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Concept Note

Global change and silvicultural research

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1. The rapidity of the global change and the complexity of the phenomena involved make any forecast of future environmental conditions rather uncertain: the only thing we can be sure of is that the future will be different from the present and that most ecosystems will be living in conditions never experienced before. The awareness of an uncertain but certainly different future motivates the search for innovative solutions for a sustainable management of forest systems. Distinctively, accepting that the future will be different from both the past and the present makes it necessary to develop flexible management strategies to promote the proper adaptation. Therefore, it is expedient to fully recover the experimental character of silviculture.

From a scientific point of view, one of the most important premises under this perspective has been to consider the forest as a complex biological system (Ciancio 1996). From this approach, some guiding principles for forest management in times of global change have been derived worldwide (references in: Messier et al. 2013, Nocentini et al. 2017), among which: promoting the structural and compositional diversity of forest stands by adapting silvicultural treatment to the variety of structural and microsite conditions of the forest; exploiting the self-organizing potential of forest stands to increase their resistance and resilience; adopting flexible planning approaches; involving the stakeholders in decision-making processes, on the various operational scales.

2. Adaptive management seeks to improve operational practices in an iterative way, by gradually learning from the results of the practices applied. However, this must not fall into empiricism or intuitionism, since neglecting any methodological approach of exploration and interpretation of the consequences of management alternatives may lead to an exclusive reliance on technical experience, which illogically presupposes relatively stable operating conditions over time. It is therefore fundamental that silvicultural experimentation be based on systematic work.

Observational investigations and manipulative experiments frequently lead to results that may appear similar, even though their robustness, in general, is not: the higher is the control or manipulation in a research protocol, the more stringent are, in general, the inferences that can be induced. On the other hand, it is important to be aware that problems of spatial and temporal scales and operational setting can limit the level of rigor achievable by a manipulative experiment in silviculture. For example, it may be difficult, or impossible, to find suitable areas for the replication of treatments on an operational scale or to meet some of the assumptions required by the analysis methods. But most importantly, controlled experiments are often very expensive. As a result, silvicultural research protocols are frequently established on an observational basis only, although the resulting deductions are generally weaker (or partial) than those obtained through controlled experimentation.

Critical methodological aspects, often underestimated, concerning controlled experiments in silviculture should be however given due consideration. First of all, the search for a stringent causality has often led researchers to simplify the object of study and consequently, although not explicitly, to corroborate the simplification of the cultivation techniques experimented and then applied. Secondly, if the forest is recognised as a complex biological system, experimental methods must also explicitly take into account the peculiar character-

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istics of systems of this kind, such as the non-linearity of the relationships between the components, the spatial and temporal hierarchy, the low predictability, etc.: several methodological solutions are available (e.g. Sit and Taylor 1998), but this subject is rarely given adequate consideration by researchers. Thirdly, the "time" factor is a variable that can make the value of the results of silvicultural experiments ambiguous: in fact, if the future is different from the past, probably, in the context of a given experimentation the future will be different from the "experimental" past, and all the more so if the experimentation is long-term.

Finally, a further consideration is necessary: the impact of silvicultural management practices cannot, in general, be fully grasped through observations on single experimental plots, where it is not possible, e.g., to observe the effects on large scales. In relation to this, a key element is the integration of information from several sources (sample surveys, modelling, etc.): from this point of view, an interesting example is the analysis of the positive relationship between dendrological diversity and forest productivity, highlighted on both observational (Liang et al. 2016) and experimental basis (Huang et al. 2018).

3. In most cases the correct assessment of silvicultural practices takes a very long time. To overcome this constraint, summary and comparative analysis of existing data and circumstances can sometimes be useful: it is the method of so-called chronosequences and so-called retrospective studies. However, though these approaches can significantly reduce the time to obtain corroborated evidences and generally have relatively low costs, their results should be considered with caution, especially because of the difficulty of ensuring effective homogeneity and comparability of the situations and conditions being compared. This type of analysis may provide useful support in exploratory studies, e.g. in order to indirectly evaluate long-term management actions or in order to evaluate the impact of phenomena that cannot reasonably be recreated (e.g. hurricane damages) but could hardly be proficuously exploited for predicting future scenarios.

The most suitable way to conduct observational or manipulative studies in silviculture is through long-term, permanent protocols. Perhaps, the best known and most significant examples are those linked to the experiences from Central Europe, where, for example, thanks to experimental plantations established over a century and a half ago it has been possible to demonstrate the advantages of mixed forest management in terms of productivity compared to monospecific stands, and, with reference to environmental changes, the increase in growth favored by the lengthening of the growing season and the fertilizer effect of nitrogen depositions in recent decades (Pretzsch et al. 2019).

4. Relevant knowledge has been recently achieved on the structural and functional features of forest ecosystems, through the exploitation of increasingly sophisticated tools and techniques, by biochemistry, information technology, statistics, genetics, plant physiology, ecology, dendrometry, geomatics, etc. Scientific advancement requires an excellent level of training for researchers, who must understand and improve the state of the art and respond to the increasingly complex challenges of forestry through a multidisciplinary approach and a constant dialogue with the international community. On the other hand, an in-depth silvicultural culture remains essential, also to guarantee a truly effective dissemination of research results and their operational transfer.

In order for this latter to happen, it is necessary that observational and experimental data be collected, analyzed and interpreted under coherent theoretical apparata: as Deléage (2000) points out, making observations and collecting data, albeit in a refined way, without the trace of a theory is only "scientific philately". This is why it is important to know the conceptual paths and theories that characterize forest sciences: it is just on this basis that our commitment as researchers can be constantly reformulated and relaunched with ideas and motivations always renewed, according to the fast pace that characterizes global change.

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