Ecological engineering: from concepts to applications

Foreword

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Abstract

The International Congress “Ecological Engineering: from concepts to applications”, Paris, was held on 2-4 December, 2009 [3].
These three days were dedicated to the exploration of new breakthroughs in ecological engineering and reflections on the way to develop the field and ground it on sound ecological and conceptual bases.

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The Congress shown that ecology can provide the conceptual framework necessary to the development of practices that enable to manage natural and anthropized ecosystems in a rational and sustainable way and to increase the quantity and quality of the ecosystem services they provide. We saw for instance, during these 3 days, many examples indicating that ecology can help understanding and disentangling ecological mechanisms and that taking these mechanisms into account could help optimizing engineering practices adapted to local conditions and environmental changes. The congress was very interdisciplinary, as the community interested by ecological engineering is really large and diverse. Attenders called for linking better theories to concrete applications (and vice versa), and to take into account all possible levels of ecological organization from the individual to the ecosystems and the landscape. Evolutionary aspects should then also be included in order to better integrating the time scales.

Finally, the dialogue should be reinforced in the future to build real systemic and integrated approaches in ecological engineering. This requires the close cooperation between people from social (socio-economical, socio-political) sciences, from engineering sciences (urban development, physics, chemistry…) and all environmental disciplines. This also requires tight interactions between the academic word and practitioners and stakeholders.

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3. Congress objectives

Ecological engineering (EE) can be defined as the application of ecological principles to the creation, management and rehabilitation of ecosystems. It can be used to design management that is more sustainable,
adaptive, multifunctional, inspired by (or based on) mechanisms that govern ecological systems (self-organization, high diversity, heterogeneous structures, resilience, for example). Restoration of heavy metal-polluted soils using plants able to fix the pollutants, the sustainable management of soil fertility, water purification using microorganisms, and ecological manipulations of lakes to avoid water eutrophication are examples of ecosystem engineering among many others. Beyond their diversity, the manipulations involved by ecosystem engineering all aim at minimizing the quantity of energy and resources we have to spend to solve a particular problem relatively to the quantity of energy and resources provided by natural processes [4].

The growing need for an integrated approach of management and restoration of ecosystems is a clear consequence of the increase of human influence on the planet earth. In the last half century the world human population has doubled, the consumption of natural resources has been multiplied by six, biodiversity has drastically decreased and the degradation of many ecosystems and global environmental modifications are obvious. In view of this emergency situation, it is important that the overall scientific community get organized to help tackling these environmental issues. Ecology is a priori the scientific discipline the more capable of providing the conceptual framework necessary to the development of practices that enable to manage natural and anthropized ecosystems in a rational and sustainable way. This discipline has so far been underused although it could help optimizing practices. Ecological theory is both needed to develop general solutions and adapt them to local conditions. Moreover, ecology is the only scientific field capable of providing the scientific bases necessary to implement ecosystem manipulations, for example to mitigate the effect of global climatic changes. Such ecosystem manipulations could potentially have very negative impacts if not well designed.

Conversely, modern scientific ecology needs concrete examples of applied management to test its theories in constrained and well-defined conditions. The outputs required by practitioners, stakeholders, and policy makers for ecosystem engineering are indeed good forcing processes to encompass the range of the studied ecological variables in terms of heterogeneity, limits and the occurring interactions between these variables. In the same vein, the full development of ecological engineering requires stakeholders, scientists from engineering sciences, socio-economical sciences, and all environmental sciences to work together both to build a common general framework and to ground their work on concrete common projects.

Ecological engineering is also particularly relevant for developing countries. Indeed, the need for sustainable exploitation of ecosystems is very high in these countries where populations are still quickly growing and where individuals and institutions have often difficulties to develop practices based on high input rates (energy, water, mineral nutrients).

In this context we organized a congress aiming at gathering international specialists in the different fields of ecosystem engineering in order to:
- Reinforce the dialogue between scientists working with theoretical approaches and the ones aiming more directly at developing applications to define more precisely the theoretical foundations of ecological engineering;
- Look for the key points enabling to put effectively in touch scientists, practitioners developing techniques of ecosystem engineering and ecosystem managers;
- Promote the development of ecosystem engineering.

During the three-day congress, 6 keynote presentations, 60 talks and about 40 posters have been presented. Sessions have been structured to regroup presentations on classical ecological engineering topics (such as restoration, heavy metal remediation, or natural resource management), but more transversal sessions have also been organized. Some emphasized the importance of broad classes of processes, such as microbial processes, which can be useful to find solutions to many different problems in virtually any type of ecosystem. The first and last sessions dealt with the “Conceptual bases of ecological engineering”. Together with two keynote presentations (“Ecological engineering: its development in an energy-rich society and its future in an energy-limited one” by W.J. Mitsch; “Grand Challenges for the Future of Ecological Engineering” by C.G. Jones), they were meant to address issues relevant to the general development of ecological engineering. Such presentations and sessions are important because ecological engineering is still in its infancy in most countries and thus requires both conceptual development and thinking about its place in ecological sub-disciplines. Such presentation should also help determining general rules for the design of sustainable systems [5].

Two sessions (“Management of temperate and Mediterranean agro-ecosystems” and “Management of tropical agroecosystems”) and a keynote presentation by C. Dupraz (“A challenge for ecology: the engineering of cropping systems with pluri-specific vegetations”) were devoted to subjects related to agronomy and vegetal production.
Modern agriculture has permitted to feed a steeply increasing human population. However, it is now widely acknowledged that this agriculture is not sustainable because it has mined soil resources [6] and has numerous negative side effects on ecosystems and human populations [7]. This shows that new practices are necessary [8,9]. They can appeal to the principles of organic agriculture, ecological intensification, agroecology or agro-forestry. However, they are all based on the idea that agriculture should be more based on ecological natural processes and require the mobilization of ecological knowledge from many sub-disciplines and the acknowledgment that ecological interactions are the result of Darwinian evolution [10]. Because such practices aim at reaching more sustainability and require bridging the gap between basic ecological knowledge and the development of applications, they can indeed be coined as ecological engineering. In this context, “ecological engineering” would not only constitute a new title for old practices, but could also help integrating ecological and agronomic knowledge in new and unforeseen ways.

Despite efforts towards reducing urban, industrial and agricultural pressures, many aquatic ecosystems remain strongly affected by anthropic perturbations [11]. One session was thus devoted to the management of aquatic ecosystems, and to the general objective of attaining their “good ecological status”. Several presentations dealt with this aspect in the context of the European Water Framework Directive implementation process. One main objective of this directive is to develop integrated protection and management approaches at the scale of the river basin in order to attain a general protection of the ecology of all waters, and specific protection of unique and valuable habitats or water resources. In accordance with this objective, one session dealt with the management of watersheds in order to improve water quality and ecosystem functioning. The keynote presentation by E. Jeppesen (“Restoration of lakes in different climate zones: From theory to practice”) highlighted the fact that management and restoration approaches have been mainly applied to northern temperate aquatic ecosystems, and stresses the necessity of developing methods of ecological engineering adapted to warm waters.

One important idea behind the practices of ecological engineering is that they should benefit not only to human societies but also to the rest of nature. This aspect and the notions of system health and sustainability were developed in the keynote presentations of R. Costanza (“Ecosystem Health and Ecological Engineering”), B.B. Jana (“Conceptualizing ecological engineering and its application towards poverty alleviation and sustainable development”), and in several communications of the session “Ecological engineering and socio-economical issues”. In the same vein, the workshop organized by the International Ecological Engineering Society within the EECA congress, dealt with the “Benefits of Ecological Engineering Practices”.

4. Congress assessment

We saw during these 3 days many examples indicating that ecology and engineering sciences can help: (1) understanding and disentangling ecological mechanisms; (2) integrating them in predictive frameworks; (3) optimizing practices; (4) adapting them to local conditions and to environmental changes. Several presentations described promising conceptual frameworks. Many interesting examples of ecological engineering were described. However, theories and concrete applications were not always strongly linked. In our opinion, to tackle concrete issues, the explicit reference to Ecological Engineering and to these frameworks would be useful to develop more sustainable solutions for: (1) restoring ecosystems; (2) maintaining or orientating ecosystem functions; (3) increasing ecosystem services they provide (“ecologically intensive” agronomy…); (4) creating new ecosystems.

EE is clearly based on ecological knowledge. As underlined by William Mitsch, ecological engineering should be the acid test of ecological theories integrating:
- Whole-ecosystems;
- Multi-site experiments (comparison along a latitudinal gradient, catalogue of case studies);
- Monitoring for “ecological quality” assessment;
- Environmental management;
- Feedbacks between practitioners and researchers.
Obviously, there are still many steps to go in order to fully achieve this synergy.

EE is mostly viewed as a manipulation at the scale of ecosystem. Some talks also documented interesting manipulations at the population and community scales: we think EE should implement manipulations at all ecological scales of organization from the individual and the microcosm to the ecosystem and the landscape; and
that evolutionary, past and future selection, aspects should also be better taken into account for better integrating the time scales.

We had imagined this congress as very interdisciplinary. It has been a success in the sense that we had presentations on various systems and with many different approaches. The community interested by EE is really large and diverse, but the dialogue should be reinforced in the future to build real systemic and integrated approaches. Moreover, we probably missed, in the congress:
- scientists from social (socioeconomical, socio-political) sciences;
- practitioners, stakeholders, and policy makers…
- scientists from all engineering disciplines (e.g. urban ecology, physics, chemistry…).

In conclusion, congress participants seem to agree on the fact that ecological engineering is quickly developing. However, they also pointed out various issues that must be addressed to quicken this development: (1) Ecological engineering is needed to build a better future and more sustainable relations between human societies and nature but the development of the discipline requires itself a radical change in our perception of this relation; (2) An ethical framework is still to be built for ecological engineering; (3) We must promote pluri-disciplinary and complementary approaches (education, mutual information transfers between academic communities, practitioners, and stakeholders).

Acknowledgments

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