Is the management of forest soil fertility at a turning point? A brief conclusion

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It is quite a challenge to produce a definitive conclusion around a question like the fertility of forest soils, because this fertility evolves with time and is under the pressure of management practices and climate. We therefore chose to present three different points of view on this topic, two from young researchers who contributed to the workshop and the third from a senior researcher in forest ecology with only little background in soil science.

Gregory Van der Heijden, junior scientist

"The REGEFOR workshops are always important events in the community of forest managers and forest scientists. These workshops are an opportunity for these two communities to meet, share knowledge and discuss challenges that the French forest already is or will be confronting in the near future. I would like to emphasize that these exchanges are really bidirectional. During their presentations, the researchers describe the advancement of scientific knowledge. Through their questions and during the round-tables, discussions and brain-storming sessions, the stake holders share their experience, the problems they encounter and their concerns. Such exchanges are very useful for all participants: the advancement of science contributes to an improved and sustainable management of forest ecosystems while the expertise of managers helps to frame and focus novel research questions.

After my forest engineering studies, I joined a forest research unit with precisely this view of how research should work: a useful, problem-oriented and shared research that works hand in hand with stakeholders. There are indeed many other opportunities to foster similar exchanges, but the REGEFOR workshops remain a highlight in this respect. That is why it was with great pleasure that I attended for the first time this workshop.

The context for a sustainable management of forest soil fertility was set during the different talks. It displays three major components: (i) the changes of forest management (shorter silvicultural rotations; increased biomass export; enhanced slash harvest; mechanization of harvesting), (ii) the changes in the regime of atmospheric deposition, and (iii) climate change (increasing average temperatures, increased occurrence of extreme events like storms or drought events, lengthening of vegetation seasons or increased atmospheric carbon dioxide content). These changes may severely impact forest ecosystems and particularly soil fertility in the long term.

In such a context of change, management strategies need to be adapted to such changes if they are to be sustainable economically, ecologically and socially. The 2013 REGEFOR workshop 'Is the management of forest soil fertility at a crossroads?' strongly contributed to this objective of sustainable management. If I were to keep only one take-home message, I would choose the definition of soil fertility. Soil fertility has three major components: (i) a physical one (structural stability, physical properties, water retention capacity….); (ii) a chemical one (chemical soil properties, nutrient pools…) and (iii) a biological one (biological activity in the soils, micro and macro fauna…). This definition is very useful as it summarizes the complexity of soils and the absolute need to take all three components into account when aiming at a sustainable management of forest soil fertility."

Ludovic Henneron, PhD student

"French forests are mostly semi natural ecosystems under human management. Management aims at optimizing the diverse ecosystem services provided by forests, the main one being the production of wood for the industry. Nevertheless, and as opposed to agro-systems, forest ecosystems do usually not receive any artificial inputs of nutrients through fertilization while they frequently grow on rather poor soils. In this respect, forest are fragile ecosystems, and maintaining their productivity depends on an efficient nutrient recycling through the biogeochemical cycles particularly in the soil compartment. Maintaining the fertility of such soils is therefore a major issue.

Climate change and the changes in management required to mitigate its amplitude and to adapt to a new climate, may have major consequences on forest soil fertility. As an example, the increasing need for renewable energy in replacement of fossil fuels results in an increasing pressure on forest ecosystems, due to the increased need of wood biomass for energy. We anticipate an enhanced export of woody biomass and consequently of nutrients out of forest ecosystems. Assessing and quantifying the impact of such changes on the fertility of forest soils is an important concern for research and for a sustainable forest management. This was the main aim of the present REGEFOR workshop.

We are aware that forest soil fertility depends on complex processes and interactions between soil compartments. If the concept of fertility is quite straightforward, describing and quantifying the actual fertility remains a challenge given the large variability of soil properties according to tree species, climate… as well as the difficulty to select reliable indicators and monitoring protocols.

Major scientific advances were obtained recently in our understanding of the processes governing soil fertility in forests. With respect to the abiotic component, isotopic markers have become a powerful tool to trace the cycle of nutrients in the forest ecosystems. Important advances were made in modeling soil processes; they now provide a quite comprehensive view of the overall nutrient cycles in forest ecosystems. The characterization of microbial communities and their taxonomy with tools from genomics and molecular biology yielded major advances in soil biology. Nevertheless, the biotic soil component remains poorly understood, and there still is a deficit in our understanding of the importance of soil organisms, as well as of their interactions in nutrient cycling and maintaining the level of soil fertility. Interestingly, biotic processes are still poorly taken into account in the nutrient cycling models.

This novel knowledge should be transferred to forest managers and lead to new recommendations for management practices with a limited impact on soil fertility as well as decision supporting tools for managers. Questions will nevertheless arise around the social, technical and environmental

feasibility of these recommendations, as well as around changes in the organization of the bio-energy industry and of the harvesting procedures. Answering such complex questions is a prerequisite for an efficient knowledge transfer from research to practice."

Erwin Dreyer, senior researcher in functional forest ecology

"Forest soil fertility was seen as a stable parameter defining the potential productivity of forest sites. It was the basis of site indexes and used to produce detailed site catalogues. Yet, this parameter is surprisingly prone to significant shifts with time and may evolve at time scales shorter than the life cycle of trees in forest stands. Similarly to many other features of forest ecosystems, soil fertility underwent a complex history, with a tight dependence to anthropic factors like silvicultural practices. In Europe, important fertility transfers occurred, mainly under the form of exports out of the forests towards agricultural areas. Harvesting wood (often young wood and quite rich in nutrients) for fuel has been the main source of energy during centuries. Extensive grazing by cattle and foraging by pigs was another source of nutrient export out of the forest ecosystems. Centuries and even millennia of such practices resulted in poor forest productivity, with stands confined to the less fertile soils and submitted to heavy harvest that often largely exceeded current production and was well beyond sustainability. The situation started to change in the mid-19th century, when coal was substituted to wood as the main source of energy, followed by oil and natural gas (methane), and when the population density began to severely decline in the rural areas of Western Europe. Recently, significant nitrogen rich deposits in addition to reduced wood harvests contributed to additional fertility for the forest soils. Many indexes revealed an increase of this fertility (mainly under the form of N availability) during the last decades. Particularly efficient indicators were the changes in understory vegetation or in the complex isotopic signatures in the soils. The situation seemed clear, and forest soil fertility has been increasing, in the long run with some negative side effects like acidification and imbalances among nutrients.

Nevertheless, the analysis of nutrient budgets and of nutrient cycling in forests revealed that the balance between nutrient export and import remained a sensitive issue, and that a net export of nutrients from forests could start again if the wood for energy industry, expected to partly substitute the consumption of fossil fuels, results in massive harvests of slash. This is not yet the case, but anyway the talks and discussions during this workshop showed that the question of forest soil fertility remains a major issue in forest ecology and management. It probably is of little use to expect 'natural' processes to maintain, not to mention increase, the fertility in the long run. This concern is shared by researchers and forest managers.

A second very visible change is the spectacular evolution in soil science applied to forest ecosystems during the last decades. The use of stable isotopes as tracers, with protocols based on the variations of natural abundance or on artificial labeling, led to an improved understanding of the nutrient dynamics within the dense networks of forest observation and experimentation sites helped accumulate data over long time spans that revealed sometimes unexpected deviations of nutrient availability. Finally, the raise of new approaches in soil microbiology like the use of the microbial metagenome as an index of the biodiversity of the microbial communities (mainly but not only fungi and bacteria) opens avenues for research that were unexpected a few years earlier.

The present REGEFOR workshop contributed to summarize the knowledge gained during recent years and of the remaining concerns and open questions. It also helped open new perspectives

about such rather ancient questions. Maurice Bonneau, who passed away recently, would certainly have appreciated to witness this evolution in the field he contributed to develop decades ago."

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