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Soil and Tree Disturbances Due to Forest Operations - an Unresolved, Interdisciplinary Issue

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Summary

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Forest soils are a crucial node for the various environmental and technological processes in the managed forest. In the paper authors review the compexity of the impacts on the forest ecosystem caused by road construction and logging operations and discuss the future research activities in that field. The interdiciplinary approach is emphasized and research priorities are suggested. The studies are needed where structural parameters of the soils are related to the plant vitality. This will help us to understand the forests response on the impacts and enable us to develope the practical techniques for soil and stand protection during forest operations.

Introduction

Forest soils are a world in themselves and a crucial node for the various environmental and technological processes in the managed forest. Undisturbed soils contribute vitally to the effective retention of the material and energy flow through forests. Such conception has been mostly recognized through mistakes during work in managed forests, where additional and often contradictory objectives have to be met, unfortunately not without consequences for the soil and trees.

The scientific response to that problem during the last twenty years 'produced' an enormous quantity of studies, which have been trying to enlighten particular aspects of the forest operations' impact on forests. Today, excellent summaries about soil compaction (HILDEBRAND 1991, WASTERLUND 1994), soil erosion and mass movement (STANDISH & al. 1988), water quality and quantity

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changes (ADAMS & RINGER 1994) and vegetation damages (MENG 1978, BUTORA & SCHWAGER 1986) exist, however the puzzle is far from being solved.

The purpose of this paper is to inform the scientists from related fields with the research needs, to warn against overestimating the particular aspects of the subject and thereby encourage the synthesis that is urgently needed.

Forest technique - the source of disturbances

Construction works in the forest, site preparation and logging operations are the primary cause of mechanical impacts the on site and to the stands. They all occur in the 'same forest' hence they have to be evaluated simultaneously.

Logging is the most costly phase of the wood transport. It determines the extent, the structure and the layout of permanent and temporary roads in order to minimize transportation, construction and maintenance costs. Due to the steadily rising costs of labor, logging has been mechanized and today the majority of the timber extraction is done by tracked or wheeled vehicles. This trend will continue in the future, even though the silvicultural practice will be pushed towards selective cuttings. Increased traffic on the roadless areas of lighter machines is expected in the future (WASTERLUND 1995), therefore the impacts will continue to cumulate in the forests.

Environmentally friendly machines already exist, however they can not be used in many forests due to technical and/or economic conditions. Regardless of further development of forestry machines, forests under small scale private ownership will continue to be affected yearly by inadequate machinery on ineffective road networks (ROBEK 1994). Forest operations in 'action' are actually the last step, where all mistakes in planning, approving and training can not be corrected nor hidden. Contemporary methods for quality control in forest operations are too trivial to precisely adress the impacts or not adapted for practical work.

Forest site responses to soil disturbances

Effects on soils

Natural forest soils have a complex layered structure, containing obstacles like roots or stones and are always covered with organic material. As a reaction to the dynamic forces of vehicle and load, the morphological disturbances of the topsoil (displacement, mixing, rutting) and/or structural disturbances of the mineral soil occur.

The areal extend of the visual soil disturbances in selective cutting can range from 5 - 30% (STANDISH & al. 1988) after single action. With next cuttings it can increase due to previous disturbances and decrease due to natural recovery. The temporal dynamic of the surface disturbances is up to 10 years, if they are not supported by severe structural disturbances of the mineral soil.

Visual disturbances do not reflect structural changes. The former can extend beyond the contact area and vary with depth. The degree of the structural disturbances depends on many factors (soil moisture, contact pressure, texture, obstacles) and it should be expressed with various parameters (dry density,

penetration resistance, macroporosity, air permeability, gas diffusivity, ...). As a rule of thumb we can say that a machine with less than 50 kPa static pressure will not cause structural disturbances, when operated under the soil moisture below field capacity (MATTHIES &. al. 1995). Otherwise severe disturbances can be expectedand they can persist for decades.

Effects on trees

Disturbed soil is also the substrate for tree growth and the roots are the most severely affected, since they have to develop in an altered environment. Roots simply need water, nutrients and oxygen at the same time and almost at the same place (HILDEBRAND 1994). They are not affected by the disturbed structure itself, but by the processes that depend upon the structure. The major part of the net photosynthesis is used below ground for the continuous replacement of small dying roots, for which the oxygen is needed. The small roots are 'engaged' with the mychorrhizae fungi that protects tree roots against pathogens. What happens with the short root's turnover in compacted soils and what it means for the tree's vitality and growth we do not know.

The fine and medium roots beneath the surface can be torn away during traffic movements, but wounds on the roots with a diameter of over 20 mm in the root collar region are crucial for rot formation. Since the machines operate in the stand the wounds also cumulate on the stem, usually up to 1 meter high. They may reduce the wood quality, cause tree rot, reduce growth and decrease income by up to 15% (MENG 1978). The responses of the tree growth on harvesting impacts are seldom straightforward due to numerous influencing factors. Edge effects of trees standing next to skid trails interfere with the growth decline due to rot formation and root damages can be compensated due to more light and free soil space on the track side. If we also take into account the tree's different requirement during its long life we will find that generalizing the results from the tree to the stand may be very hazardous.

Effects on other vegetation and fauna

We have very little data about the disturbance responses on non-commercial vegetation. The responses are faster and more dynamic but they are difficult to detect and evaluate. An even faster response can be observed in pedofauna, but very few studies so far have concentrated on this topic. In both cases the soils natural variability usually exceeds the disturbance effects itself. The impacts on forest fauna, the large areas of forest have to be taken into account and than the contribution of harvesting operations to the observed effect in populations is very difficult to prove and judge.

Effects on management goals

In managed forests environmental and social objectives have to be reached beside timber supply. Several catchment studies have shown that we hardly charge solely forest operations for the changes in water quality and

quantity. The increased water peaks and sediment yields are evident in large scale clearcuts but in the selective cuttings the results are not consistent. The same can be said about the relations with the other management goals. We can agree on large impacts but we are not able to fine tune forest operations on the basis of existing knowledge.

Challenges and priorities

It is obvious that practical environmental protection is a matter of economics, where a minimax task has to be solved. Although some countries have set allowed soil disturbance standards on the basis of the soil physical parameters, they are often argued, rarely controlled and never taxed. We must first understand the vegetation response on harvesting impacts, therefore more studies are needed where structural parameters are related to the plant vitality. Recent improvements in soil analytical methods have encouraged us to relate the physical parameters with the plant physiology. This task has, in our opinion, the outmost priority and the question can not be solved without tight cooperation between technical and biological sciences. The nature of the forest response should be the basis for holistic quality control in forestry.

The next level of the priority should be dedicated to the development of a set of practical guidelines and simple impact evaluation methods for forest practice. They have to summarize the existing knowledge although not simplify the phenomena. We have to introduce the impact vector into the forest management planning as well as in forest operations. The task should be done with cooperation between researchers, forest managers and forest extension services.

The last priority level is dedicated to fulfill the gaps in our knowledge about the enormous variability of the effects of the harvesting impacts on the forests, as well as to routine soil monitoring programs and to single aspects oriented studies.

Conclusion

All wood transport related activities increase the material and energy flow through the forest ecosystem. They are in contradiction with the 'essence' of the forest, therefore it is obvious that the disturbances can only be decreased but not avoided. But we have to look for another way round, too. In managed forests transport should be considered as an important, complex multi-objective oriented tool for achieving the goals within the ecosystem management, therefore creative progress in that field is really waiting for us. Do not hesitate!

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