Fourth International Conference on Forest Vegetation Management
Nancy, France, June 17-22, 2002

Synthesis: Ecological Impacts of Forest Vegetation Management

J. L. Michael [1] and M. Hermy [2]
[1] USDA Forest Service, Southern Forest Experiment Station, Auburn, Alabama 36849
[2] Catholic University of Leuven, Laboratory for Forest, Nature and Landscape Research, Leuven, Belgium

Ecological impacts of forest vegetation management are highly complex with many interactions. Interactions are bounded on the one hand by hierarchical levels from genes to species to ecosystems and on the other hand by the tools used and the intensity of management applied to each level of possible interactions. Some impacts are easy to measure, but impacts become more difficult to measure and understand as the scale increases from the stand to landscape level. At the larger scales tools and terms are often not well defined among scientists in the global community.

Our assignment is to provide a synthesis of the presentations dealing with the impacts of forest vegetation management on the ecosystem and the effects of silvicultural practices on vegetation dynamics.

We will approach this task by providing some statistics on the oral papers and posters presented, some thoughts on the predominant themes for this meeting, missing links essential to forest vegetation management (integrated approaches) and a few concluding comments.

Every activity in the forest (intervention, recreation, etc.) has associated with it an impact on the ecosystem. Environmental impact papers were few in number. It is tempting to credit Dr Zedaker with this result for the dramatic decrease in environmental impact papers due to his statement at the last meeting (IFVMC3) "Ecosystem effects... Not! Advocacy...Oui!" At that time, he proposed that we already know enough about environmental impacts. We do not agree that his comments are responsible for the fewer numbers of impact papers nor do we agree that we already know enough about environmental impacts. We believe that the culture in which the meetings are held greatly impact the contributions. When these meetings were held in Auburn, Alabama, 50% of the papers and posters (139) related to herbicides and only 6% dealt with diversity. Now in the context of Nancy, France we find ourselves in a land that has greatly reduced its use of herbicides for forest management. Only 18% of the papers and posters (156) dealt with herbicides. This reduction has come about for many reasons and we will explore some of those. Approximately 28% of the 156 papers presented at this conference dealt with the issue of ecological impacts. Most of these papers were directly related to species diversity (Table 1).

Table 1. Contributions reporting ecological impacts from forest vegetation management.

Category	Oral	Poster	Overall
Ecosystem Impacts	4	5	9
Genetic Diversity	-	-	-
Species Diversity	18	10	28
-*Plant Species*	13	4	17
-*Mammals*	3	1	4
-*Amphibians*	1	2	3
-*Birds*	1	0	1
-*Invertebrates*	0	2	2
-*Mycorrhiza*	0	1	1
Ecosystem, Community, Landscape Structure	4	3	7
Overall	26	18	44

The dynamics of forest vegetation management and their ecological impacts are shaped by interactions of multiple layers that issue principally from land ownership, requirements of the dominant species under management and the management approaches utilized to achieve land owner objectives. Where forest land is owned or held in trust by the government for the people, management objectives are frequently determined by the public. Where forest land is considered production forest and the objective is maximum production of fiber, a different set of management approaches are applied. Ownership then largely determines the intensity of management. Management objectives also shape decisions to manage for production of various species. When forests are managed for climax or near climax species (ie. oak, beech, other shade tolerant species) as opposed to successional stages (ie. southern yellow pines), vegetation (plant competition) management utilizes very different strategies and tools. So, for example, management for oak and beech (shade tolerant species) allows for greater reliance on natural or spontaneous regeneration, use of cover crops, preemptive colonization and all-age multispecies stands. In the southern USA, where management of loblolly pine (and other species) for fiber including pulp and construction materials predominates, the aim is to interrupt old field succession to insure maximum productivity. Loblolly pine is a shade intolerant species and so use of cover crops, preemptive colonization and presence of a large number of other species is counter-productive in this tree-farming approach.

The physical appearance and biological composition of a stand of trees at any given point in time and space are dictated by the interactions of dominant species requirements, ownership, government regulation, management and former history. For example, in New Zealand, 70 % of forest lands are publicly owned and these are native forests set aside for preservation. Harvesting is not allowed. Another 15% are privately owned native forests where sustainable harvest is allowed. The remaining 15% is privately owned wood-producing land where herbicide use is perhaps the most intensive in the world. In Flanders, Belgium government regulations prohibit herbicide use so also private forests (70% of forests) are not allowed use of herbicides, but there is a government supplement paid to landowners who open their land to public use. Here the aim is to produce 'natural' looking mature forests and aesthetics is an economically valuable forest attribute. However, herbicides are an essential tool in forest vegetation management in many countries of the world, especially where intensive management, short-rotation forestry is the principal approach. In Canada where 90% of forests are publicly owned, herbicides approved by the Provinical government may be used and may even be applied directly to standing water and wetlands. In this situation, maximum fiber production is the main objective and Canada is the world's leading exporter of forest products. In the USA, approximately 70% of the forest land is privately owned and much of that is intensively managed using herbicides registered for forestry by the US Environmental Protection Agency. Public lands are managed with the use of herbicides, but at a much lower intensity than on private lands. In the USA, unlike Canada, herbicides may not be used in wetlands or sprayed directly into water unless they are registered for aquatic weed control.

We have seen that the dynamics of forest vegetation management are strongly influenced by the two main approaches related to management objectives: natural and artificial regeneration. Natural or spontaneous regeneration may be used in some cases for fiber production and may be applied to intensive or extensive forestry. Systems like shortleaf pine, longleaf pine, and many hardwood species are amenable to natural regeneration. Most often we have seen here in Europe that natural regeneration aims more to produce in the long term a natural-looking forest than the more short-term high-yield biomass production (compare 120-180 year rotations in France to 20 year rotations in the southern USA). A few papers dealt with guiding species composition on a site to arrive at the composition of the managed forest. This concept is diametrically opposed to the artificial regeneration method utilized in many countries of the world where high-yield biomass production is the objective and where monocultures of crop species usually make up the managed unit. The 'monoculture' management approach produces tree farms in which the crop species is selected because of local site conditions that will maximize productivity. Even in these tree farms much biodiversity exists. In addition, the requirement to protect water quality in most countries results in the leaving of zones (streamside management zones, buffer zones, riparian areas, etc.) of more or less natural vegetation around water courses which act as seed sources for maintenance of native species and species diversity both in the conserved area and in the managed stand.

Environmental impacts of forest vegetation management were reported in 5 categories: community and soil disturbances, synthetic herbicides, natural herbicides, preemptive colonization of cover crops, and diversity issues. Diversity issues, while a semidistinct topic, has underlying threads that are carried through all the other issues.

The principal issue surrounding soil disturbance as a result of forest vegetation management was that of diversity. Gondard,Deconchat and Neary et al. reported highly variable results in studies of the impacts of disturbance on species diversity. Neary reported increases in the occurrence of non-native invasive species correlated with disturbance. Wagner and White (conifer sites in Canada), Dumas et al. (pine plantations in France), and Berthelot et al. (poplar plantations in France) demonstrated the inability of traditional diversity indices (Shannon and Simpson) to distinguish the effects of cutting, mechanical weeding and chemical weeding. There were no reports on the impacts of soil disturbance on erosion, sediment loading of streams, or direct stimulation of seed banks.

The impacts of herbicides on the environment were reviewed and additional information presented for imazapyr, glyphosate and triclopyr. The potential for adverse impacts of herbicides has often been reported and feared, but actual adverse impacts of forest herbicide use are seldom reported. Judicious choice of active ingredient, formulation, and application method coupled with a respect for sensitive sites and good neighbor policies generally result in effective herbicide applications with minimal to immeasurable impacts. Some minor temporal and spatial impacts on the ecosystem may include temporary shifts in species diversity and abundance, but these are not long lasting and no changes in ecosystem function have been reported as a result of the herbicide used to the exclusion of the management itself. Use of motor-mechanical vegetation control has been reported and is often presented as a substitute for herbicides. However, the safety of motor-mechanical methods is normally assumed and seldom supported by scientific studies. While there were many discussions at these meetings about motor-mechanical vegetation control, there were no reports that considered the environmental impacts or worker safety issues that accompany motor-mechanical control: carbon monoxide emissions, spillage of gasoline and oil products, fire hazards, and worker accidental injury to name a few.

Thompson et al. reported concentrations of glyphosate observed in the field when glyphosate was applied directly to wetlands and streams in Canada were considerably below those shown to cause adverse impacts on amphibians and concluded there was no significant risk to sensitive amphibian larvae. Michael reported that offsite movement studies indicate stream contamination is very ephemeral, lasting only a few minutes at the highest concentrations which are below USA health and safety standards, and for less than 3 months at extremely low concentrations, usually at or below analytical capabilities. When stream contamination occurs it is at such low levels as to be biologically unimportant. The possibility exists for chronic exposure impacts when carcinogenic, mutagenic or teratogenic herbicides are used, but none of the herbicides registered for forestry use in the USA are known agents in these classes. In addition, technology exists and is in general practice in many parts of the world which further reduces herbicide concentrations in streams draining treated areas (use of streamside management zones).

The pressure to reduce synthetic herbicide use has resulted in the application of 'natural' herbicides, bilanaphos and citronella oil. However it was pointed out that bilanaphos, a "natural" trimer produced by a fermentation process using *Streptomyces sp*. is much more toxic than the synthetic monomer glufosinate (a registered synthetic herbicide) and may be environmentally less acceptable in terms of impacts. Bilanaphos inhibits glutamine synthetase, an enzyme found in livers of mammals. Most synthetic herbicide development has focused on enzyme systems or metabolic processes not found in mammals in order to reduce potential mammallian toxicity. Similarly citronella oil is a natural coumpound, but the very high application rates required for weed control (~500 kg/ha) raised questions about its environmental safety. Adverse impacts are a function of both exposure and toxicity. Use rates similar to those required for citronella (more than 500 times higher than the synthetic glufosinate to which it was compared in this case) raise the issue of potential adverse impacts for non-target species based on high exposure. Another issue is the land base and agricultural practices (and their environmental impacts) required to grow sufficient amounts of plants from which to extract the active ingredient to supply a market need, even a very specialized market.

The replacement of synthetic herbicide technology with the use of nurse crops or in other terms, preemptive colonization, has been around for a long time. West in New Zealand reported at the IFVMC2 on nurse crops for weed control in reforestation and Reinecke has been using the system for 20 years in Germany. Frochot et al. reported a slightly new approach in afforestation experiments using species which are not naturally very strong competitors, but which sowed at an appropriate density preclude the growth of serious competitors. Schutz reported on the necessity of using this technique in Swiss forests because of a ban on herbicide use stipulated in forest legislation since 1991. This technique, it should be pointed out, is not universally applicable. That is to say that it has not been applied to shade intolerant pine species except in the case of the New Zealand work previously reported and in that case glyphosate was used as a site preparation treatment prior to seeding. The results of Miller's COMP research indicate use of pre-emptive colonization may result in reduced productivity in some locations, especially in the southern USA. The most obvious environmental impact of pre-emptive colonization is the introduction of a very large seed bank, especially when the species are not native. Issues of non-native invasive species is a growing problem world wide and care must be taken to carefully engineer the mix of seeds used in these applications to insure against extreme changes in biodiversity. Little is known about the impacts of this technique on faunal diversity, mycorrhizae, soil microbes, etc.

Impacts and Diversity Research Needs may be summarized as follows:

- Consideration of temporal and spatial scale in discussions of observed treatment responses for vegetation management studies.
- Better understanding of how pollutants move off site into streams (overland flow, macropore flow, contributions from ephemeral drains, etc.)
- What are the impacts of fertilizers, tank-mixtures of 2 or more herbicides, and their interactions on the terrestrial and aquatic ecosystems.
- What do we really know about endocrine disruptors, gender aberrations, morphological aberrations and herbicides?
- Comparisons of treatment responses (impacts) for various management tools (herbicide, motor-manual, preemptive colonization, etc.) to provide managers with more information about the approaches available to them and the relative severity of adverse impacts.
- Holistic studies that identify ranges of natural variability as a means of comparing observed treatment responses to determine nature of impacts. This gets to the issue of replicated studies with good control plots and considerations of temporal-spatial variability.
- Scope of diversity research and response variables. Most papers have reported on vascular plants above ground. Bryophytes and epiphytes were not well represented. Fungi, microbes, and invertebrates (representing 60% of biodiversity on earth) are not covered.
- Research is only as good as the tools used and the measurements taken. There have been several reports now over the last 4 meetings that suggest or state that the widely used Shannon-Weiner and Simpson indices do not identify changes in diversity resulting form forest vegetation management. We need to determine the usefulness of these indices and perhaps identify more sensitive tools (e.g. various species guilds or plant functional types) measuring disturbance impacts.
- Control measures effective against invasive species, particularly non-native species.

Concluding Remarks

Many different management objectives require many different ways of getting there. We need to come to a fuller understanding and acceptance of the needs and objectives of various forest managers. It is important to understand why we do things differently. Perhaps we should accept that a diversity of approaches will be essential to accommodate for local demands and ecosystem properties. Globalisation - doing everywhere the same - in this diverse world is not a good point or an aim.

Our understanding of diversity issues is hampered by our tendency to fragment diversity into studies of vascular plants without full consideration of other organisms. It has been said during this conference that traditional diversity indices are too insensitive to detect treatment responses. There are two possibilities here: Shannon's index on diversity and Simpson's index of richness are insensitive to the perturbations caused by vegetation management or they are indeed sufficiently sensitive and our prejudices or biases are telling us there is a difference when there is not. In the latter case, it may be that we need to be measuring additional parameters to more fully describe changes we think we see. Perhaps, as in the Braun-Blanquet school of phytosociology, we need to add cover, importance values, sociability indices, and look at specific species groups or plant functional types etc. to our list of tools.

Two extremes have been voiced at this conference with respect to the management of forest vegetation: herbicides are a good and useful tool with few lasting adverse impacts on the environment vs use of herbicides is not scientifically defensible because herbicides are dangerous and the same job can be accomplished with other management systems. It should be remembered that forestry practices have evolved around the globe to meet local needs and they have been refined over more than a hundred years. Practices that work in loblolly pine the Southern US, radiata pine in New Zealand, Eucalyptus in Australia or the Douglas Fir/Sitka Spruce/Western Red Cedar forests of Canada are not necessarily the best practices to be used in oak-beech forests of France. While fiber productivity may be enhanced through use of herbicides and intensive control of competition, Europeans - partly because of high populations density in many parts of Europe - have attached other values (aesthetic, recreational, etc.) to their forests which are not considered in production forests of many other places.

The perception of herbicides as extremely dangerous to the environment has given rise to two prevalent themes at this conference which have not proven out. The first is that naturally occurring herbicides are much safer than synthetic, however we have seen that bilanaphos may be more toxic than the synthetic compound glufosinate that it mimics and has to be applied at somewhat higher rates to accomplish the same end. Citronella oil is another example which must be applied at approximately 500 kg/ha to accomplish the same efficacy of 0.75 kg/ha of glufosinate. Then comes the issue of production for citronella oil. How much land would have to be devoted to the culture of the plant from which citronella oil is extracted to meet the demands of even a small market. Will these plants grown in monoculture have to be treated with even more dangerous insecticides to insure crop stability? It should also be remembered that the most toxic compounds known are naturally occurring, not synthetic. *Streptomyces spp*., used to produce bilanaphos, is best known for the antibiotic compounds produced by its many species. These antibiotic compounds are particularly potent against fungi and may represent a threat against rhizosphere organisms and therefore site productivity.

The second is by implication that mechanical methods of vegetation management are much safer than herbicides. However consideration of the impacts both to the environment and to individual workers of the health and safety issues should be assessed more thoroughly.