A Review of Efficient Assessment for Forest Damages in United States of America

Zubair Fathi

MSc student of forest management, Faculty of Natural Resources, University of Kurdestan, Iran
ZubairFathi2018@gmail.com

Abstract: The main purpose of this study is investigation efficient assessment of forest damages in United States of America. One of the most serious threats to the forest ecosystems is fire. Damage caused by fire not only affects forests' extension but also their roles and services. Forest fire has catastrophic effects once it extends to nearby populations, affecting lives and properties. International efforts to assess and address forest management have resulted in the development of numerous studies focused on simulations of the evolution of forests Mostly a non-parametric efficient frontier technique, namely data envelopment analysis (DEA) has used for assessment of forest damages. allows the comparison of forest fire damage in USA by computing relative efficiency scores and quantifying improvement targets. The main results from this review study suggest that the regional fire agency and USA policy should be focused on prevention and control programs for which relevant damage savings can be realized. It is our hope that this study can help our governments to better understand forest fire damage control and plan their operational prevention activities.

[Fathi Z. **A Review of Efficient Assessment for Forest Damages in United States of America.** *World Rural Observ* 2019;11(2):27-35]. ISSN: 1944-6543 (Print); ISSN: 1944-6551 (Online). http://www.sciencepub.net/rural. 5. doi:10.7537/marswro110219.05.

Keywords: Forest damages, Forest fire, Forest pathology, Forest management

1. Introduction

Forests provide many benefits to both society and the economy and play an important part in the preservation of natural biological diversity and the mitigation of climate change. They act as effective carbon sinks and as physical air filters contributing to the biomass production. Additionally, forests have an essential influence on the Millennium Development Goals' achievement. Further valued aspects of forests are their wildlife, preservation of biodiversity, carbon sequestration and provision of food, fuel and shelter. Forest damage is a complex problem involving the interaction of exposures to acids and other air pollutants, forestry practices, and naturally occurring soil conditions. Sustainable management of forests is highly important to provide these goods and services. Damage and other disturbances naturally occur in forests and are important for many ecological processes, but an important element of sustainable management is to develop and apply silvicultural practices that restrict forest damage to acceptable levels.

Fungi, insects, game browsing, and abiotic agents such as fire, wind, and drought tore the major causes of forest damage (e.g., Edmonds et al., 2000). In addition, large-scale damage has been strongly associated with anthropogenic air pollution (e.g., Schulze, 1989). Direct visible damage caused by high levels of air pollution has been known for more than a century, but has mainly been detected in the vicinity of soot-emitting industries. However, the effects of acid rain and air pollution have also typically included acidification of surface water and forest soils. Although several experimental studies have shown a negative correlation between plant growth and acidification of forest soils it is less apparent that these effects significantly affect forest condition. On the contrary, few field studies have found clear indications of negative effects of long range air pollution on forest condition.

One of the most serious threats to the forest ecosystems is fire. Damage caused by fire not only affects forests' extension but also their roles and services. Although fires are sometimes essential and beneficial for forest regeneration, they are also detrimental if they are out of control or occur repeatedly in the same area. In fact, it is virtually impossible to exclude fire from most forests, because the efforts to do so can be very expensive. Hence, fire management agencies use the resources allocated to them to minimize what they judge to be the net harmful impact of fire.

International efforts to assess and address forest management have resulted in the development of numerous studies focused on simulations of the evolution of forests. A number of studies analyses statistically the causes of fire in different regions of the world, focusing on the human influence, socioeconomic and environmental variables and weather conditions. Other factors, such as spatial variables, and land cover have been examined with respect to the probability of fire occurrence. Other studies evaluate forest fire risk zones using fuzzy logic methodology as an expert system and contingent valuation method. Additionally, operational research methods have also addressed fire management systems. To the best of our knowledge, no efficiency assessment of fire forest management has been undertaken to date. One reason could be that data on forest fires are underreported at the global level. The aim of this paper is to compare forest fires' damage in USA by computing relative efficiency scores and identifying improvement targets. This benchmarking exercise will hopefully lead to the identification of local best practices and their promotion.

In particular, there exist a number of DEA applications to forest management and forest industry. Thus, several DEA studies have addressed the efficiency of forest management and the potential gains from reorganizing forest districts in USA computes the Malmquist productivity index of eight new Taiwan forest districts after their reorganization. Scientists also studied the efficiency of local forest districts in the Danish Forestry Extension Service, estimating the benefits of potential mergers. The main concepts of forest damages shown in Figure 1.

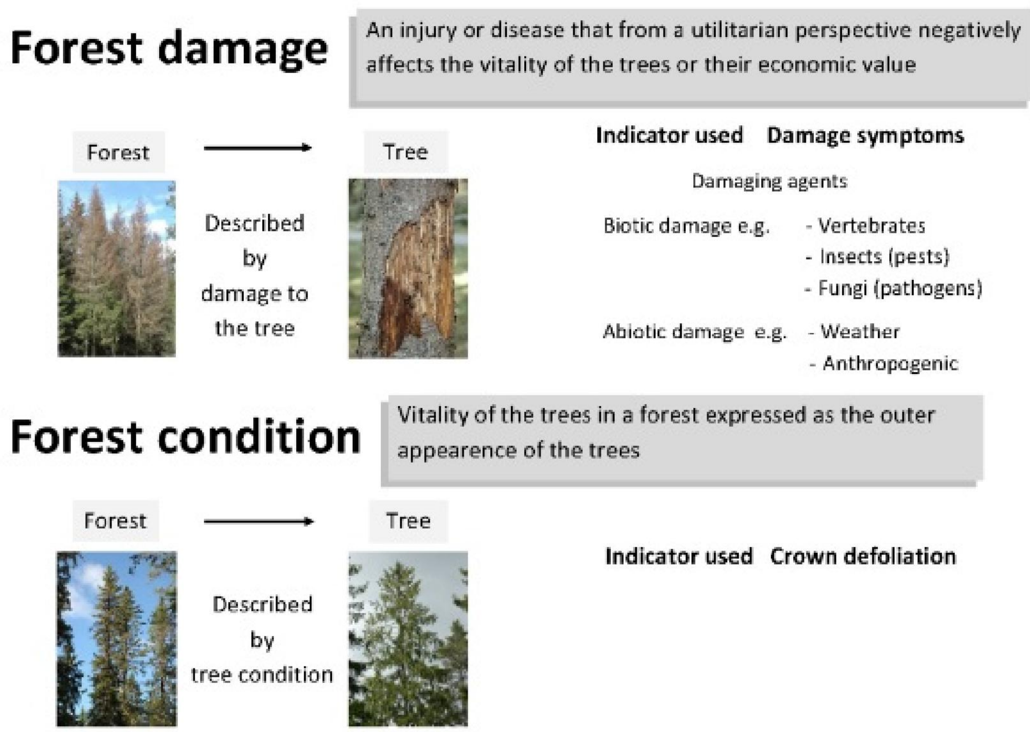

Figure 1. Main concepts of forest damage

After 2000, a decreasing trend in the number of fires and burned areas is noticeable, due to improvements in the fire protection services of the countries, as well as mutual assistance between the countries. The perceived increase in the number of fires in the 1990s is most likely due to an improvement in forest fire data collection methods. Finally, the number of fires in the five SEMS seems to have stabilized over recent seasons.

Forest damage can be seen as an injury or a disease that has biotic or abiotic causes. Manion (2015) defines three different types of diseases that may cause forest damage: (i) biotic (insects, fungi, etc.), (ii) abiotic, and (iii) decline. Unlike the first two, involving specific causal agents, the decline type involves an interacting set of factors, and the exposure of trees to long-term factors that predispose and contribute to the decline. This concept was further developed in a discussion of ecological stability of forests. Predisposing factors including genetic potentials, site conditions, climate, and air pollution can destabilize the forest. Inciting factors, such as insect and fungal attacks, frost, and drought, may cause degeneration of an unstable ecosystem and evident damage. Canker and rot-decay fungi are considered to be factors that have long-term effects on forest ecosystems.

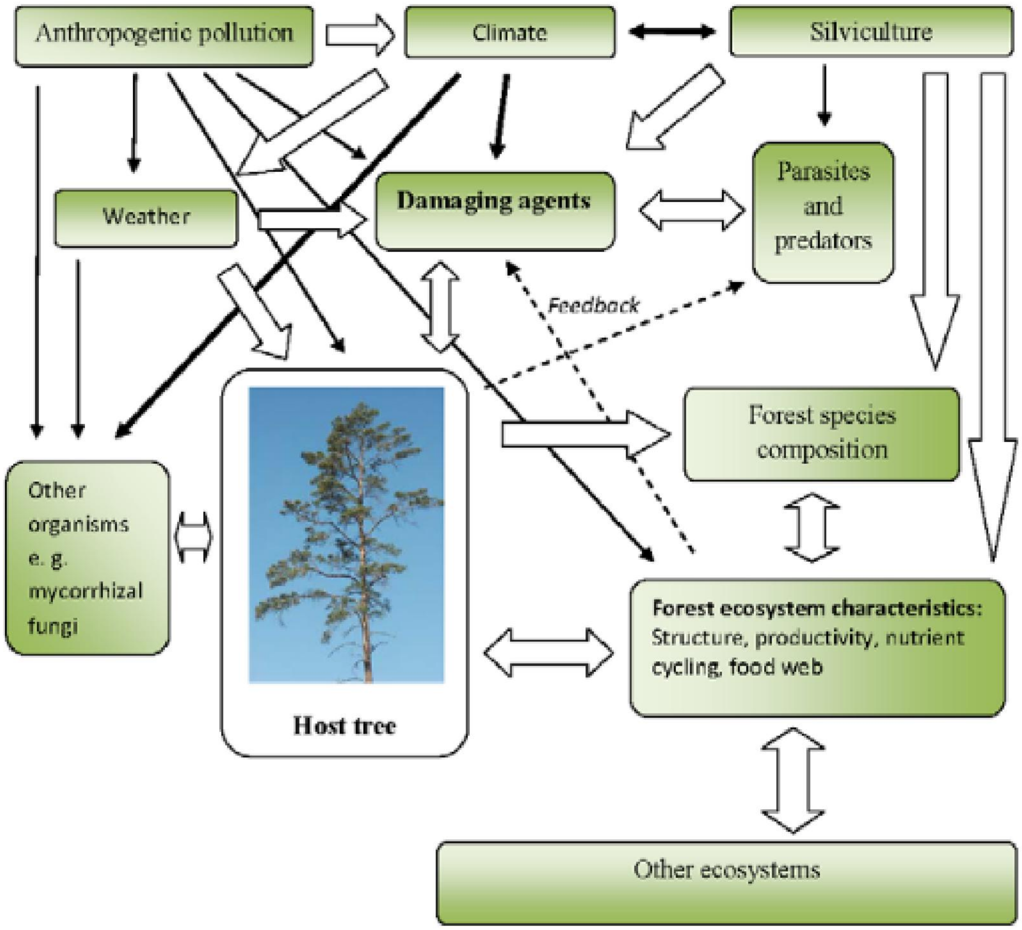

Figure 2. Impact of damaging agents on forest ecosystem processes

Forest Monitoring

Forest damage can appear in various forms, ranging from distinct symptoms to diffuse decline. Thus, to meet information demands, assessments of forest condition need to cover both specific, known damage causes as well as the general state of the forest. Thompson concludes that observations for monitoring purposes require suitable sampling designs and reliable methods for measurement and assessment. Relevant, accurate, and timely information is required for supporting decisions, not only to meet commercial objectives but also to enhance environmental protection, biodiversity and recreational services. The emergence of these additional forest objectives, and their interactive requirements, have increased the demands for information. Information regarding forest condition is needed by diverse decision-makers, ranging from governmental organizations responsible for mitigation strategies and law enforcement, to land owners trying to avoid severe damage to their forests. Hence, assessments of strictly defined damage symptoms and damaging agents are needed. A program for monitoring forest condition should, besides having a basic robust structure, also include forest damage impact assessments. Monitoring, defined as keeping under surveillance, should ideally be carried out regularly over long periods. A wise choice of methods simplifies compilation of the data. In the large-scale monitoring of forest condition, time series of damage symptoms and damaging agents are of core interest.

Assessment of forest condition and forest damage Defoliation is a key variable when monitoring forest condition. However, for assessments of forest condition to be valuable for decision-making, data on damaging agents are required and thus they are also generally assessed. In ICP Forests, various types of damage symptoms and causes of damage are included. In the USA, a comparable set of damage symptoms is recorded and the damaging agents included are those that are most common or cause most damage to USA forests (Table 1).

Table 1. most common or cause most damage to USA forests

TREE DAMAGE SYMPTOMS		CAUSE OF DAMAGE	
Affected part	Symptom	Agent group	Agent/factor
Stem / Collar	Fallen Tilted	Abiotic/climate	Wind/Snow; Frost; Other
	Broken	Anthropogenic	Forestry; Other
	Wounds (debarking, cracks, etc.) Necrotic parts Resin flow Signs of fungi Signs of insects Decay/rot	Mammals	Elk; Reindeer; Roe deer; Wild boar; Other large mammals; Beaver; Rodents; Other mammals.
	Planting damage Spike knot Multiple stems	Insects	*Tomicus sp.*; *Ips typographus*; Other bark beetles; *Pityogenes*; Other insects
		Fungi	Resin top disease; Rot or cancer; *Gremmeniella abietina*; Needle cast; *Melampsora pinitorqua*; Unspecified rust fungi; Other fungi
Tree crown	Dry top Defoliation Discolouration	Competition	Physical interactions
		Fire	
		Other	

New approaches in monitoring forest damage

Today, monitoring plays a crucial role in environmental science, policy development, and implementation. In the future, the demands for reliable monitoring are likely to increase due to the increased pressures on ecosystems, the changing climate, and a growing human population that needs to manage resources more intensively for producing renewable raw materials. To meet information requirements, the assessment of forest condition needs to cover specific damage symptoms, agents, and effects, as well as the general state of the forest. Further, the methods applied in the inventories should be reliable, practical and cost-effective. Thus, recognition of the limitations of the past and current inventories is essential for gauging their reliability, interpreting the results, and considering possibilities for introducing new approaches that are better adapted to today's information needs. Large outbreaks of insects and fungi can be detected in extensive crown condition monitoring programs. However, in many cases, damage occurs only at limited points in time and space, and such outbreaks may have severe economic implications while they are difficult to detect with sparse monitoring networks. Although there is a demand for durable long-term surveys, monitoring schemes must continuously be adapted to meet the societal demands. Lovett et al. conclude that a combination of good foresight and understanding of the monitored system can produce monitoring data with high information value. Further, although the focus during recent decades on defoliation assessments has contributed to our understanding of forest condition and damage, it has not been fully successful in capturing emerging needs and demands for data that can assist in timely mitigation of forest damages.

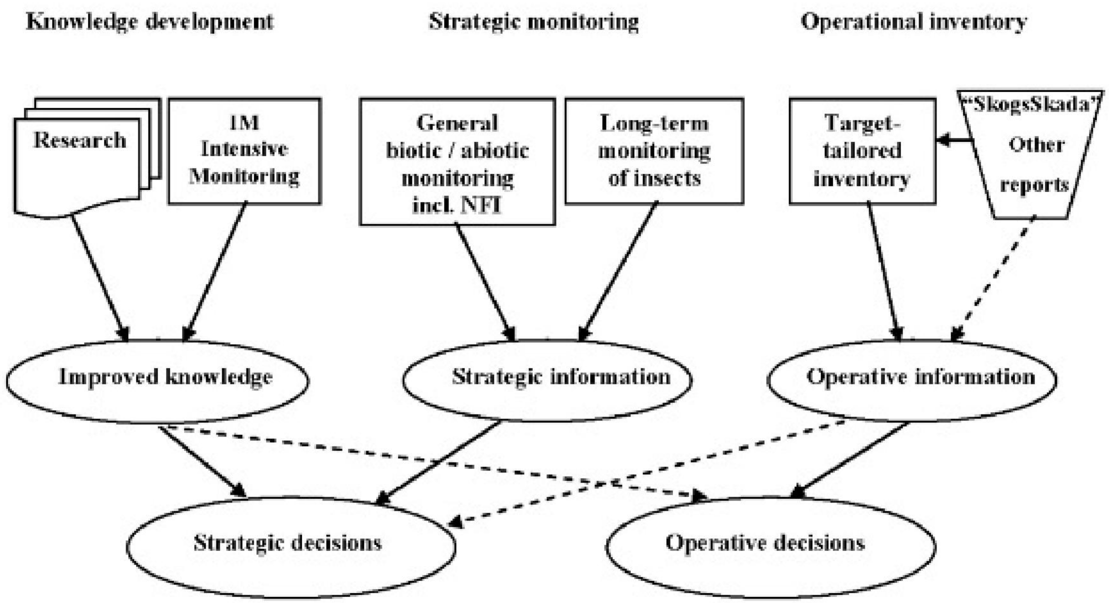

Figure 3. An overview of the new monitoring system

The first step is to identify locally important insect and fungus outbreaks. In this step an important role is proposed for the reporting and analysis system, to provide first assessments of the damaging agent, the amount of damage and geographic location. Once damage is judged to have reached a degree where intervention is required, there is often a need to collect additional information to support specific mitigation decisions. At this stage specific inventories, tailored to provide information relevant for the specific scheme being elaborated, should be utilized. Information for operational-level decision making needs to be adapted to the specific needs of a certain damage mitigation scheme.

Disease resistance: revisiting the type concept for tree damages

This model of intensification with a strong dependence on external, fossil fuel inputs has been increasingly put into question, and new paradigms for intensification have been widely adopted. However, recent forest intensification has largely followed the old model, with a great expansion of monospecific, and sometimes monoclonal, plantations. The philosophy of some tree breeding strategies still strongly relies on selecting or designing an ideal tree, i.e., "superior genotypes" for mass propagation using biotechnology and genome engineering. The questions raised by this approach—what should be an ideal tree? how to select the ideal tree? —have been addressed by many studies and reviews.

The forces that allow disease to persist at an overall moderate level in otherwise undisturbed ecosystems have long been a subject of study and speculation. Wide genetic variation in host resistance and pathogen virulence have been evidenced in such ecosystems, where they are sustained by and result from evolutionary dynamics between hosts and pathogens. In contrast, the association between low diversity and high disease incidence has been called the "monoculture effect" in reference to the agricultural context in which frequent, severe epidemics require the use of pesticides to maintain yield loss below acceptable levels.

Just as disease tolerance has the potential to increase disease overall, a major challenge for breeders lies in the fact that characters of interest are relevant at stand level, while selection is based on individual performance. Going still further, breeding for genetically diverse populations has received increasing attention in recent years, especially in the context of a "Darwinian agriculture" to address future challenges of changing climate and sustainable management. In particular, human-mediated (artificial) group selection has been suggested to offer a wider scope for improvement than selection on individual fitness traits. Natural selection is thought to operate mostly among individuals and more weakly at a group level, and is thus expected to have favored traits linked to individual performance even if costly to group productivity. As a consequence, individual traits that improve group performance could offer greater opportunities for artificial selection. An application of this concept for resistance traits was recently proposed by Anche et al. (2017), who investigated the use the basic reproduction ratio, R0, which is a key epidemiological parameter defined at the population level, in breeding programs using individual assessments. This issue was central to Colin Donald's type concept, which balanced individual performance against competitive ability and population performance, but it was largely overlooked. As an agronomist, Donald focused on yield, but his arguments are particularly relevant for disease resistance. Disease resistance can be visualized as an emerging property of populations, in that it is strongly affected by density- and frequency-dependent ecological and evolutionary processes. Indeed, durable resistance to pathogens is a population attribute that can only be assigned retrospectively. Rather than relying on "durable resistance genes," durable resistance should be considered in terms of a strategy to minimize the pace of evolution of virulence in the pathogen population. This can be achieved by a variety of approaches based on an adequate deployment of multiple resistance genes either by pyramiding and/or by heterogeneous deployment in space and time, so as to diversify the selection pressure on the pathogen. Growing clonal mixtures of 5–20 genotypes for short-rotation coppice of willow has proven to be feasible and effective for both disease reduction and yield increase over a long term. Nevertheless, such experiments with trees are relatively few, and are centered on genotypes that were selected on their individual performance.

A new system for assessing and monitoring damage

The information needs assessment and review of existing methods resulted in a proposal for a new monitoring system. The new system includes complementary components targeting different needs, intended to provide a broad spectrum of information needed for decision-making. The comprehensive monitoring system incorporates strategic monitoring, operational inventories of forest damage, and research-related monitoring. National Forest Inventories are primary sources of data for national and large area assessments of the state of forests. However, the NFI design makes it difficult to monitor rapid changes, e.g., changes in insect populations during the vegetation period. Further, in order to maintain high-quality assessments there is a limit to the number of damage agents that can be included. Thus, in addition to measurements in the NFI, long-term monitoring of insect populations on separate plots would be conducted as part of the new USA system.

Discussion

In a study of surveyor consistency in presence/absence sampling for monitoring vegetation, significant differences were found more often between observers of a less experienced group than between members of an experienced group. Experience improves observers' skill to detect differences and changes, but other underlying conditions also affect visual perception ability. Expectations of what is seen, and what it is seen as, will also influence the assessments. Monitoring forest damage often involves collecting data through ocular assessments. Visual observations of damage are affected by weather and visibility as well as the status of the target object. On the calibration courses several of the disturbance factors affecting the observations are constant. However, the quality of the assessments also strongly depends on the experience and visual perceptions of the observers. The process of making observations can be broken down into three steps. The first step includes a vision; the observer becomes aware of what is seen, but not what it is. Secondly, he/she notices an object and finally recognizes the object as a certain object. In most cases assessments (observations) are influenced by presumptions about the observation and the situation. Notably, observers are influenced by the information given. For these reasons, guidelines for inventories must be as objective as possible. Significant differences between observers indicate that observer bias also influence the results, in accordance with previous reports it affects assessments of forest damage together with both sampling error and natural variation. In addition to the bias component the observer variability has to be considered. The control survey revealed that assessments of damage with good agreement were obtained during the first two years. Although shoot blight is a distinct symptom, there are uncertainties regarding the best way to monitor it. similar results were obtained in later control surveys, indicating difficulties in identifying the cause of damage and the assessable part of the tree crown. This variability is important not only between observers but also among the observations made by a single surveyor. These errors also affect any trend analysis based on the data, but the effects of the errors are reduced when the time series are long and several observers have been involved each year. This highlights the importance of distinct descriptions, accurate assessments of damage symptoms, and stable identification of causal agents to improve estimates of forest damage. Results from later tests of assessments of different damage symptoms and causes have shown poor reproducibility, especially for low degrees of damage symptoms. This has led to the inclusion of threshold values in the inventory of forest damage in the NFI. Our study of the applicability of national forest inventories for estimating forest damage outbreaks concludes that large-scale monitoring has good potential for estimating geographical distributions, areas, and the epidemiology of extensive disease outbreaks. This conclusion is supported a clear correlation between changes in defoliation and the degree of damage caused by pathogens and pest organisms. In terms of sampling errors, accurate estimates can be obtained from the National Forest Inventory data, indicating that NFI´s provide trustworthy time series, which is a core concern for strategic-level decision-making. Although this introduces risks of missing low degrees of damage, which may indicate initial phases of outbreaks, it is considered essential in order to ensure the reliability of the inventory data. The accuracy of the assessments should be regularly tested to evaluate the quality of the inventory, and thus obtain a better understanding of the results.

Conclusion

In this context of global changes, characterized by strong new selective pressures put on entire ecosystems by human activities, the coupling of ecology and evolutionary biology has become essential for the understanding of forest diseases and their management. At the turn of the twenty-first century, Paul Manion reviewed some recently evolved concepts in forest pathology, which had modified the way of thinking about diseases and their practical management. Shortly more than 10 years after, the ecological view advocated in this prospective article has gained increasing recognition, and has also been the subject of substantial new evolution. It is remarkable to note that neither of the terms “global” nor “evolution” (except for that of concepts) were used by Manion. The recognition of global change in all its dimensions, including not only climate change but also accelerating global trade, habitat destruction, and other human-caused effects on the environment, has profoundly affected all areas of science and society in the last 15 years. In particular, two major changes affecting forest pathology—the world movement of species with trade, and the rise of plantation forestry to meet growing needs of an increasing human population— have led to an increasing number of emerging diseases, mobilizing the efforts of forest pathologists, and these trends are expected to continue. Three important advances, which have important practical implications and which also open new questions for future research.

1. Not everything is everywhere (especially forest pathogens). American chestnuts have been successively impacted by three exotic pests and pathogens in the last century showing the increasing difficulty for breeding programs to keep pace with biotic threats in woody perennials. The view on the processes underlying geographic variation in microbial distributions has changed from purely ecological explanations (“everything is everywhere but the environment selects,” a combination of ecological and evolutionary explanations supported by evidence of limited (natural) dispersal in many microbial taxa. Human mediated transfers putting into contact non-coevolved species therefore result in ecological and evolutionary dynamics that challenge processes operating in natural communities. These new introductions may overwhelm the ability of the community, or even of artificial selection, to respond.

2. Pathogen evolution can occur at short time scales. New prospects for an ecological and evolutionary intensification could benefit from rapid changes in technology and wood usages as material or fuel (e.g., engineered wood products, composite materials, wood pellets), which will likely remove some of the obstacles to the use of diverse plantations. The recognition that evolution can take place at short time scales is not very new, but it has been increasingly supported by evidence linked to anthropogenic changes, such as breakdowns of human selected resistance in a medical or agricultural context and adaptation of invasive organisms. Forests have already paid heavy tribute to invasions by exotic pathogens, but still, limited domestication of forest trees has up to now restricted impacts on forest pathogen virulence as those seen in agriculture. problems in monospecific planted forests are likely to increase in the future, since experience demonstrates that high productivity achieved in the first rotations, often associated with enemy escape, is likely to fade away with time due to the progressive arrival of natural enemies, i.e. tree pests and diseases.

3. Some experimental manipulations at small spatial scales have highlighted the role of microbial communities in disease control, while observations at larger scales have revealed environmental factors driving these communities. Both approaches are required to predict, and ultimately manage, microbial interactions and functions in the context of global change. Future studies working toward this aim will benefit from the development of functional metagenomics, microbial interactions modeling, as well as evolutionary platforms predicting the outcomes of multispecies interactions. The tree is a multi-trophic community fingerprinting methods, and, more recently, high-throughput sequencing techniques, have revealed that the epiphytic and entophytic microbial communities are much more complex than previously realized. Pathogens themselves host a diversity of parasites.

Special efforts should also be developed in regions, such as tropical areas, where high biological diversity is present but has received limited attention so far due to a lack of funding and trained researchers. Spectacular advances and reducing costs in DNA technologies have recently enabled considerable progress in the knowledge of phylogenetic diversity of forest pathogens. Uncertainties, especially regarding the emergence of new diseases, are likely a key component of the future of forest pathology. An obvious policy recommendation is therefore to maintain the expertise in the taxonomy, biology, epidemiology, and ecology of forest fungal pathogens needed to respond quickly to disease outbreaks in more economically developed countries.

References:

1. Aguayo J, Adams GC, Halkett F, Catal M, Husson C, Nagy ZA, Hansen EM, Marcais B, Frey P (2018) Strong genetic differentiation between North American and European populations of Phytophthora alni subsp. uniformis. Phytopathology 10:190–199.
2. Anche MT, de Jong MCM, Bijma P (2018) On the definition and utilization of heritable variation among hosts in reproduction ratio R0 for infectious diseases. Heredity 113:364–374.
3. Bálint M, Tiffin P, Hallström B, O'Hara RB, Olson MS, Fankhauser JD, Piepenbring M, Schmitt I (2017) Host genotype shapes the foliar fungal microbiome of balsam poplar (Populus balsamifera). PLoS One 8, e53987.
4. Bálint M, Barta L, Hara RBO, Olson MS, Otte J, Pfenninger M, Robertson AL, Tiffin P, Schmitt I (2017) Relocation, high-latitude warming and host genetic identity shape the foliar fungal microbiome of poplars. Mol Ecol.
5. Bazin E, Mathe-Hubert H, Facon B, Carlier J, Ravigne V (2017) The effect of mating system on invasiveness: some genetic load may be advantageous when invading new environments. Biol Invasions 16:875–886.
6. Berbegal M, Perez-Sierra A, Armengol J, Grünwald NJ (2018) Evidence for multiple introductions and clonality in Spanish populations of Fusarium circinatum. Phytopathology 103:851–861.
7. Borer ET, Kinkel LL, May G, Seabloom EW (2016) The world within: quantifying the determinants and outcomes of a host's microbiome. Basic Appl Ecol 14:533–539.
8. Botella L, Tuomivirta TT, Vervuurt S, Diez JJ, Hantula J (2015) Occurrence of two different species of mitoviruses in the European race of Gremmeniella abietina var. abietina, both hosted by the genetically unique Spanish population. Fungal Biol 116:872–882.
9. Brusini J, Robin C (2017) Mycovirus transmission revisited by in situ pairings of vegetatively incompatible isolates of Cryphonectria parasitica. J Virol Methods 187:435–442.
10. Carroll SP, Jørgensen PS, Kinnison MT, Bergstrom CT, Denison RF, Gluckman P, Smith TB, Strauss SY, Tabashnik BE (2015) Applying evolutionary biology to address global challenges. Science 80:1–16.
11. Castagneyrol B, Jactel H, Vacher C, Brockerhoff EG, Koricheva J (2018) Effects of plant phylogenetic diversity on herbivory depend on herbivore specialization. J Appl Ecol 51:134–141.
12. Coince A, Cordier T, Lengellé J, Defossez E, Vacher C, Robin C, Buée M, Marçais B (2017) Leaf and root-associated fungal assemblages do not follow similar elevational diversity patterns. PLoS One 9, e100668.
13. Di Bella JM, Bao Y, Gloor GB, Burton JP, Reid G (2016) High throughput sequencing methods and analysis for microbiome research. J Microbiol Methods 95:401–414.
14. Edwards, R., J. G. LaDue, J. T. Ferree, K. Scharfenberg, C. Maier, and W. L. Coulbourne, 2016: Tornado intensity estimation: Past, present, and future. Bull. Amer. Meteor. Soc., 94, 641– 653.
15. Ellen ED, Rodenburg TB, Albers GA, Bolhuis JE, Camerlink I, Duijvesteijn N, Knol EF, Muir WM, Peeters K, Reimert I, Sell- Kubiak E, van Arendonk JA, Visscher J, Bijma P (2017) The prospects of selection for social genetic effects to improve welfare and productivity in livestock. Front Genet 5:377.
16. Ennos RA (2018) Resilience of forests to pathogens: an evolutionary ecology perspective. Forestry 88:41–52.
17. Eschen R, Rigaux L, Sukovata L, Vettraino AM, Marzano M, Gregoire JC (2019) Phytosanitary inspection of woody plants for planting at European Union entry points: a practical enquiry. Biol Invasions.
18. Fortuna MA, Zaman L, Wagner AP, Ofria C (2016) Evolving digital ecological networks. PLoS Comput Biol 9, e1002928.
19. Hacquard S, Schadt CW (2015) Towards a holistic understanding of the beneficial interactions across the Populus microbiome. New Phytol 205:1425–1430.
20. Kembel SW, O'Connor TK, Arnold HK, Hubbell SP, Wright SJ, Green JL (2018) Relationships between phyllosphere bacterial communities and plant functional traits in a neotropical forest. Proc Natl Acad Sci 111:13715–13720.
21. Karstens, C. D., W. A. Gallus Jr., B. D. Lee, and C. A. Finley, 2015: Analysis of tornado-induced tree fall using aerial photography from the Joplin, Missouri, and Tuscaloosa–Birmingham,

Alabama, tornadoes o. J. Appl. Meteor. Climatol., 52, 1049–1068.
22. Lefevre F, Boivin T, Bontemps A, Courbet F, Davi H, Durand-Gillmann M, Fady B, (2018) Considering evolutionary processes in adaptive forestry. Ann for Sci 71:723–739.
23. McKown AD, Guy RD, Quamme L, Klápště J, La Mantia J, Constabel CP, El-Kassaby YA, Hamelin RC, Zifkin M, Azam MS (2016) Association genetics, geography and ecophysiology link stomatal patterning in Populus trichocarpa with carbon gain and disease resistance trade-offs. Mol Ecol 23: 5771-90.
24. Oswalt, S. N., W. B. Smith, P. D. Miles, and S. A. Pugh, 2017: Forest resources of the United States: A technical document supporting the Forest Service update of the 2010 RPA assessment. U.S. Forest Service General Tech. Rep. WO-91, 218 pp.
25. Peterson, C. J., and C. M. Godfrey, 2015: Side-by-side tree and house damage in the Moore, OK EF5 tornado: Lessons for the enhanced Fujita scale. Special Symp. on Severe Local Storms: The Current State of the Science and Understanding Impacts, Atlanta, GA, Amer. Meteor. Soc., 831.
26. Schenkman, A. D., M. Xue, and M. Hu, 2016: Tornadogenesis in a high-resolution simulation of the 8 May 2003 Oklahoma City supercell. J. Atmos. Sci., 71, 130–154.
27. Smith, G. M., Y.-L. Lin, and Y. Rastigejev, 2016: Orographic effects on supercell: Development and structure, intensity and tracking. Environ. Nat. Resour. Res., 6, 76–91.

5/28/2019