fe^{3+} (close to 10 %) is observed at this soil depth. DOC concentration decreases through the whole soil profile in both drained (-88 %) and matrix (about -60 %) waters

reflecting C adsorption and/or mineralization throughout soil profile (Gallardo *et al*. 1998).

Tension lysimeter water (obtained *in situ*) from *C* showed an increase of Na^{+} (19 %) and Mn^{2+} (87 %) respecting waters extracted from *Ah* horizons; by contrast, Fe^{3+} content in soil water decreased through the soil profile. This latter result characterizes the edaphogenetic *brunification* process (Gallardo *et al*. 1998), because the free Fe released in the *Ah* is later precipitated as sexqui-oxide in *Bw* horizons.

Matrix water from *C* horizons obtained applying 1.5 MPa showed only a noticeable increase in Na^{+} (>80 %) and $Si(OH)_4$ (>100 %) respecting *Ah* horizons. Matricial waters, with null or very slow circulation, reflect the pseudo-equilibrium maintained with mineral surfaces and as well with soil solution (Sposito, 1981). Obviously, the weathering of silicate rocks favours the increment of $Si(OH)_4$ and Na^{+} contents in matrix waters (Westall & Stum1980). These results indicate that the existence of kaolinite is a result of weathering processes where liberation, enrichments, and losses of silica and bases are occurring in these soils throughout the time. Nevertheless, retention of most of the cations in soil profiles, mainly in *Bw*, shows the efficient adsorption of bioelements in the soil compartment.

References

Gallardo J.F., Cuadrado S., Prat L. 1980. Características de los suelos forestales de la Sierra de Gata. *Studia*

Oecologica, 1: 241-264.

Gallardo J.F., Vicente M.A., González M.I. 1998. Transfer of dissolved organic matter from soil to a stream catchement located at the "*Sierra de Gata*" mountains (Western Spain). In: *Humic substances in*

ecosystems. A. Zaujec, P.Bielek, S.S. Gonet (eds), Slovak Agriculture University, Nitra (Slovakia). 167-172.

Macías, F. 1981. Formation of gibbsite in soils and saprolites of temperate-humid zone. *Clay Miner.*, 16: 43-52.

Marschner B. & Kalbitz K. 2003. Controls of bioavailabity and biodegradability of dissolved organic matter in soils. *Geoderma* 113: 211-235.

Sposito G. 1989. The chemistry of soils. Oxford University Press, New York, 277 pp.

Westall J. & Stumm W. 1980. The hydrosphere. In*: The handbook of environmental chemistry*, Vol.1-A: The natural environment and the biogeochemical cycles. Springer-Verlag, Berlin. 258 pp.

The importance of deep soil layers to supply water to agro-forestry systems: A study case of a mature chestnut orchard in Northern Portugal

Afonso Martins 1, Fernando Raimundo 1, Olga Borges 2, Isabel Linhares 1 , J. Paulo Coutinho 3, J. Gomes- Laranjo 3, & Manuel Madeira 4

[1] Dep. Edafologia, Universidade de Trás-os-Montes e Alto Douro, Ap. 1013, 5001-911 Vila Real Tel. 259 350209; e-mail: amartins@utad.pt

[2] DRATM, Qta do Valongo, 5370 Mirandela

[3] Centro de Estudos da Terra, do Ambiente e da Vida, UTAD, Apart. 1013, 5001-911 Vila Real

[4] Departamento de Ciências do Ambiente, ISA, Tapada da Ajuda, 1349-017 Lisboa

Abstract

Traditional soil management practice in chestnut orchards of Northern Portugal involves several surface tillages during the year to control weeds and to conserve water. During the last seven years several measurements were carried out: soil moisture measurements to 30 cm depth, leaf water potential and biomass productivity, which show that the regular frequent tillages don't provide any advantages to the soil available water and on biomass production when compared with less intense tillage practices, such as no tillage with the retention of natural ground vegetation or no tillage with seeded pasture, under tree canopy. These results led to a recent study where the role of deep soil layers in providing water supply to the trees moisture was evaluated. Using a TDR (Time Domain Reflectometry) device, measurements were done at different depths to 75 cm during dry season. TDR values were compared with moisture values from pF curves for soil samples of the same layers. To assess the water uptake status of trees, predawn values for leaf water potential (w) were measured with a Scholander Pressure Chamber during the same period. Following results were obtained: (i) Soil moisture content in the 0-30 cm layer decreased from the beginning of dry season until the values lower than the wilting point (1500 KPa) were obtained and this decrease was independent of the soil treatments. (ii) Similar situation as for the 30cm soil depth was observed for 75 cm soil depth, whereas it occurred at the middle of the dry season. (iii) At the end of August, the predawn values for leaf water potential (w) sharpely decreased following the soil moisture values. These results corroborate previous results, emphasising the important role of deep layers to supply water to trees. These results also raise the question of the utility of surface tillage for water conservation and reinforce the opinion of the need of

changing the soil management practices in chestnut orchards as a requirement to improve the sustainability and productivity of these agro-ecosystems.

Soil scarification induced nitrate leaching through podzolic soil at a clear-cut area

Piirainen Sirpa[1], Finér Leena[2], Mannerkoski Hannu[2] and Starr Michael[3]

[1]The Finnish Forest Research Institute, Joensuu Research Centre, P.O. Box 68, FIN-80101 Joensuu, Finland, email: sirpa.piirainen@metla.fi

[2]University of Joensuu, Faculty of Forestry, P.O. Box 111, FIN-80101 Joensuu, Finland

[3]The Finnish Forest Research Institute, Vantaa Research Centre, P.O. Box 18, FIN-01301 Vantaa, Finland

Abstract

Forest clear-cutting with soil scarification may increase the leaching of nutrients from the soil leading to soil acidification, degradation of soil productivity and the eutrophication of recipient surface waters. We have been carrying out a catchment-based (Kangasvaara) study in eastern Finland (63° 51'N, 28° 58'E) to determine the effects of current clear-cutting (stem only) and soil scarification practice on site productivity, nutrient leaching and stream and ground water quality (Finer et al., 1997). The old mixed stand dominated by Norway spruce was clear-cut in September 1996, soil scarification was done in September 1998 and planted with Scots pines in June 1999. It was already known that the cycling of N at the study area was very tight before clear-cutting, since the leaching of N below the B-horizon was small (0.1 kg ha^{-1} a^{-1}) and mainly in the form of organic N (Piirainen et al., 1998). After the clear-cutting, some 173 kg N ha^{-1} was left at the soil as logging residues (Finér et al., 2003) there was no net release of N from logging residues in the first 3 years after cutting (Palviainen et al., 2004). In the soil leachates collected at the clear-cut area with no scarification the nitrate (NO_3-N) concentrations increased a little especially in 1999 compared to the uncut forest, but values remained low < 0.4 mg L^{-1} (Piirainen et al., 2002). The hypothesis for this study was that soil scarification will further increase the NO_3-N formation and leaching through the soil explaining the observed increased NO_3-N concentrations in the stream of the study catchment (Ahtiainen et al., 2003).

In this paper, we show the effects of soil scarification on the nitrate concentrations in soil water, groundwater and spring water at a 3-year-period. Two study plots with zero tension lysimeters were established on the clear-cut area after the soil scarification in 1998. The soil was classified to a Haplic Podzol. Soil water from below the organic (O), eluvial (E) and illuvial (B)

horizons at the mound, at the undisturbed soil and from below the E- and B-horizons at the furrow were sampled once a week from spring to autumn. Spring water and groundwater from a well, both located at the bottom of the clear-cut and scarified slope, were sampled twice (spring) or once (groundwater) a month. In the first year after soil scarification there were no differences in soil leachates NO_3-N concentrations between mounds, furrows or unscarified soil and the annual average concentrations were <0.4 mg L^{-1} from below the O-, E-, or B-horizons. High average concentrations of NO_3-N (maximum 1.2 mg L^{-1}) in soil leachates were observed in 2000 and 2001 and the concentrations were the highest below the mounds, but increased concentrations were observed also below the furrows compared to undisturbed soil. Nitrate concentrations were higher from below the mineral soil horizons than below the O-horizon. In ground and spring water NO_3-N concentrations (average 1.04 mg L^{-1}) were highest in 2001.

The N mineralization and also nitrification were probably enhanced in the mounds with double organic layer thus the NO_3-N concentrations in the soil leachates beneath them were higher than in the soil water beneath furrows or undisturbed soil. The increase in groundwater and spring water NO_3-N concentrations were delayed one year. If we assume that the water flux below the B-horizon was 5% of the bulk precipitation amount (Piirainen et al., 2002), the NO_3-N flux below the B-horizon was 0.26, 0.21 and 0.05 kg ha^{-1} a^{-1} at the mounds, furrows and unscarified soil in 2000. Since the mounds covered 25% and the furrows 30% of the area the NO_3-N flux from below the B-horizon of the whole clear-cut and scarified area increased to 0.15 kg ha^{-1} a^{-1}.

References

Ahtiainen M, Finér L, Haapanen M, Kenttämies K, Mattsson T and Rämö A 2003 Näkyvätkö hakkuun ja maanmuokkauksen vaikutukset valumaveden laadussa - tehoavatko ympäristönsuojeluohjeet? Finn. For. Res. Inst. Res. Pap. 886, 25-33 (in Finnish).

Finér L, Ahtiainen M, Mannerkoski H, Möttönen V, Piirainen S, Seuna P and Starr M 1997 Effects of harvesting and scarification on water and nutrient fluxes. Finn. For. Res. Inst. Res. Pap. 648, 38.

Finér L, Mannerkoski H, Piirainen S and Starr M 2002 Carbon and nitrogen pools in an old-growth, Norway spruce-mixed forest in eastern Finland and changes associated with clear-cutting. For. Ecol. Manage. 174, 51-63.

Palviainen M, Finér L, Kurka A-M, Mannerkoski H, Piirainen S and Starr M 2004 Decomposition and nutrient release from logging residues after clear-cutting of mixed boreal forest. Plant and Soil (in print).

Piirainen S, Finér L, Mannerkoski H and Starr M 2003 Effects of forest clear-cutting on the carbon and nitrogen fluxes through podzolic soil horizons. Plant Soil 239, 301-311.

Piirainen S, Finér L and Starr M 1998 Canopy and soil retention of nitrogen deposition in a mixed boreal forest in eastern Finland. Water, Air, and Soil Pollut. 105, 165-174.

Use of micro-cups to sample soil solution and application to forest ecosystems

Mark Bakker[1], Marie-Pierre Turpault[2] & Gilles Nourisson[2]

1 INRA-Bordeaux, UMR TCEM, INRA-ENITAB, 71 av. Edouard Bourlaux - BP 81, 33883 Villenave d'Ornon cedex, France

[2] INRA-Nancy, Equipe Biogéochimie des Ecosystèmes Forestières, 54280 Champenoux, France

Abstract

Micro-cups as developed by Göttlein in Germany in the 1990's (Göttlein *et al.* 1996) have the advantage of sampling soil solution in high spatial resolution with minimal disturbance. They potentially permit the monitoring of soil solution in the vicinity of tree roots and could as such contribute in our understanding of forest tree nutrition and its whereabouts in time and space. However, their application in the field needs to be developed to overcome many practical problems and to relate the results to existing methods in soil solution studies. We used these micro-cups at two different field sites in France and compared several forest plots differing in species or fertiliser treatment. Our contribution aims at presenting some methodological aspects and a selection of results obtained by the micro-cups.

Reference:

Göttlein A, U Hell & R Blasek (1996) A system for microscale tensiometry and lysimetry. Geoderma 69: 147-156

Persistent nitrate leaching after bark beetle attack in the unmanaged zone of the highlands of the Bavarian Forest National Park

Christian Huber[1]_

Manuela Baumgarten, Axel Göttlein, Verena Rotter

Fachgebiet Waldernährung und Wasserhaushalt, TU-München, Am Hochanger 13, D 85354 Freising, Germany
(Huber@forst.tu-muenchen.de)

Abstract

A dramatic outbreak of bark beetle infestation, which is unique in its dimensions in Europe, occurred during the last decade in the Bavarian Forest National Park causing the death of almost all trees of the mountainous spruce forest in the unmanaged areas.

Since 1999 we have investigated the elemental cycling of intact spruce ecosystems and dead wood ecosystems in the highlands with different time spans after bark beetle attack. The main objective of this study is to determine the duration of the nitrate pulse, and to quantify nitrate concentrations and fluxes. In a chronosequence we investigated the elemental concentrations in seepage water of intact stands, and of dead wood stands from the beginning of the die-back ("year 0") to the 9th year after the "die-back", and for later years (16 to 20 years after the "die-back").

The intact stands in this region are probably N-saturated. However, lower nitrate concentrations were determined in our investigation (approx.30 µmolc l^{-1}) than in an earlier study of an intact stand. Few months after the "die-back" of the stands, NH_4^+ concentrations had increased in humus efflux and NO_3^- concentrations in the mineral soil. The nitrate pulse lasted for a long time. Even 9 years after the "die-back" elevated nitrate concentrations were found, however significantly increase from year 1 to year 5 compared to intact stands. Average NO_3^- peak and flux weighted concentrations remained usually below the European level of drinking water (50 mg l^{-1} = 806 µg NO_3^- l^{-1}) due to the dilution effect of the high precipitation in the area. Lowest concentrations were usually determined after the snow melt and the highest concentrations in autumn. Five years after the die-back the highest average NO_3^- concentrations were determined (1100 µmolc NO_3^- l^{-1}). During the next years the concentrations were reduced from year to year. In later years (16 to 20 years after the die-back) nitrate concentrations reached very low values, mostly below

the values of the intact stands. No relevant net uptake of N by ground vegetation was observed during the first 7 years after the die-back. However on plots uncovered by vegetation, and mulched with slash significantly higher NO_3^- concentrations were detected from year 2 to year 5 than on plots with full coverage by vegetation. Part of the observed heterogeneity in nitrate could be attributed to these patterns. The consequences of these changes for the hydrosphere and the elemental supply of the soil are discussed in the presentation.

Effect of land use on the soil water dynamic in dehesas of CW Spain

G. Moreno and E. Cubera

Universidad de Extremadura. Avda. Virgen del Puerto. 10600 Plasencia, Cáceres, Spain.

gmoreno@unex.es

Abstract

Joffre and Rambal (1993) reported that water balance between two components of the dehesa (grass and tree) indicated a clear influence of the tree on the water dynamic. Similarly Cubera *et al.* (2004) reported a certain dependence of the trees on the water located beyond the tree cover. On the other hand, Joffre *et al*. (1999) have shown that at a regional scale the mean tree density in dehesas depended on the mean annual rainfall. These studies refer to dehesas with the combination of native grasses with scattered trees. However, in dehesas different structures of vegetation are found as a consequence of a combination of land use: i) oak tree intercropped with cereal (*C*), ii) oak tree with native grass vegetation (*G*), iii) oak tree with abundant understory (*M*), and iv) dense forest (*F*).

We have studied how soil water dynamic is affected by the vegetation structure at four holm oak *Quercus ilex* dehesas in Central-Western Spain. Soil moisture was studied at different distances from the tree trunk (2.5, 5, 10, 20 and 30 m), from the soil surface until a maximum depth of 2 m, in intervals of 20 cm, in four trees per plot (*C*, *G*, *M* and *F*). Measurements were made monthly by Time Domain Reflectrometry technique (TDR) during May 2002 to April 2003. Additionally we have studied the water status of trees and photosynthetic rates during the summer drought.

Soil moisture (θ) in the *M* and *F* plots was significantly lower than in *C* and *G* ones (Figure 1), indicating possible competition between trees and shrubs for soil water. Differences between *C* and *G* plots and between *M* and *F* were not significant. Soil water depletion continued at any distance even after the herbaceous plants had dried up (Figure 2), indicating that trees could use water from beyond the canopy, implying clear benefits from tree spacing on soil water consumption. Nevertheless, θ remained significantly higher in *C* and *G* plots than in *M* and *F* ones in summer, indicating that scattered holm-oak trees could not absorb all the available water, probably due to low root length density of the holm-oaks (Obrador *et al*., 2003).

Holm-oaks tress in dehesa showed very high water potential during summer regardless of the vegetation structure (Figure 3), with values quite far of the thresholds of water potential for significant stomatal closure (Salas,1999).

This indicates a high dependence of holm-oaks on deep water reserves throughout late spring and summer, which contributes to avoiding competition for water between trees and herbaceous vegetation. In fact, Obrador *et al*. (2003) found roots of holm-oak to about 500 cm depth in these sites. Only the competition among trees (in F plots) seems to impose a certain degree of water stress to holm-oak trees.

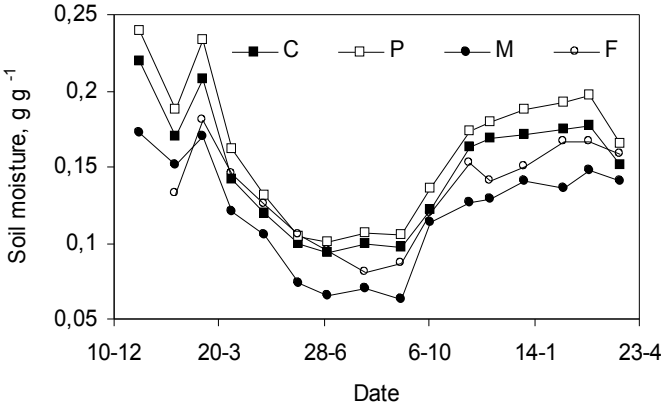

Illustration 1: Seasonal evolution of soill moisture, averaged for the whole profile (1 m), in dehesas plots differing in vegetation structure.

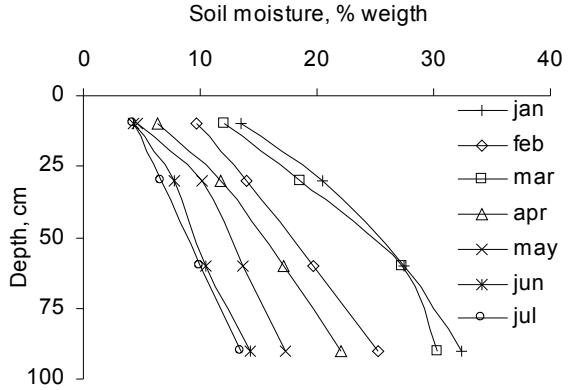

Illustration 2: Seasonal evolution of soill moisture, averaged for the whole profile (1 m), in dehesas plots differing in vegetation structure.

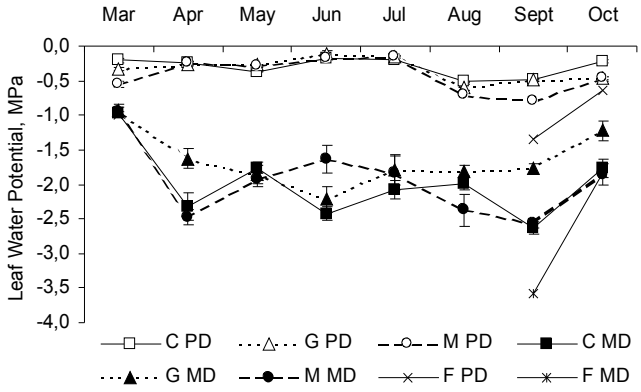

Illustration 3: Seasonal evolution of leaf water content (predawn and at midday) in holm-oaks in dehesa plots with different vegetation structure. Its is observed that even in M plots trees show a good hidric status along the summer (quite far of –1 and –4 MPa for predawn and midday water potential, respectively, according to Sala 1999). Only F plot seems show a certain degree of water stress.

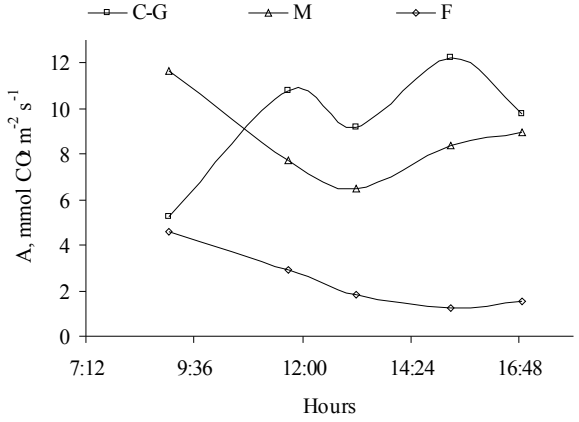

Illustration 4: Seasonal evolution of CO2 accumulation rate in holm-oaks in dehesa plots with different vegetation structure. It is observed a very significant decrease in A with the increament of woody vegetation in dehesa (F < M < C = G).

Porosity and available water of temporarily waterlogged soils in a Quercus robur (L.) declining stand

Vincke Caroline*, Delvaux Bruno**

** Unité des Eaux et Forêts, Croix du Sud, 2/9, 1348 Louvain-la-Neuve, Belgique*
Tel : + 32 10 47 37 05 ; Fax : + 32 10 47 36 97 ; e-mail : vincke@efor.ucl.ac.be
*** Unité des sciences du sol, Croix du Sud, 2/10, 1348 Louvain-la-Neuve, Belgique*

Abstract

Since the mid-1980's, pedunculate oak (*Q. robur* L.) decline has been reported in Belgium forests as well as in other European countries. Although oak trees are drought-tolerant species, repeated and/or intense long lasting drought can be a major inciting factor in oak decline. In Atlantic temperate areas, climatic drought is an accidental and unpredictable event and permanent soil characteristics can induce seasonal (edaphic) droughts.

In this paper, we determined the porosity and water properties of temporarily waterlogged clayey soils supporting forest stands of declining 101 years old Quercus robur trees in Belgium (50°06'N, 4°16'E). Our study is aimed at (i) determining water supply to oak by coupling EW measurement with detailed root distribution, (ii) assessing soil mechanical constraints to oak roots. The experimental design consisted in two plots differing in stem density. Besides pedunculate oak, other broadleaved species are present, among which *Acer pseudoplatanus* L., *Fraxinus excelsior* L., *Quercus rubra* L. An important herbaceous cover includes *Circaea lutetiana* L., *Carex pendula* Huds. and *Rubus fruticosus* L.

Measurements were organized *in situ* and in the laboratory over the 1999-2001 period. Soil morphology and tree rooting profiles were measured on the vertical faces of trenches (one per plot) at the end of May 2000. Soil gravimetric water content was measured regularly during year 2001 et the level of the temporary water table was measured by piezometers (1999-2001). Tree water status was estimated by the measurements of predawn leaf water potential (twice in 2001) and foliar transpiration (semi-hourly, during the 1999-2001 period). Physico-chemical and mineralogical properties were measured for each horizon, as well as X-ray mineralogy. The porosity and water properties were measured by establishing in the laboratory the water retention curves on undisturbed soil samples (5-6 cm^3).

The root system colonized the soil down to 160 cm, with two pools of fine roots (diameter < 5 mm) located in the surface (0-30 cm) and around 130 cm deep, despite the clayed horizons appearing at 35 cm depth. Effectively, clay content below 30 cm depth reached 46 - 51% of soil textural units and X-ray diffraction demonstrated a dominance of illite and vermiculite, the latest being

an expansive clay. The deepest horizons demonstrated strong shrink-swell properties and strong hypoxy: bulk density increased from 1.38 to 1.8 g cm^{-3} at field capacity from surface to 200 cm deep as well as the water saturation of pore space (always above 80%, whatever the moisture tension).

Extractable water in the rooting zone was calculated to be 152.8 mm, between moisture tension of 5 kPa (field capacity) and 1600 kPa (wilting point). Yet, intra-annual modifications of EW could be induced by the fact that the effective, functional rooting depth is probably not static within a season. The level of the perched temporary water table depends on the seasonal rhythm of water uptake by plants (transpiration) and on the shrink-swell behavior of clay material. The mechanical constraints for oak roots are mainly dependent upon shrinkage (the contact between roots and soil can be broken) and swelling, which induces morphological features such as flattened roots, clumped and pasted on clod faces and demonstrating anoxic constraints (purplish to blackish colors).

Plenary session 6 « DISTURBANCES AND SITE RESTORATION »

Characteristics and effects of ecosystem disturbance and consequences for site restoration

Reinhard F. Hüttl* and Oliver Bens

Chair of Soil Protection and Recultivation and Research Center Minesite Recultivation; Brandenburg University of Technology; P.O. Box 101344; D – 03013 Cottbus

** Email Prof. Dr. Dr. h. c. Reinhard F. Hüttl: huettl@tu-cottbus.de*

Abstract

Disturbance of forest sites may occur naturally (e.g. fire, earth quake, volcanism) or anthropogenically (e.g. air pollution, mining activities).

Clearly a very dramatic disturbance is caused by open cast mining measures as this impact does not only destroy forest stands but also causes a complete devastation of soil and the underlying geological parent material. As is known from ecological studies, specific disturbance effects and respective restoration measures are best studied under severe conditions. Therefore, as a case study from our investigations into the disturbance effects of open cast mining and related restoration measures as prevailing in the Lusatian lignite mining district being a typical forest landscape will be utilized.

As this mining district is one of the largest world wide, with an area of 2,500 km² being impacted by effects of open cast mining, restoration measures are not only studied on an ecosystem basis, but on the level of entire landscapes. Therefore, specific methods for scaling up from site to the landscape level are part of this ongoing comprehensive research project addressing the following objectives:

- analysis of the impact of anthropogenic disturbance at the ecosystem and landscape level,
- analysis of ecosystem and landscape development after anthropogenic disturbance, and
- evaluation of rehabilitation options in manmade landscapes for the establishment of ecosystems after severe disturbance.

In this context, unknown physico-chemical, biological and eco-physiological interactions are studied. Using these results, models for major land use sectors are developed and integrated at the watershed scale. Alternative land use scenarios are set up and evaluated in an interdisciplinary effort. This knowledge is a prerequisite for decision support tools to be developed by both researchers and managers to facilitate sustainable land use management after anthropogenic disturbance.

Does inclusion of N-fixing trees in eucalypt plantations increase soil C sequestration?

Jürgen Bauhus[1,2], Amber Pares[2,3], Christopher O'Hara[2,4], David Forrester[2] and Partap K. Khanna[5]

[1]Silviculture Institute, University of Freiburg, Tennenbacherstr. 4, 79085 Freiburg, Germany; [2]School of Resources Environment & Society, Australian National University, Canberra, ACT 0200, Australia;.[3]Botanic Gardens Trust, Mrs Macquaries Road, Sydney, NSW 2000, Australia; [4]Ministry of Defence, Canberra, Australia; [5]Institute of Soil Science and Forest Nutrition, University of Göttingen, Büsgenweg 2, 37077 Göttingen, Germany.

Abstract

Worldwide there is growing interest in the use of tree plantations for carbon sequestration. In this study we investigated whether soil organic carbon (SOC) sequestration in eucalypt plantations can be increased through inclusion of N-fixing acacias. Previous research in mixed eucalypt-acacia plantations demonstrated that aboveground C was higher in mixtures than in respective monocultures. Here we determined the amount of soil organic carbon stored in the top 30cm of soil in a 10 years old plantation consisting of different mixtures of *Eucalyptus pseudoglobulus* and *Acacia mearnsii.* The different combinations of species ranged from pure eucalyptus (E100) to pure acacia (A100) and included species mixtures of E75:A25, E50:A50; E25:A75 (where the figure following the species code represent the percent contribution of a species to tree numbers). Samples were also collected from a fertilised mono-culture of *Eucalyptus pseudoglobulus* and from the surrounding native forest area, which represented ecosystem conditions prior to plantation establishment. Total organic C, and total N were determined at two depths (0-10cm and 10-30cm), across three micro-sites (trench, mound and flat) formed during site preparation. To relate soil organic matter stocks to inputs and decomposition, litterfall and litter mass were monitored over a 2-year period in the range of mixed-species stands. In addition, a physical fractionation of the sand-sized (63-2000 µm) soil organic matter was carried out to separate different densities (light = floating in water, < 1g, medium = floating in Ludox, 1-1.3 g, and heavy = sinking in Ludox >1.3g). These density fractions of organic matter are assumed to represent material of different stability. This density fractionations were carried out for the surface soils (0-10 cm) from the E100, A100 and E50:A50 stands.

SOC was highest in the 50:50 mixture of eucalytps and acacias. It was found that quantities of SOC were related to aboveground productivity, but not related to the percent acacia in mixtures. The mixtures E25:A75 and E50:A50

also stored significantly more soil C than the surrounding native forest. In addition, N fertilisation of pure eucalypt stands did not increase SOC when compared to the unfertilised stand. Higher SOC in mixtures is also reflected in litterfall, which was highest in the E50:A50 stands and lowest in E100. The average forest floor mass decreased from 7300 kg ha^{-1} in 100E to 3500 kg ha^{-1} in 100A. The resulting decay constant of litter decomposition in 100A was more than twice as high as in 100E, indicating a more rapid respiration of litter-C or faster incorporation of litter-C in the mineral soil with increasing proportions of acacias. A faster incorporation of C in the mineral soil is supported by higher organic matter concentrations and thus less advanced decomposition in the light and heavy fractions in mineral soil under 100A when compared with 100E and 50A:50E. The concentrations of N in the light, medium and heavy organic matter fractions increased with increasing proportion of acacias, which corresponds with the higher quantities of N cycled under acacia than eucalypt. However, there was no consistent pattern for the quantities of N stored in the 0-30 cm mineral soil under the different mixtures.

Our results indicate that inclusion of acacias in eucalypt plantations may provide means to increase SOC and to compensate for any SOC losses that may occur as a result of site preparation. Increased C sequestration in mixed stands is partly attributed to increased aboveground productivity and also to the increased incorporation and stability of soil organic matter fractions derived from acacia litter.

Biodiversity and biomass of understory vegetation in a *Eucalyptus globulus* Labill. coppice as affected by slash management

Marta Carneiro, António Fabião, Maria C. Martins, Cláudia Cerveira, Conceição Santos, Carla Nogueira, Mário Lousã, Manuel Madeira & André Fabião

Instituto Superior de Agronomia, Tapada da Ajuda, P-1349-017 Lisboa, Portugal, email: mcarneiro@isa.utl.pt

Abstract

Effects of different options of harvesting debris management on biodiversity and biomass of understory vegetation in a *Eucalyptus globulus* coppice were assessed through a field trial installed in March 1993, after tree harvesting. The experimental area was installed at Quinta do Furadouro (close to Óbidos, in West Central Portugal), where Dystric Cambisols derived from Cretacic sandstone are the dominant soil unit. The mean annual rainfall averages about 600 mm, with less than 10% between May and September; mean annual temperatures reaches 15.2ºC. The experiment consisted of four treatments in a coppice area with five replicates, following a randomised block design. Treatments were: removal of slash (R), broadcast of slash over the soil surface (S), broadcast of slash as in treatment S, but with woody residues concentrated between tree rows (W), and incorporation of slash into the soil by harrowing up to 20 cm depth (I). Each experimental plot measured 18 × 18 m and was surrounded by a buffer strip 6 m wide.

Surveys of vegetation were performed during the first 6 years after coppice (by the quadrat method) and in the 9th and 10th years (by the line interception method). Tree height was measured during the experiment period and, after the 2nd year, diameter at breast height was also measured. Basal area and timber volume were estimated from those data, the latter only from the 5th year onwards. The average number of species per treatment plot and the proportion of soil cover for plant species were estimated, and the Shannon-Wiener diversity and equitability indexes determined for each treatment and year. The understory vegetation was randomly sampled for aboveground biomass measurement from the 2nd to the 6th years, as well as in the 9th and 10th years.

The removal of slash gave the highest number of species in most years (with an occasional exception in the 3rd year, when the highest score was in treatment I). The lowest number of species occurred in different treatments (S-I) along the experiment. However, the differences between treatments were statistically significant ($p<0,05$) in the 2nd, 3rd and 9th years. Soil cover (in

proportion of total plot area) was usually highest in treatment R, except in the 1st and 5th years, when treatment I obtained the highest values, and in the 6th year, when the highest soil cover occurred in treatment W. The lowest values occurred mostly in treatment S, except in the 6th year, when treatment I had the lowest proportion of soil cover. Differences in the proportion of understory soil cover between treatments were never statistically significant. Species diversity was not clearly affected by treatments: significant differences between treatments only occurred occasionally (in the 3rd year) and were apparently related to differences in the number of species. Thus, differences in the equitability index between treatments were never significant.

Biomass of understory vegetation did not decrease along the experimental period, and was usually highest in the treatments R or I (the latter in the 2nd and 5th years), and lowest in the treatment S, but differences between them were not significant. Broadcast of slash over the soil surface tended to inhibit the development of understory vegetation, leading to the lowest number of species during the first 3 years of the experiment, and to the lowest proportion of soil cover during most of the experimental period. However, differences between treatments only were statistically significant for the number of species in the 2nd and 3rd years, respectively between treatments S and R, and between S and all the other treatments. Tree growth did not show any clear effect of treatments. The estimated timber volume was consistently highest in treatment S, followed by I, during the last 5 years of the experiment, but differences were not statistically significant.

Most of the significant effects were observed during the first half of the experiment period. At the end of the experiment the biodiversity and biomass of the understory vegetation were apparently independent of the treatments. Removal of harvesting residues did not show significant negative effects on tree growth and timber production, and did not lead to a significantly higher biodiversity and biomass of the understory vegetation. Results suggest that slash removal do not necessarily have negative effects on production or vegetation biodiversity, but such conclusions should consider site specificity.

Site restoration by gmelina *arborea* stands grown as monoculture and agrisilviculture system in Central India

Sunil Puri and S.L. Swamy

Department of Forestry, Indira Gandhi Agricultural University, Raipur (C.G.) 492 006

Email : spuri56@yahoo.com

Abstract

India is the second largest country in Asia to raise plantations and has renewed its interest as part of global and national policies to rehabilitate the degraded lands, which almost cover 175 million ha. This large tract of degraded land has potential and could become crucial in national and global efforts to enhance carbon sequestration. Both agroforestry and tree plantations have strong potential for sequestering carbon. It is postulated that the land management practices such as agroforestry and monoculture tree plantations have different impacts on development of degraded lands, especially on soil organic matter and nutrient pools. The repeated tillage and land preparation operations in agroforestry for growing inter crops increase the rate of decomposition of organic matter that could reduce the soil carbon, whereas the C accumulation in undisturbed soils of monoculture plantations will significantly increase over a period. Two contrasting hypotheses exist regarding the effects of soil resources on biomass and nutrient allocation patterns: differential allocation and constant allocation. The present study attempts to test these hypotheses in plantations on degraded land. Moreover, understanding of allocation patterns of carbon and nitrogen for a given species in relation to site quality and land use becomes crucial to devise site specific management practices for maximizing biomass and carbon storage. We, therefore, investigated allocation patterns of carbon and nitrogen in monoculture and agroforestry plantations of *Gmelina arborea* on wastelands and abandoned agricultural lands. The study was conducted at two sites at Chhattisgarh, Central India. The site 1 is located at Forestry Research Farm of Indira Gandhi Agricultural University, Raipur (latitude 21^{o}12'N and longitude 81^{o}36'E), while site 2 is situated at Kusumi village of Durg district (latitude 21^{o}76'N longitude and 81^{o}40'E). The site 1 was an abandoned agricultural land, which was not cultivated for the last five years. The site 2 was a barren wasteland, lying fallow unutilized for the last few decades.

Tree growth, biomass, carbon storage and nitrogen allocation patterns were compared in three stands of *Gmelina arborea* (Linn.). Monoculture stands were planted on abandoned agriculture land and red lateritic wasteland, whereas agrisilviculture system was established on abandoned agriculture land. Stands

were planted at 4m x 4 m spacing in July 1998. Stand type and age significantly influenced tree growth (dbh, height and crown length), biomass production and carbon storage. At 5-year age, total stand biomass ranged from 10.4 to 21.7 Mg ha^{-1}. Monoculture stands on abandoned agricultural lands had 52.2% and 35.2% higher biomass than on red lateritic wasteland and agrisilviculture system. For mean total standing biomass (15.4 Mg ha^{-1}) at five years age, leaves, stem, branches and roots contributed 3.9%, 66.2%, 9.1% and 20.7%, respectively. Carbon (C) concentration was highest in stem (44.1-45.7%) followed by branches (44.6-45.3%), roots (42.8-43.5%) and leaves (39.5-40.5%). However, nitrogen (N) concentration followed the order: leaves (1.8-1.9%) > branches (0.31-0.37%) > stem (0.31-0.36%) > roots (0.31-0.34%). Accumulation of C and N increased with plantation age. Total C in trees ranged from 4683 to 974 kg ha^{-1} and nitrogen from 37 to 90 kg ha^{-1} in 5 yr-old stands. Biomass and carbon storage followed differential allocation pattern. Relatively more C was allocated to roots in red lateritic wastelands, while it was higher in above ground components in monoculture stands on abandoned agricultural land. Among 8 crops grown in agrisilviculture system, soybean and cowpea in rainy season while wheat and mustard crops in winter season showed higher yields. Planting of *G. arborea* increased soil organic C by 53%, 15.2% and 5.2%; N by 35.2 %, 6.4% and 66% under monoculture stands on abandoned agricultural land, agrisilviculture system and monoculture stands on red lateritic wastelands, respectively. Total C storage before planting varied from 9371 to 26304 kg ha^{-1}, which enhanced between 32244 to 45770 kg ha^{-1} after 5 years of planting. Net C storage (soil + tree) varied from 1288 to 19486 kg^{-1} with mean annual storage of 2649 kg $ha^{-1}yr^{-1}$. The present studies have demonstrated that growth and biomass of stands were strongly influenced by the land use practice. Monoculture stands contributed higher C and N storage in tree and soil compartments. Regular tillage for cultivation of intercrops in agrisilviculture system might be responsible for low C accretion in the soil. Despite the fact that world over emphasis is given on agroforestry practices, the present studies reveal that monoculture plantations are better for abandoned agricultural lands. Perhaps that may be due to the fact that in present study competitive interactions dominated rather than complimentary interactions.

Changes in Surface Soil Chemistry of Plantations in Japan.

Masamichi Takahashi, Masaki Kato, and Kazuhiro Ishizuka

Forestry and Forest Products Research Institute, Japan
1 Matsunosato, Tsukuba, Ibaraki, 305-8687, Japan
e-mail: masamiti@ffpri.affrc.go.jp

Abstract

Numerous natural forests in Japan have been converted to man-made forests, especially since the 1960s. Because nutrient cycling is constrained by species characteristics, conversion of tree species may change soil conditions through the cycling. We examined changes in soil chemical characteristics of Japanese plantation forests on a nationwide scale.

In the early 1990s, the Forestry Agency Japan surveyed soil chemistry of the mineral surface soil (0 to 5 cm) at 1034 monitoring sites throughout Japan. Five years after the survey, the soils were reexamined to check the changes in their chemical properties. Because the analyses were done using composite samples, comparison was made on a whole-country basis.

Among plantation species, Japanese cedar (Sugi, *Cryptomeria japonica*) had a detectable change in soil chemistry. Exchangeable Ca content in Japanese cedar forests increased significantly from 8.8 cmol/kg to 10.1 cmol/kg in five years on average, although Ca also decreased in many forests. Other plantation species, like Japanese cypress (Hinoki, *Chamaecyparis obtusa*), Japanese Larch (*Larix kaempferi*), and Todo fir (*Abies sachalinensis*), exhibited slight but significant decreases in exchangeable Ca. Slight decreases of exchangeable Mg and K were found in all species, including the Japanese cedar. Comparing soil types in Japanese cedar forests, the increments in exchangeable Ca were significant in moderately moist and slightly wet brown forest soils that are suitable sites for Japanese cedar.

In temperate moist forests, a decreasing tendency of exchangeable cations would be reasonable due to leaching by high precipitation, as found in many forests except for Japanese cedar. The only exchangeable cation that increased in five years was Ca in the Japanese cedar forests. Although there were exceptions, the relatively high increase rate of exchangeable Ca in Japanese cedar forests suggests that active Ca cycling changes surface soil characteristic in a short period. Because Japanese cedar accounts for about 50% of all reforested areas, surface soil conditions may have been changing in the past few decades in Japan.

Recycling organic residues in marginal lands restoration

Cabezas, J. G; Alonso, J. and Lobo, M.C

Instituto Madrileño de Investigación Agraria y Alimentaria. I.M.I.A.
Finca "El Encín" Apdo. 127. 28800. Alcalá de Henares (Madrid).
Telf: 918879472. Fax: 918879474. mcarmen.lobo@imia.madrid.org

Abstract

Introduction

Inadequate agricultural techniques and climatic conditions in Mediterranean areas have led to significant soil organic matter and nutrient losses increasing erosion processes, especially when soil is not covered by vegetation. Restoration of soil should be carried out by improving edaphic soil properties to permit the development of native vegetation cover.

The application of treated sewage sludge may induce an increase in organic matter and nutrients soil content, and a significant improvement in the soil physical properties, as porosity, water holding capacity and infiltration capacity

The aim of this paper relates to evaluation of organic wastes application to soil rehabilitation where seeding and plantation of herbaceous and shrubs plants are used to restore degraded ecosystem in order to improve the soil edaphic properties favouring the introduction of climax vegetation.

Materials and methods

Two different treated sewage sludge (composting with pruning wastes, CP, and treated by thermal drying, TD) were applied to a marginal agricultural soil located in Alcalá de Henares (Central Spain). Two doses of each treatment were assayed according to the heavy metal content and the sewage sludge European legislation (Directive 86/78/EEC).

TD treatment was assayed at 22 and 46 t/ha, and CP treatment at 8.5 and 85 t/ha.

The assay was carried out in a greenhouse using polyethylene containers. The shrubs species selected were *Rosmarinus officinalis* L., *Thymus vulgaris* L., *Retama sphaerocarpa* (L.) Boiss y *Tamarix gallica* L. The herbaceous seeding (a mixture of gramineous and legumes) was assayed at two doses (100 and 200 Kg/ha).

Soils and plants were sampled and analysed periodically according to Official Spanish Analysis Methodology (Agriculture Ministry, 1993). Leaf chlorophyll content was evaluated by the method proposed by Inskeep and Bloom (1985).

Results and discussion

The application of both treatments produced a decrease in the pH values, whereas electric conductivity, organic matter and nutrients were significantly increased.

Nitrogen and phosphorus leaching may constitute a potential contamination for groundwater. Both treatments improved significantly physical soil properties (aggregates stability and porosity). Heavy metals increased in treated soils with higher values found in soil treated with TD treatment, but their levels were under the limits established by current legislation. Treated sewage sludge application increased plant germination percentage and biomass production (leaves and roots) in herbaceous vegetation. Plants on amended soils had higher nitrogen content in leaves and roots.

The chlorophyll content showed an increase in plants from sewage sludge treatment.

Conclusions

Restoration processes in marginal lands should include the succession to naturally occurring vegetation using native species (herbaceous and shrubs) that contributes favourable ecological soil characteristics to establish climax vegetation.

The treated sewage sludge application improves physico-chemical properties in marginal soils which favour the germination and growth that control and prevent soil from erosion. Moreover, sewage sludge favours the seed bank germination and the establishment of surrounding species. This fact means a lower need of seeds and fertilizers for the restoration.

Bibliography

- Agriculture Ministry. 1993. Official Spanish Analysis Methodology. Volume III.

- Council Directive 86/278/EEC of June 1986 on the protection of the environment, and in particular of the soil, when soil sewage sludge is used in agriculture.

- Inskeep, W. & Bloom, P. (1985). Extinction Coefficients of Chlorophyll a and b in N,N-Dimethylformamide and 80% Acetona. Plant Physiology. 77, 483-485.

The effect of site preparation intensity on root development, mortality and growth, in *Castanea sativa* and *Pseudotsuga menziesii* species of young forest plantations

F. Fonseca[(1)], T. de Figueiredo[(1)] A. Guerra[(1)] & A. Martins [(2)]

[(1)] Dep. de Geociências, Escola Superior Agrária de Bragança, Campus de St. Apolónia, ap. 172, 5301-855 Bragança. Telefone: 273 303253; Fax: 273 325405; e-mail: ffonseca@ipb.pt

[(2)] Dep. Edafologia, Universidade de Trás-os-Montes e Alto Douro, ap. 1013, 5001-911 Vila Real. Telefone: 259 350209; Fax 259 350480

Abstract

In Portuguese conditions, the productivity of most soils used for forest plantations is limited by low root support, low available water volume and low nutrient availability. This requires soil preparation operations before planting, using more or less intense tillage in order to decrease those limitations. However, there is a lack of information concerning the effect of those operations on soil properties and plant behaviour. In order to improve the knowledge about this subject, a study is conducted supported by an experimental field established near Bragança, NE Portugal. This field was established in 2001, at 700 m height, mean annual rainfall 1000 mm, mean annual temperature 12^{o}C and Mediterranean climate conditions, consisting of six treatments, randomly distributed, in plots with 375 m^2 area and comprising three blocks, each one in different topographic positions (near flat plateau, gentle slope shoulder, steep mid-slope). *Pseudotsuga menziesii* (*PM*) and *Castanea sativa* (*CS*), were used as forest species, on 4 × 2 m density and separated lines (2 for *PM* and 2 for *CS*), with 12 plants on each line by plot. The following treatments were applied: (a) No tillage and hole plantation with hole digger (SMPC); (b) Continuous subsoil mobilisation, using a covering shovel and plantation in the furrow (RCAV); (c) No previous subsoil mobilisation with furrow-hillock surface soil with two plough passes and plantation in the hillock side (SRVC); (d) Located subsoil mobilisation, followed by two plough passes, leaving furrow-hillock surface soil and plantation as in (c) (RLVC); (e) Continuous subsoil mobilisation, followed by two plough passes, leaving furrow-hillock surface soil and plantation as in (c) (RCVC); (f) Continuous subsoil mobilisation followed by continuous plough and plantation in the furrow (RCLC).

The deepness and density of root system, mortality after plantation, before summer period and after that and growth (height and diameter) during the two first years, were quantified on both planted species. The obtained results shows: (i) root density is higher on *PM* at 10-20 cm depth while *CS* shows a deeper

rooting system with higher density at 20-30 cm depth and higher soil volume exploited, especially on more intense treatments; (ii) after plantation and before summer period the highest mortality was observed on the lowest intensity treatments (SMPC and RCAV), and also on the highest intensity treatment (RCLC); (iii) after summer, the higher mortality was also observed on the lowest intensity treatments, while the lower values were detected on the intermediate treatments (SRVC and RLVC); (iv) plant growth (height and diameter) is similar in the different treatments, but, growth, when expressed as absolute value, is higher on *PM* than on *CS*, and, when expressed as relative increments in plant diameter, is higher in *CS* than in *PM* and always higher during the second year after plantation.

Restoration of Forest Sites Affected by Acid Deposition

J. Kulhavý[1], B. Lomský[2]

[1] Mendel University of Agriculture and Forestry, Faculty of Forestry and Wood Technology, Institute of Forest Ecology, Brno, Czech Republic

[2] Forestry and Game Management Research Institute, Prague, Czech Republic

Abstract

Due to the long-term load of acid deposition to forest ecosystems about two thirds of the forest area in the Czech Republic is markedly damaged. Acid inputs range from 2.5 to 7.0 kmol H+ ha-1 year-1 which permanently exceed several times the capacity of soils for their neutralisation. Thus, the resistance of forest ecosystems to other factors such as climatic changes, acidification impacts, etc. gradually decreases. Leaching of cation nutrients (particularly Ca, Mg and K), and release of aluminium ions in soils and the presence of excessive N nutrition to plants may lead to the absolute or relative shortage of nutrients affecting productivity and health of forest stands.

Moreover, forest stands are being managed to increase the proportion of broadleaved to "near-natural forests" and the question is addressed whether this change will improve soil properties and processes. As the implementation of such measures will require considerable funds, crucial arguments are needed to persuade the decision-making authorities.

The paper will present the assessment of effects from the application of different fertilizers to prevent or decrease yellowing Norway spruce foliage.

Limiting factors for reforestation of minesoils from Galicia (Spain)

F. A. Vega, E.F. Covelo, M.L. Andrade

Departamento de Biología Vegetal y Ciencia del Suelo. Universidad de Vigo. Las Lagoas. Marcosende 36200 Vigo. España. Tel: 986 812630; Fax: 998812556. e-mail:florav@uvigo.es.

Abstract

Opencast mines produce a large amount of waste because the ore is a small fraction of the total volume of the mined material. In mine spoils, the soils have severe physical, chemical and biological limitations. Restoration of soil function and soil quality is essential to long-term ecosystem stability (Bendfeldt et al., 2001). Soil characteristics and limitations associated with the mining development on acid soils have been studied by several authors (Merrill et al., 1998; Stewart and Hossner, 2001), but few studies have been conducted to describe the possibility of revegetation of minesoils from Galicia (Spain) (Leirós et al., 1989; Monterroso and Macías, 1998; López Tercero et al., 2003).

The objectives of this work were to characterize soils from the tailings of two opencast mines (Galicia, Spain) and to determine the chemical and physical soil quality indicators and limiting edaphic factors for forest production in order to improve the present management practices to improve the environmental quality.

At four tailings on opencast mines of Galicia (N.W. Spain), soil samples were taken and their chemical and physical properties and the limiting edaphic factors for the forest production were measured. Minesoils came from two mine tailings (Touro: copper mine, and Meirama: lignite mine) located in Galicia (Spain). Two zones were selected in the Touro copper mine soils: i) The tailings formed by the waste materials of depleted copper mine, and ii) the decantation bank where the sludge from the copper extraction in the flotation plant was deposited. Two tailings with different age·(3 and 10 years old) were selected in the Meirama lignite minesoils. Five soils (Anthropic Regosols) were selected in each zone. Sampling was carried out from the surface horizon (AC). Five samples from each site sample were taken and stored in polyethylene bags. The samples were air dried, passed through a 2 mm sieve and homogenized in a vibratory homogeniser for solid samples and five subsamples from the composed sample were taken for the analyses.

The percentage of the >2 mm fraction was weighed, and the stones were weighed separately. **Soil** chemical analysis was carried out on the sieved fraction. The samples were analysed for particle size distribution, stoniness, density, porosity, pH, nitrogen, organic carbon, effective cationic exchange

capacity (CECe), exchangeable cations, iron, aluminium and manganese oxides, and heavy metal contents. A mineralogical analysis of the fraction <2 μm has also been performed.

For every one of the physical or chemical parameters some critical values were assigned, following the SFCC model (Soil Fertility Capability Classification) proposed by Buol et al. (1975) and adapted by Macías and Calvo de Anta for Galicia (Macías et al., 1983; Macías and Calvo de Anta, 1987) and soil quality indicators (Arshad and Coen, 1992; Karlen and Stott, 1994; Doran and Jones, 1996; Burger and Kelting, 1998; Powers et al., 1998; Schoenholz, 2000).

The main physical limitations of the minesoils are their low effective depth (< 50 cm), high porosity (>60 % in two minespoils), and stoniness (> 30%), which make them vulnerable to soil erosion and seriously affect the forest production. Minesoils from the decantation bank of copper minesoils did not have physical limitations.

The main chemical limitations of minesoils are their acidity (pH from 3.62 to 5.71), and aluminium saturation (>60% in copper minesoils, and >20% in lignite minesoils), low CECe (5.34 to 9.47 cmol kg^{-1}), organic matter (0.83 to 15.04 mg kg^{-1}) and Ca and Mg contents, and imbalance between exchange bases.

Minesoils from the decantation bank of copper minesoils are strongly limited by the high Cu content (1218 mg kg^{-1}).

References

Arshad MA, Coen G. 1992. Am. J. Altern. Agric. 7(1-2): 25-31.

Bendfeldt ES, Burger JA, Daniels WL**.** 2001**.** *Soil Sci. Soc. Am. J.* 65: 1736-1744.

Buol SW, Sanchez PA, Cate RB, Granger MA. 1975. In: Bornemizza E, Alvarado A (eds). North Carolina State University Raleigh, NC; 126-145.

Burger JA, Kelting DL. 1998. In: Davidson EA, Adams MB, Ramakrishna K (eds.). SSSA. Special Publication, 53: 17–52.

Doran JW, Jones A. 1996. SSSA. Special Publication 49: Madison, WI.

Karlen DL, Stott DE. 1994. In: Doran JW, Coleman DC, Bezdicek DF, Stewart BA (eds). SSSA. Special Publication: Madison, WI; 35: 53-72.

Leirós MC, Gil F, Carballas M, Codesido C, González MV, Guitián F. 1989. An. Edaf. Agrob. 45: 85-100.

López-Tercero A, Andrade L, Marcet P. 2003. Mine Conf. Proc.. Mining and the Environment Spiers G, Beckett P, Conroy H (eds). Sudbury, Canada; 2: 977-984.

Macías F, Calvo de Anta R. 1987. EFCE Publication Series: 68(I): 65-72

Merrill SD, Ries RE, Power JF. 1998. SSSA Special Publication 62(1): 263-271.

Monterroso C, Macías F. 1998. Soil Sci. Soc. Am. J. 62(6): 1741-1748.

Powers RF, Tiarks AE, Boyle JR. 1998. In: Davidson EA, Adams, MB, Ramakrishna K (eds). SSSA. Special Publication.Madison, WI; 53: 53-80.

Schoenholtz SH. 2000. Forest Ecol. Manag. 138: 335-356.

Stewart WM, Hossner LR. 2001. J. Environm. Qual. 30:1143-1149.

Plenary Session 7 « RESIDUES RECYCLING »

Residual recycling for forested land sustainability

JM Carnus , AL Thomas –Chéry, L Denaix , A Bailly, JY Gautry , M Ben Brahim

Inra – Bordeaux Aquitaine, AFOCEL – Station Centre Ouest, ONF – Office National des Forêts

carnus@pierroton.inra.fr

Abstract

Within the framework of the future European strategy for soil protection (COM (2002), 179), consideration is given to the safe use, recovery, recycling and disposal of sewage sludge[1] and other biodegradable wastes (biowastes)[2] , with emphasis on the responsible recycling of organic residuals through land application as part of an overall strategy on the prevention and recycling of wastes (COM (2003) 301). In EU-15, 45 % of total annual production of 7.3 million tonnes of sewage sludge (dry matter) is currently recycled on land, largely in agriculture. Recycling of sludge on forested land is almost non-existent and is even forbidden in a few European countries such as Germany. Beyond the generally accepted statement that the use of residuals should be prohibited in natural forests, it is also recognised that in the context of more intensively managed forest systems for biomass or wood production, positive effects of sludge and biowaste application can be expected.

In France, recent regulations (1998) on sludge utilisation on land allow applications on forested land but only under experimental conditions. In this context, the research community has been asked to develop additional pertinent information on the environmental sustainability, economic viability and social acceptability of such recycling forest systems which policy makers may be able to use. The main questions which have been addressed concern the fate of heavy metals and other potentially toxic elements in forest ecosystems, the effects on ecosystem functioning and on biodiversity, the potential transfer to the food chain, and the social acceptance. Methodologies include in-situ mesocosms studies, dose-response forest experiments and social surveys. A national network representative of organic residuals types, forest soils conditions and tree species has been established in the past four years. Long term monitoring and demonstration sites are essential components of this integrated experimental approach. Initial results, including effects on forest ecosystem functioning (growth, nutrition) and biodiversity, and effects on forest environment (soil, water) are presented for forest plantations receiving low rates of application of municipal or pulpmill sludge.

[1] Sewage sludge is defined as (i) residual sludge from sewage plants treating domestic or urban waste waters ; (ii) residual sludge from septic tanks ; and (iii)

residual sludge from sewage plants other than those referred in (i) and (ii) – (directive 86/278/EEC of 12June 1986 on the protection of the environment and in particular of the soil when sewage sludge is used in agriculture).

[2] Biodegradable waste is defined as waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard » - (Directive 99/31/EC of 26 April 1999 on the landfill of waste).

Effects of harvesting residue management on productivity, organic carbon stocks and soil characteristics of Eucalyptus globulus Labill. coppices

M. Madeira[1], M. C. Magalhães[2], A. Azevedo[3], A. Fabião[1], J. P Pina[4] & M. C. Araújo[4]

[1]Instituto Superior de Agronomia, Tapada da Ajuda, P-1349-017 Lisboa, Portugal, email: aa15309@isa.utl.pt;

[2]Escola Superior Agrária de Coimbra, Bencanta, P-3040-316 Coimbra, Portugal;

[3]Escola Superior Agrária de Santarém, S. Pedro, P-2000-655 Santarém, Portugal;

[4]Celbi (Celulose Beira Industrial) S. A., P-3081-853 Leirosa, Portugal.

Abstract

Sustainable management of forest resources includes retention of nutrients and protection of soil organic carbon and soil structure to ensure long-term soil fertility and productivity of later rotations. Potential depletion of soil nutrients and adverse changes in soil characteristics are particularly likely to affect production systems in Portugal where fast-growing tree species, such as *Eucalyptus globulus* plantations, are involved. Tree growth, organic C status and soil properties of a *E. globulus* stand were studied at a site (Quinta do Furadouro) located in Central Portugal, after coppicing of first rotation, under four treatments, in which harvesting residues from the first crop were utilised (Jones *et al.*, 1999)..

The study was carried out in a flat area, where the mean annual rainfall is about 600 mm, and mean annual temperature reaches 15.2ºC. Soils correspond to Dystric Cambisols derived from Cretacic sandstone; they are sandy loam and have low organic C content (10 g kg^{-1}) and extractable P (8 mg kg^{-1}) (Magalhães, 2000). The treatments were: removal of organic residues (harvesting residues and soil litter layers) from the soil surface (R); broadcast of harvesting residues on the soil surface (S); as for treatment S, but with woody material concentrated between stump rows (W); incorporation of organic residues into the soil by harrowing up to 20 cm depth (I). Treatments were installed in 18m × 18 m plots, surrounded by a buffer strip 6 m wide, and replicated five times in different blocks.

Tree growth (height and diameter at breast height) and amount of forest floor litter layer were assessed. Decomposition of harvesting residues was assessed from weight loss using the litter bag technique. The amount of organic C in the forest floor litter layer was quantified through samples taken from 1m ×1 m areas within the experimental plots. Bulk density was determined from

undisturbed samples; soil aggregation index and aggregate size distribution were determined on samples taken from the top soil. The concentration of organic C, N, base cations and extractable P in mineral layers were determined up to 30 cm depth. Nitrogen mineralisation was assessed in laboratory under aerobic and anaerobic conditions. Treatment differences were tested by ANOVA and Tuky test ($p<0.05$).

After 10 years, differences between treatments in tree growth were not significant. The timber volumes were 236.5, 285.5, 287.4 and 273.1 m^3 ha^{-1}, respectively in treatments R, S, W and I. The biomass of understory vegetation amounted to 1.09, 0.64, 1.17 and 0.75 Mg ha^{-1} in the same treatments, and these values were not significantly different.

Harvesting residues incorporated into the soil decomposed faster than those placed on the soil surface. After 2 years, the former released greater amounts of N, Ca and P than the latter. At the beginning of the experiment the amount of organic residues on the soil surface in S and W treatments was 65.4 Mg ha^{-1}, whereas in the R and I treatments was almost null. Despite these differences, at the end of the experiment, the forest floor litter layer mass in treatment S (14.2 Mg ha^{-1}) was similar to that measured in treatments R (14.5 Mg ha^{-1}) and I (15.5 Mg ha^{-1}). Therefore, organic carbon stock in the forest floor litter layer did not dependent on the treatments. The amount of nutrients (N, Ca, Mg, K and P) in such layer followed the same trend as weight.

Concentrations of both NO_3^--N and NH_4^+-N in the mineral soil layers were very low but nitrate was predominant. The amount of NH_4^+-N produced through incubation in anaerobic conditions was not significantly different among treatments. Similar result was observed for the mineral N (NH_4^+-N plus NO_3^--N) produced under aerobic conditions. In this case the amount of NO_3^--N was negligible in comparison to that of NH_4^+-N.

Bulk density values, aggregation index and aggregate size distribution did not show significant differences between treatments. Similar trend was observed for concentrations of organic carbon, N, extractable base actions and extractable P in the 0-20 cm soil layer. The amount of organic carbon was also similar between treatments.

Results showed that removal of the forest floor litter layer and harvesting residues did not lead to decrease of soil fertility, soil C stock and tree productivity. They also stressed that under site conditions similar to those occurring in this experimental area, removal of harvesting residues (e. g. for energy production) is a possible option without deleterious effects on the sustainability of forest plantations under intensive management.

References

Jones, H.E., Madeira, M., Herraez, L., Dighton, J., Fabião, A., Gonzales-Rio, F., Fernandez Marcos, M., Gomes, C., Tomé, M., Feith, H., Magalhães, M. C. & Howson, G. 1999. *The effect of organic matter management of the productivity of Eucalyptus globulus stands in Spain and Portugal: tree growth and harvest residue decomposition in relation to site and treatment. For. Ecol. Manag*., **122**: 73-86.

Magalhães, M. C. S. 2000. *Efeitos de Técnicas de Preparação do Solo e Gestão dos Resíduos Orgânicos em Características Físico-Químicas do Solo de Plantações Florestais.* Dissertação de Doutoramento. Instituto Superior de Agronomia, Lisboa.

Leaching of heavy metals (Cu, Ni and Zn) and organic matter after biosolids application to Mediterranean forest soils

Montse Toribio [1] and Joan Romanyà [2],

[1] *Departament de Biologia Vegetal, Facultat de Biologia, Universitat de Barcelona, Spain*
Email address: mtoribio@ub.edu

[2] *Departament de Productes Naturals, Biologia Vegetal i Edafologia, Facultat de Farmàcia, Universitat de Barcelona, Spain. Email address: jromanya@ub.edu*

Abstract

The increasing quantity of biosolids obtained by sewage treatment processes makes it necessary to find safe and feasible ways for their disposal. Repeated applications of heavy metals-contaminated biosolids can significantly increase potentially toxic metals concentrations in soils. Metal transfer from biosolids to soil and subsequently to freshwater and plants pose potencial health risks, since they can enter the food chain and the environment. Biosolids-applied metals may be retained by the soil as a result of their adsorption on hydrous oxides, clays and organic matter, the formation of insoluble salts, or presence of residual biosolids particles. Heavy metals are highly persistent in soil, with residence times of as much as thousands of years.

The aims of this study are to investigate the retention capacity of Cu, Ni and Zn of three contrasted Mediterranean forest soils treated with biosolids, to explore its relationships with soil properties and to evaluate Cu, Ni, Zn and organic matter leaching. Three contrasted Mediterranean forest soils (loamy-basic soil, clay-basic soil and loamy-acid soil) were incubated in 45 PVC columns (5 replicates x 3 soils x 3 treatments) of 10.5 cm of diameter containing a layer of 30 cm of soil. Treatments were (a) soil application of low metal content biosolids (LMB), (b) soil application of metal-enriched biosolids (MEB), and (c) control. The biosolid application represented a dose of 6 kg dry weight m^{-2}. All columns were covered at the bottom by a permeable inert tissue to prevent soil losses and by a PVC container to collect all leachates.

Soil columns were incubated at room temperature during 110 days and were irrigated weekly with deionised water to make a total of a 1100 mm. Leachates were collected and filtered with Whatman 2.5-µm cellulose filter and were analyzed for pH, C.E., DOC, and soluble Cu, Ni and Zn concentrations. All cation analysis were carried out by ICP-OES (Thermo Jarrel Ash, Polyscan 61E) and dissolved organic carbon analysis by $K_2Cr_2O_7$ oxidation. Soils were analyzed before and after the incubations. The pseudototal heavy metal (Cu, Ni and Zn) were determined by hot *aqua regia* digestion and the labile fractions (Cu, Ni and Zn) were extracted using oxalic acid (5mM).

Biosolid derived Cu, Ni and Zn were found readily leached through the 30 cm columns of three soils but its concentrations were well below limit the water quality criteria of the Spanish legislation. Concentrations of Cu, Ni and Zn in leachates were different among soils, but there were not differences between control and LMB columns. The leachates concentrations of Cu, Ni and Zn in the MEB columns were highest in all studied soils although the greatest differences were observed in the loamy-basic and loamy-acid soils. In the clay-basic MEB soil leachates, after the addition of 600 mm of deionised water, Cu concentrations decreased to the concentrations of control and LMB. Ni concentrations were higher in the MEB leachates for the loamy-acid soil than for other soils but when we had irrigated with 800 mm of deionised water, Ni concentrations in leachates were similar in all soils. In the clay-basic soil, Ni concentrations in leachates did not show any effect of biosolid additions since the beginning of the incubation. In loamy-acid soils Zn concentrations in MEB columns were about 100 times higher than in control. Other soils showed high amounts of Zn in the leachates of the MEB columns but differences from control were not as high as in the loamy-acid soil. In the clay-basic soil, after the addition of 400 mm of deionised water Zn concentrations in leachates of the MEB columns decreased to similar levels than control and LMB leachates. The loamy-basic soils showed higher Zn concentration in the leachates of MEB columns throughout the studied period.

DOC-concentrations in the leachates in biosolid amended soils were similar to its respective controls except in the organic matter poor loamy-acid soil where DOC-concentrations of LMB and EMB were higher than control. DOC-concentrations of our Mediterranean soils leachates were considerably higher than in other temperate soils.

The increase in Cu in the leachates of the clay-basic soil can be explained by DOC or pH related transport effects. The Ni and Zn concentrations were higher when DOC and clay content were low. Other authors have reported a clay control of Zn absorption in basic soils. In loamy-acid soils Zn and Cu in the MEB leachates showed a similar trend . In these soils Zn concentrations were one order of magnitude higher than Ni concentrations.

Loamy acid soils showed the highest metal cocentrations in leaching while the clay-basic soils showed the lowest. However, the amount of heavy metals in the leachates, and also in the labile fractions, were far below the limits of toxicity for all studied soils. Thus, after one single addition of biosolids, for the studied Mediterranean soils the risk of heavy metal toxicity for plants and of groundwater contamination appears to be very low.

Effects of wood-bark ash application on nutritional status, tree growth and biomass production in a young *Pseudotsuga menziesii* plantation

Fernando Solla-Gullón, Martín Santalla, Roque J. Rodríguez-Soalleiro, Agustín Merino

Escuela Politécnica Superior, Universidad de Santiago de Compostela, E-27002 Lugo, España (e-mail: fersogu@lugo.usc.es)

Abstract

Pseudotsuga menziesii plantations are of increasing importance in the temperate Atlantic region of Europe, and grow under a broad range of forest site conditions. Differences in the nutrient supply are reflected by considerable variation in tree vigour and growth in this species. The soils in Northern Spain are typically acidic and poor in nutrients and *Pseudotsuga menziesii* plantations therefore have a generally poor nutritional status, with frequent deficiencies in P, K and Mg (Zás, 2003). This, together with the lack of fertilization, may cause large deficiencies of nutrients in these stands. Wood ash originating from the timber industry is a possible alternative to mineral fertilizers. This by-product contains high levels of many nutrients, has a high acid neutralizing capability and low contents of heavy metals.

The aim of the present study was to evaluate the effects of the application of wood-bark ash on a six years old *Pseudotsuga menziesii* plantation of poor nutritional status. The soil under the plantation was acidic (pH 4.6), rich in organic matter (12.4 %) and contained low concentrations of available P, Ca and Mg (6.9 mg kg^{-1}, 88.9 mg kg^{-1} and 10.9 mg kg^{-1}, respectively). The responses in terms of soil chemistry, soil solution, nutrient foliar concentrations and tree growth were assessed throughout a period of four years. Part of the plantation surface (2 ha) was divided into twelve plots, which received one of three doses of bark ash (0, 10 or 20 Mg ha^{-1}) in a randomised design with four replicates.

Wood ash application led to increases in soil pH, and soil available Ca, Mg and K. The concentrations of heavy metals were always low and remained unchanged after application of the wood-bark ash. There were significant increases in foliar K, P, N, S, Ca and Zn. The improved nutritional status of Ca and K were confirmed by the use of vector analysis.

Application of wood-bark ash also increased tree yield, in terms of height, diameter, volume and tree biomass. According to height growth models developed for young Douglas fir plantations, the development of height may be increased by 26.2% in comparison to control treatment.

For tree biomass models, 24 trees were destructively sampled to develop biomass prediction equations for tree components - bark, branches, twigs and needles. Regression equations relating the dry weight of each tree component to tree variables (diameter at breast height, total height) were fitted simultaneously using seemingly unrelated regressions. The use of these equations, along with the data from chemical analyses allowed us to estimate differences in biomass production, as well as in nutrients accumulated by tree components from different treatments.

References

Zás (2003). Foliar nutrient status and tree growth response of young *Pseudotsuga menziesii* (Mirb.) Franco to nitrogen, phosphorus and potassium fertilization in Galicia (Northwest Spain). Invest. Agrar.: Sist. Recur. For. 12, 75-85.

Effects of harvesting residue management on decomposition and C, N, CA and K dynamics in Eucalyptus plantations

A. Azevedo[1], M. Madeira[2], L. Hilário[2] & P. Marques[2]

1Escola Superior Agrária de Santarém, Sector de Geociências, Quinta do Galinheiro, Ap. 310, 2001-904 Santarém, e-mail: a_azevedo@esa-santarem.pt

[2]Instituto Superior de Agronomia, Tapada da Ajuda, 1349-017 Lisboa, Portugal, email: aa15309@isa.utl.pt

Abstract

In Portugal, *Eucalyptus globulus* commonly planted in soils with low organic C and nutrient status (Madeira, 1995). Thus, at the end of the rotation period, the amount of nutrients in the forest floor litter layer (organic layers) and in the harvesting residues is an important proportion of the amount of nutrients which may become available during the next rotation. In those plantations, following clear-felling, nutrient availability may depend on the presence and placement of harvesting residues (Smethurst & Nambiar, 1990). It is important to establish slash management practice which is effective to match nutrient availability with requirement in replanted Eucalyptus stands (Smethurst & Nambiar, 1990). For this reason, decomposition of Eucalyptus harvesting residue (leaves, bark, twigs, branches), according to its placement in the soil, was assessed to provide information on nutrient release dynamics during the early phase of replanted Eucalyptus stands.

The study was carried out in Central Portugal, in an area occupied by an *E. globulus* plantation, which was twelve years old at clearcutting. The mean annual rainfall is about 700 mm, 75 % of which occur from November to April; mean annual temperature is 15 ºC. Soils are Dystric Cambisols and had low contents of clay (87.8 g kg^{-1}), organic C (11.8 g kg^{-1}), and extractable P (2.1 g kg^{-1})and K (< 40 g kg^{-1}); the effective cation exchange capacity was less than 1.45 $cmol_c$ kg^{-1}. Organic C, N, P, Ca, Mg and K in organic layers and harvesting residues were, respectively, 46, 16, 69, 76, 63 and 55 % of the amount in the system, considering a soil depth up to 30 cm. Harvesting residue decomposition was followed for a 5-year period, using the litterbag technique (Swift *et al*., 1979). Treatments were: residues on the soil surface (RS) and residues incorporated (RI) into the soil at 15 cm depth. During the first two years of experiment, litterbags were sampled every three months, and thereafter every six months. Residue decomposition rate was assessed through the model $X=X_0 . Exp(-Kt)$. Proportion of N, P, Ca, Mg, and K left behind was calculated as the quotient between the amount at each sampling time and the initial.

Residue incorporated into the soil decomposed faster than those placed on the soil surface. After two years, annual decomposition rate of leaves was 1.5 times greater in RI treatment than in RS treatment; differences for bark and branches was more pronounced, i.e. 2.6 times greater in the RI treatment. Annual decomposition rate varied substantially among harvesting residue components. At the end of the study, annual decomposition rate of harvesting residues was similar among treatments: values were 0.54 (RS) and 0.55 (RI) for leaves; 0.34 (RS) and 0.32 (RI) for twigs; 0.27 (RS) and 0.28 (RI) for bark; and 0.18 (RS) and 0.23 (RI) for branches. Weight loss of harvesting residues was negatively correlated with the C/N ratio.

At the end of the experiment, the amounts of N, P, Ca, Mg and K left behind were similar in treatments, and were respectively 24, 28, 22, 14 and 4 % of the initial. During five years, the release of N, P, Ca, Mg and K was, respectively, 200, 11, 332, 60 and 136 kg ha^{-1}. Calcium was released steadily (≈ 70 kg ha^{-1} yr^{-1}), whereas P, Mg and K were mostly released during the first two years (respectively, 53, 65 and 90 %). During this period N release from RI was greater (38 % of the initial) than from RS (25 % of the initial); conversely, the N mineral concentration in the soil was greater in the latter than in the former. Leaves were a source of nutrients; except for Mg and K, woody residues were a sink for N, P and Ca. Phosphorus and Ca release begun one year after residue incubation, while N release was observed only three years after.

Results suggest that woody residues are a sink for N during the early decomposition phase. Incubation of harvesting residues into the soil promoted N immobilization. Apparently, during the first two years additional application of N, P and K is not needed to maintain tree growth. Treatments did not affect tree growth and concentration of N, P and K in leaves. After three years deficiency of N was observed in both treatments.

References

Madeira, M. V. 1995. Efeito das plantações de *Eucalyptus globulus* nas características do solo em condições mediterrânicas (Portugal). *Rev. Flor.*, 8 (1): 3-22.

Smethurst, P. J. & Nambiar, E. K. S. 1990. Effects of slash and litter management on fluxes of nitrogen and tree growth in a young *Pinus radiata* plantation. *Can. J. For. Res*., 20: 1498-1507.

Swift, M. J., Heal, O. W. & Anderson, J. M. 1979. *Decomposition in Terrestrial Ecosystems*. Blackwell Scientific Publications, Oxford.

Managing Harvest Residues In Hoop Pine Plantations Of Subtropical Australia

Tim Blumfield1 & Zhihong Xu1

1 Faculty of Environmental Sciences, Griffith University, Nathan, Qld. 4111, Australia

Abstract

For decades the burning of harvest residues was standard practice in plantation forestry in southeast Queensland, Australia. Erosion losses from the sloping land of hoop pine (*Araucaria cunninghamii*) plantations and losses of N through volatilisation raised issues concerning the sustainability of this practice and led to the use of windrows, formed along the contours of the slope, as a means of retaining residues on site. The standard spacing of windrows on sloping land has been 15 m, allowing 3 tree planting rows between windrows. However, this spacing was arbitrary and no work had been undertaken to determine the optimum distance between windrows which would allow the nutrients released through decomposition to be available to the trees of the following rotation. A series of experiments have been performed to examine how the decomposition of windrowed residues affects soil carbon (C) and nitrogen (N) over a period of time. In particular, we were interested in differences between soils beneath the windrows and soils in the area that had been scraped clear of residues between the windrows. We looked at; potentially mineralisable N (PMN) in plantation soils 1, 2 and 3 years following windrow formation; in situ N mineralisation in the tree planting rows between the windrows; in situ N mineralisation under an alternate residue management strategy; and N release from decomposing windrowed material.

Materials and Methods

All experiments were conducted in the hoop pine plantations at Imbil State Forest, approximately 180 km north of Brisbane in southeast Queensland, Australia. PMN was determined using anaerobic incubation and presented as a percentage of the total N pool as determined by mass spectrometry. The sequential, in situ technique was used to determine N mineralisation (N_{min}) in the tree planting positions between the windrows over a 24 month period. The same technique was used to compare N_{min} between the cleared area between windrows and areas where residues had been left as a uniform cover on the ground. ^{15}N-labelled residues were used to determine the movement of residue-derived N from windrows and subsequent N availability to trees of the following rotation.

Results

Three years following windrow formation, PMN was significantly higher ($p<0.001$) in the soil directly beneath the windrows than in the soils in the area between the windrows. There was no significant difference ($p>0.05$) in PMN in the soils from these positions 1- and 2-years following windrow formation. Net N_{min} was not significantly different ($p>0.05$) between cores installed along the 3 tree planting rows though the cores in the lower position on the slope had significantly higher soil moisture ($p<0.05$) and significantly higher nitrification ($p<0.05$) than cores installed in the upper and middle tree planting rows over the 24-month period. Soil moisture was significantly higher ($p<0.001$) during the first 12 months following harvesting in the area where residues had been retained as a uniform groundcover than in the cleared area between the windrows. The area between the windrows had a steady rate of net N_{min} throughout the sampling period with a cumulative total of over 300 kg N ha^{-1} mineralised over the 24-month sampling period. During this same period, over 200 kg N ha^{-1} was lost from this area due to leaching. By contrast, the area where the residues had been retained as a cover had a net N immobilisation for the first 20 months following harvesting and with a total of about 120 kg N ha^{-1} mineralised by the end of the sampling period. Losses of N through leaching were approximately 100 kg N ha^{-1} over the entire sampling period under the residue cover. ^{15}N derived from decomposing residues was only detectable in soil samples taken from areas within 0.3 m of windrow sections containing ^{15}N-labelled hoop pine residues. The soil samples taken from other positions along the transacts, which passed from 5 m up-slope to 10 m down-slope of the windrow sections, did not have levels of ^{15}N greater than the natural abundance of the surrounding area for a period of 30 months following windrow formation.

Discussion

Windrow formation pushes harvest residues into piles occupying approximately 20% of the plantation area. Decomposition proceeds at a reasonably rapid pace within the subtropics with combined residues having a half life of approximately 34 months which correlates well with loss of N from the residues (Blumfield *et al.*, 2004). However, results from the trial using ^{15}N-labelled residues have shown that the N released during decomposition is immobilised in the soils directly beneath the windrows and, in the presence of the large reservoir of C within the windrow, is likely to remain immobilised for a considerable period of time. This is further supported by the results of the anaerobic incubation which showed that after 3 years, PMN, which is a good indicator of biological activity, was substantially greater in the soils beneath the windrows than in the cleared areas between the windrows. There was no

significant difference in N_{min} between the 3 tree planting rows over the 24-month period of the in situ mineralisation study, which also suggests that the decomposing residues had no effect on N_{min} in the cleared area, even for the tree rows closest to the windrows. When residues are left as an even cover over the harvested area there is a substantial period of N immobilisation in the presence of the available C from the residues compared to the cleared area between the windrows. As a result, N losses through leaching are substantially reduced with about 100 kg N ha^{-1} lost from the covered area compared to 200 kg N ha^{-1} in the cleared area over the same period (Blumfield and Xu, 2003). Further research may test the even distribution of harvest residues across the site using the coarse woody debris to form the windrows and act as barriers to erosion or the use of a fallow period between rotations to allow the breakdown of residues and the immobilisation of mineralised N prior to windrow formation and planting.

Conclusion

Windrows are valuable barriers to the down-slope movement of water and entrained sediments, thereby preventing erosion on the often steeply sloping sites of the hoop pine plantations. However, hoop pine plantations are N limited and, under the current spacing regime, while it is probable that the maturing trees in the 2 outer rows will be able to utilise N from the windrows, it is possible that the trees in the middle rows, up to one-third of all the trees, may suffer from N deficiency.

References

Blumfield, T. J., Xu, Z., Mathers, N. J., Saffigna, P. G., 2004. Decomposition of 15N-labelled hoop pine harvest residues in subtropical Australia. Soil Sci. Soc. Am. J. (In Press).

Blumfield, T. J., Xu, Z. H., 2003. Impact of harvest residues on soil mineral nitrogen dynamics following clearfall harvesting of a hoop pine plantation in subtropical Australia. For. Ecol. Manage. 179, 55-67.

Eucalyptus residue management effects on nutrient leaching and soils properties

M. X. Gómez-Rey[1], M. Madeira[1], P. Gamito[2], A. Azevedo[3], P. Marques[1] & L. Hilário[1]

[1] Dpto. de Ciências do Ambiente, Instituto Superior de Agronomia, Tapada da Ajuda, 1349-017 Lisboa, Phone +351213653262; Fax +351213635031; email: edchus@usc.es

[2] Universidade Lusofona de Humanidades e Tecnologias, Av. do Campo Grande, 376, 1749 - 024 Lisboa email: pedro.gamito@sapo.pt

[3] Escola Superior Agrária de Santarém, S. Pedro, P-2000-655 Santarém, Portugal

Abstract

A large proportion of *Eucalyptus globulus* plantations in Portugal are grown in soils that are low in organic carbon and nutrients (Cortez, 1996). There are concerns that soil fertility may decline under plantations, due to losses of organic matter and nutrients (especially N) during the harvesting phase, through export in harvesting residues and through leaching (Carlyle *et al.,* 1998). Harvesting residues (especially when chopped to small size) with high C/N have the potential to immobilize N and thus reduce leaching. Effects of harvesting residue management (especially woody residues) on nutrient leaching (especially N), organic C contents and soil fertility were investigated in an experiment under controlled conditions (lysimetric experiment).

Zero tension lysimeters containing homogenised soil from a *Eucalyptus* clear-felled site were used to assess the effect of slash placement and woody residues on leaching of N and on soil chemical properties without plant uptake. Each lysimeter contained 25 kg (dry weight) of sieved (5 mm) homogenised soil (Dystric Cambisol from the Eucalyptus site) mixed with 500 g of forest floor litter layer, and 1488 g of slash (300, 88, 100 and 100 g of leaves, bark, twigs and branches, respectively) and packed to a bulk density of 1.3 Mg m^{-3}. Treatments were as follows: (A) soil and organic residues (other than branches) incorporated into the soil; (B) as A with branches chopped and placed on the soil surface or (C) incorporated into the soil; (D) as A with branches cut in bits 10 cm length on soil surface or (E) incorporated; (F) soil and all organic residues on the soil surface with branches chopped or (G) in bits; (H) absence of residues (control). Each treatment was replicated five times. Leachates were sampled for a six-year period, and analysed for pH, N-NH_4^+, N-NO_3^-, Ca, Mg, K and P. At the end of the experimental period, all lysimeters were destructively sampled and soil analysed for pH, organic C, N, extractable bases and

extractable P. Remaining organic residues were analysed for N, C, Ca, Mg, K and P.

Lysimeter drainage volume was correlated with rainfall. Organic residues on the soil surface originated the greatest volume of leachate. Incorporation of woody harvesting residues into the soil reduced N leaching, especially when residues were chopped (8.6 kg ha^{-1} yr^{-1} vs control 19.6 kg ha^{-1} yr^{-1}). The highest N leaching was observed in the treatment without woody residues (A, 30.3 kg ha^{-1} yr^{-1}), but, at the end of the experiment, losses only represented 17% of the N added through organic residues. Losses of N through leaching were primarily related to $N\text{-}NO_3^-$ produced during winter months of the first three years.

In contrast, content of Ca, Mg and K leached was generally higher in treatments than in control. The conditions that favour woody harvesting residue decomposition, that is, incorporation into the soil and cut in bits, were those where greater leaching was observed. Losses were significantly greater compared with the control for Ca (79.5 kg ha^{-1} yr^{-1} vs 57.9 kg ha^{-1} yr^{-1}), Mg (23.8 kg ha^{-1} yr^{-1} vs 14.3 kg ha^{-1} yr^{-1}) and K (80.3 kg ha^{-1} yr^{-1} vs 12.4 kg ha^{-1} yr^{-1}). Phosphorus leaching did not show significant differences among treatments.

Potassium was highly mobile, especially during the first year of the experiment. Proportion of K leached in relation to total added was always higher than 50% and even reaching values of 100%. Conversely, Ca showed the lowest mobility and its loss at the end of study ranged from 17.7 to 32.5%.

At the end of the experiment, retention of organic residues showed negligible effect on soil chemical properties and organic C stock. Values of pH-H_2O and pH-KCl were similar among treatments, but they were lower than those observed in the control, and were also lower than those of the soil substrate at the beginning of the experiment. Placement of organic residues on the soil surface decreased leaching of Ca, Mg, K and P, resulting in greater concentration of these nutrients in the upper soil layer (0-5 cm) which significantly decreased with soil depth. Such a placement also significantly increased C organic and N amounts in the topsoil layer. The gradient of nutrient concentrations with depth decreased in treatments where organic residues were incorporated into the soil

Results showed that nutrient leaching, soil chemical properties and nutrient availability in forest soils were affected by harvesting residues management.

References

Carlyle, J. C., Bligh, M. W. & Nambiar, E. K. S. 1998. Woody residue management to reduce nitrogen and phosphorus leaching from sandy soil after clear-felling *Pinus radiata* plantations. *Can. J. For. Res.,* **28:** 1222-1232.

Cortez, N. R. S. 1996. *Compartimentos e Ciclos de Nutrientes em Plantações de Eucalyptus globulus Labill. ssp globulus e Pinus pinaster Aiton*. Tese de Doutoramento. Instituto Superior de Agronomia, Universidade Técnica de Lisboa, Lisboa.

Application of wood ash in forest soils in Northern Spain developed on different parent materials

Beatriz Omil, Iago Seoane, Almudena Tella, Agustín Merino

Escuela Politécnica Superior, Universidad de Santiago de Compostela, E-27002 Lugo, España. (e-mail: bomilig@lugo.usc.es).

Abstract

The wood ash from bioenergy plants of timber industries is considered as a "non-dangerous" product and is usually disposed in landfills. However, because of the high concentrations of nutrients and low levels of heavy metals in the wood ash, its application to forest soils can be used for better environmental management and the nutritional status of the plantations. This method of fertilization can also provide a way of restoring nutrients exported during biomass removal at harvesting. Most of the *Pinus radiata* D. Don plantations in Northern Spain are deficient in P, Mg and Ca, that is attributed to the strong acidity of the soils and the large amounts of nutrients removed due to short rotations (less than 40 years). The objective of this study was to develop an improved system of environmental management of wood ash residues together with improving the nutritional status of forest plantations.

Wood ash was applied to six *Pinus radiata* D. Don plantations of different ages (5, 15 and 30 years) and developed on different type of soils (parent material: quartzite, serpentine and clay sediments). Changes in soils and soil solutions were monitored during the first 18 months following application of the wood ash. For this, 50 untreated plots (35 x 35 m), 50 plots in which 10 Mg ha^{-1} of wood ash was applied and 12 plots in which P fertilization (100 kg of ha^{-1} P partially acidulated, 0-29-0) was included.

Effect of ash depended on the type of soil and the plantation age. During the 18 months the pH of the soil increased in most plots and available Ca and Mg also increased. In some cases, however, the pH of the soil solution decreased, which coincided with high NO_3^- values, suggesting an enhancement of soil nitrification processes. Concentrations of heavy metals were below of the UE limits and were not different to those in the untreated plot

Evolution of metal concentrations in edible mushroomsfollowing municipal sludge application on forest land

AL Thomas-Chèry(1), H Domengine (1), J Balet (1), L Denaix (1), M Benbrahim (2), JM Carnus (3)

(1) UMR INRA-ENITA TCEM, BP 81, 33883 Villenave d'Ornon Cedex, France
(2) ONF – Office National des Forêts
(3) INRA, Unité de Recherches forestières, 69 route d'Arcachon, 33610 Cestas Cedex, France

Abstract

In France, sludge application on forest lands is currently forbidden. But the increase of sludge production concomitantly to the decrease of their contaminant content implies a new evaluation of the legislation. Therefore, a network of forest sites was set up in 1999 to investigate the environmental effects of sludge application (Benbrahim *et al.*, 2003). At these sites the transfer of metallic contaminants through the different compartments of the ecosystem (soils, vegetation, and fauna) was investigated. In this context, fungi were particularly studied as they are known to be metal accumulators (Kalac and Svoboda, 2000). Some of them are edible and commonly eaten by wildlife or humans. In such conditions, fungi can promote the transport of metal contamination to animals and humans.

The aim of this poster is to examine the metal accumulation in carpophores of edible mushrooms after application of municipal sludge.

Experiments were carried out at six sites of maritime pine forests in the South-West of France characterized by maritime humid climate and moderately drained soils varying from Humic to Ferric podzols. At each site, one or several types of municipal sludge were applied at a moderate level (3 tons dry matter sludge per hectare and per year): liquid sludge, solid sludge, solid limed sludge and composted sludge. Control plots were included at each site.

Edible mushrooms were collected in autumn 2001 and autumn 2003 on control and amended plots. In autumn 2001, all the edible mushrooms on a surface of 1 square-meter were collected and pulled together to constitute a mixed sample. In autumn 2003, only two species, *Boletus edulis* and *Hygrophoropsis auranthiaca* were collected and analyzed. The samples were brushed off, dried and milled before chemical analysis. Cd, Cu, Pb and Zn concentrations were determined on all the samples and As, Hg, Se on some of them. Samples of surface soil (0-20 cm) were collected from each site and analysed for pH-water, organic matter content and metal concentrations. Statistical analysis was performed (Variance Analysis) to evaluate the statistical

significance of the differences in mushroom trace element concentrations between treatments at each site.

Results showed a high variability for trace element concentrations in mushrooms collected from control areas. No significant correlation was found between soil parameters (pH and trace elements concentrations) and mushroom trace element concentrations. Pb, Cd or Hg concentrations in carpophores were significantly increased by liquid sludge application at 3 sites. This effect seems to be more dependent on mushroom species and sludge type than soil parameters. As and Se concentrations in carpophores were not affected by sludge application even if the concentration of trace metals increased in the soils.

These results are site and sludge-type dependant. They depend also on the mushroom species: *Boletus edulis* accumulates more Cd, Cu and Zn and less Pb than *Hygrophoropsis auranthiaca.*

References

Benbrahim M., Denaix L., Carnus J.M., Timbal J., Chossat J.C., Scheifler R., Gomot de Vaufleury A., Badot P.M., Tricot A., Lolive J., 2003. Effet environnementaux des épandages de boues de stations d'épuration urbaine en plantation de pin maritime. Tercé M (dir.). Agriculture et épandage de déchets urbains et agro-industriels, Dossier de l'environnement de l'INRA n°25, Paris, pp 95-106.

Kalac P., and Svoboda L., 2000. A review of trace element concentrations in edible mushrooms. Food chemistry 69, 273-281.

Experimental studies on sewage sludge utilization in woodland restoration in Eastern Spain

Valdecantos A.[1]*, Fuentes D.[1], Cortina J.[2], Vallejo V.R.[1]

1 Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM), C/ Charles R. Darwin 14, Parque Tecnológico Paterna, 46980 Valencia, Spain

[2] Dept. Ecología, Universidad de Alicante, Ap 99, 03080 Alicante, Spain

** Author e-mail: a.valdecantos@ua.es*

Abstract

Sewage sludge is a by-product of wastewater treatment plants. Recent estimates indicate that the total amount of biosolids produced in the European Union (considering 15 Members and excluding Italy and Sweden) in 2005 will exceed 8.300,000 Mg dry matter (European Topic Center on Waste - European Environmental Agency). Around 55 % of the total biosolids are expected to be reutilized and recycled, but there will still be 45 % that will be disposed in landfills, in surface waters or incinerated. In the Region of Valencia (Eastern Spain) 90 % of the biosolids produced in 2002 were suitable for agricultural application, according to current regulations, but only 78 % of this was used for such purpose (F. Llavador, pers. comm.). As a result, more than 350 Mg of both nitrogen and phosphorus were lost by dumping and incineration in 2002.

Mediterranean woodlands are frequently degraded due to long-term land use and disturbances. In the last decades fire frequency has increased in the whole area and ecosystems show evidences of reduced resilience (Díaz Delgado et al. 2002). Human intervention may be needed to restore pre-disturbance conditions or to accelerate natural aggrading processes (Sánchez Marañón et al. 2002). The 3rd draft of the Working Document on Sludge that the European Commission is currently considering includes sludge applications on tree plantations, re-afforestations and land reclamation. But suitable techniques to enhance the benefits from organic amendments and to reduce environmental risks are not currently available in the Mediterranean region

In the last 10 years we carried out several research and demonstration projects in the region of Valencia (E Spain) focusing on the use of sewage sludge for the the restoration of degraded lands.

In 1997 we applied low amount of dry and liquid sewage sludge (10 Mg dry weight ha^{-1}) to a degraded area planted with *Pinus halepensis* and *Quercus ilex*. Seedling survival was not affected by the amendments. Seedling growth increased by biosolid application, and biomass allocation patterns changed, but effects were short-lived.

In a pilot project started in 2000 on 3 ha area, we applied economically feasible doses within the ranges recommended for agricultural applications (220

to 360 Mg d.w. ha^{-1} of fresh biosolids containing 20 % dry matter as estimated on a planting hole basis). Most treatments resulted in increased seedling mortality and higher growth. Increases in salinity, and cracks and hollows created close to the seedling roots as sludge dried out were probably responsible for elevated seedling mortality. From an economic point of view, this type of application was feasible as compared with landfilling.

In 2003 we tested four application rates, ranging from 15 to 60 Mg d.w. ha^{-1}, of air-dried, composted and fresh sludge. Preliminary results show that application rates from 15 to 30 Mg d.w. ha^{-1} were most successful in terms of seedling survival and growth. In this presentation we discuss further ecological and technical constraints to reuse biosolids for the restoration of degraded Mediterranean woodlands.

Acknowledgements

This paper presents the results obtained in the following research projects: REDMED (UE DG XII Nº ENV4-CT97-0682), BIOMON (CICYT P4 REN2000-0181P4-03), and CICYT - FEDER (Nº IFD97-1117-C01). Fundación CEAM is funded by Generalitat Valenciana and Bancaixa.

References

Díaz-Delgado R., Lloret F., Pons X. and Terradas J. 2002. *Satellite evidence of decreasing resilience in Mediterranean plant communities after recurrent wildfires*. *Ecology* 83(8): 2293-2303

Sánchez-Marañón M., Soriano M., Delgado G. and Delgado R. 2002. *Soil quality in Mediterranean mountain environments: effects of land use change*. *Soil. Sci. Soc. Am.. J.* 66: 948-958