AGROECOLOGY IMPLEMENTED THROUGH BIOSYSTEMS ENGINEERING TECHNIQUES FOR RURAL LANDSCAPE PROTECTION

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https://doi.org/10.11118/978-80-7509-963-1-0009

Abstract
Agroecology is a scientific subject, an innovative practice and a social movement, which studies ecological processes in relation to agro-food systems, providing new concepts and tools for mainstreaming advanced management strategies of the agroecosystems. The implementation of Agroecology principles may strongly benefit from Biosystems Engineering techniques. Indeed, their synergical integration may contribute to the reduction of the environmental footprint of agriculture, while protecting biodiversity and ecosystems, so leading to better techniques, materials and tools for planning the rural landscape. Several techniques characterized by an eco-friendly impact are currently investigated by Biosystems Engineering, *e.g.*: building elements for bio-architecture, produced/integrated with natural materials (bricks insulated with straw/wool; concrete reinforced with natural fibers; "*adobe*" bricks; *etc.*); Nature-Based Solutions (NBS); fully biodegradable materials *(e.g.*, for soil mulching); remote-sensed data (from drone/satellite) exploited for precision agriculture, to optimize the use of resources (water; soil; agrochemicals; *etc.*). These solutions may support the formulation of strategies for re-designing agroecosystems at the landscape level, focusing on ecosystem services, biodiversity, water conservation, crop/livestock production, agrochemicals limitation, pollution reduction, and climate change adaptation. This review paper presents the main technical solutions of Biosystems Engineering for Agroecology, able to integrate territorial planning, reducing pollution from agriculture and protecting the rural landscape.

Keywords: Sustainable Agriculture, Biodiversity & Ecosystems, Ecological Engineering, Bio-Architecture, Landscape Planning.

Introduction

Agroecology is an approach to agriculture that aims to the promotion of the health of the agricultural environment. Over the past two decades, agroecology has become increasingly popular, although being assigned various definitions and meanings. Among the many scientific research, Wezel et al. (2009), have defined agroecology as "*a science, a set of practices and a social movement*". Other Authors (Wezel et al., 2020) stated that, within agroecology, there are the different agroecosystems that, in turn, create interactions and synergies among all factors that may ensure the balance of biodiversity. So, the primary objective of an agroecological system is its interaction and productivity as a whole, and not only that one of individual crops. Reducing the negative factors which affect the environment is closely connected to, and dependent on, the context of action, and it is necessary to take into account the biophysical, social, cultural and economic aspects of the system. Agroecology today is more relevant and important; in fact, the numerous scientific articles on the subject has peaked with nearly 800 scientific papers published only in 2022 (Fig. 1).

Biosystems Engineering techniques for implementing Agroecology

Biosystems Engineering has over the years developed significant contributions on new knowledge based on environmental principles, as well as the ability to apply those principles to agricultural practices. These competences include a wide range of expertise and skills, aimed to better understanding agricultural systems, natural resource management, land use planning, technological innovation, as well as the development of innovative technologies supporting the implementation of the concept of Agroecology. The scientific sector of Biosystems Engineering is rich of researches in the field of agroecology, which has increasingly evidenced its own multidisciplinary nature. The two macro areas of research - namely, Farm Buildings and Agro-forestry Land – most relevant to the implementation of the concept of Agroecology, are reported in Table 1, together with their specific application fields and most relevant recent scientific

publication. Farm buildings, have been investigated by scientific researches related to the valorisation of traditional material for architectural solutions (Picuno P., 2016), the development of new bio-materials (Castronuovo et al., 2015), *etc*. Several studies have discussed the materials and architectural solutions to use in green building, such as the research conducted by Manniello et al. (2022), that analyzed the structural performance of a plant - considered as a weed, for urban and rural areas, such as *Arundo donax* L. - when used to lighten concrete bricks, showing positive results in mechanical tests (Fig. 2). In addition to *Arundo donax*, some "new" plant-based materials used in green building, such as hemp and lime materials, have been more recently tested, in conjunction with conventional building materials, offering high energy savings, combined with the environmental sustainability of the components used to make it.

Highly innovative techniques are the applications of Nature-Based Solutions (NBS), as described by Convertino et al. (2023), that have examined green roof, walls, facades, covered and thermally insulated using crops, that allow urban environments to become greener and more sustainable, thanks to a significant reduction of energy consumption.
In agriculture, on the other hand, research on new bio-materials to limit environmental pollution has been extended, due to the need to reduce the plastic footprint of Mediterranean agriculture, where large amounts of waste caused by the extensive use of plastic material, may be avoided, by using fully biodegradable materials. In order to identify an alternative to replace plastic films for mulching, Martín-Closas et al., 2008 conducted a research to determine the potential of biodegradable plastics found in agriculture.

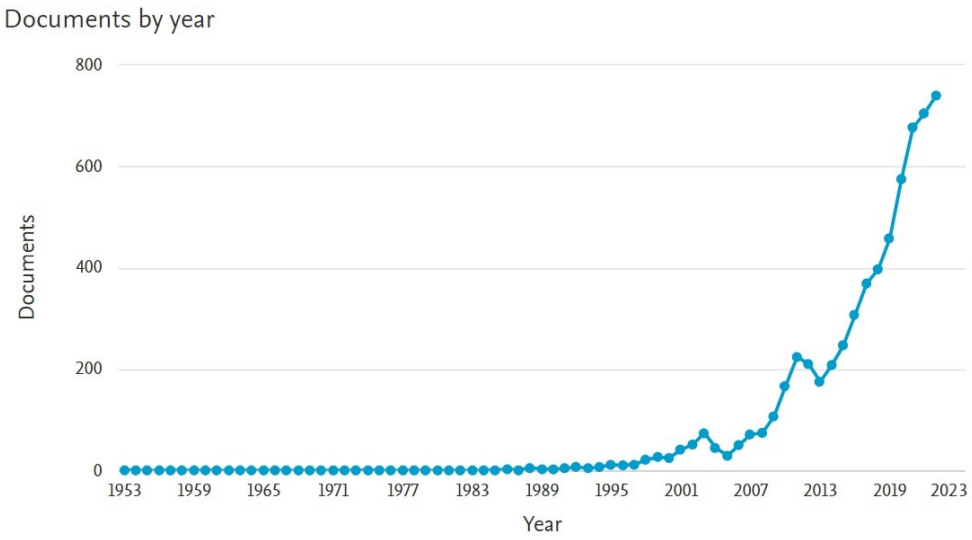

Fig. 1: Scientific papers on agroecology (Scopus database – last access: 28 February 2024)

Fig. 2: Culms of Arundo donax (L.) used to make cylindrical concrete blocks (Manniello et al., 2022).

Tab. 1: Synoptic overview of biosystems engineering

Sector	Application	Examples	References
Farm Buildings	Natural building materials	"Adobe bricks"; stone; wood; *etc.*	(Picuno, 2016)
	Conventional structural elements (*e.g.*, concrete) lightened with natural material	Concrete lightened with natural fibres having high tensile properties	(Manniello et al., 2022)
	Building insulating components with natural material	Building insulating elements made with straw, hemp, wool, *etc.*	(Castronuovo et al., 2015)
	Bio-degradable materials	Bio-based/biodegradable film for soil mulching	(Martín-Closas et al., 2008)
	Agricultural waste recycling	Biomass/agro-plastics recycling & valorization	(Castronuovo et al., 2019)
	Nature-Based Solutions (NBS)	Green roof/walls/facades, covered and thermally insulated using crops	(Convertino et al., 2023)
Agro-forestry Land	Remote Sensing & GIS	Satellite date & planning tools for landscape survey, analysis and management	(Cillis et al., 2021)
	AI, Drones & Robotics in Agriculture	Automatic implementation of remote-sensed data into landscape planning tools	(Cillis et al., 2020)
	Energy saving - Renewable energy sources in agriculture	Optimization of energy in greenhouse buildings	(Puglisi et al., 2023)
	Sustainable soil and water management	Reduction of pollution from agro-plastics	(Picuno, 2014)
	Landscape design and management	Landscape Information Modelling (LIM)	(Picuno C.A. et al., 2022)

Agro-forestry Land is linked to the use of new technologies such as GIS, Drones and Artificial Intelligence (AI). Several experimental researches have evaluated the implementation of monitoring strategies for the management, conservation, enhancement, and restoration of forest greenery. Among them, Cillis et al. (2021) collected historical cartographies that were implemented into a GIS, to assess spatial and statistical changes in the forest landscape. So, it was possible to assess how much, where and how the forest landscape has changed, in order to provide a methodology to support more detailed and sectoral studies.
Agro-forestry Land is also concerned with the development of more recent tools based on advanced technologies, like Landscape Information Modelling – LIM (Picuno C. A. et al., 2022)

Discussion

Due to several linkages between agricultural systems, their natural surroundings, and other activities that address biodiversity and ecosystems, rural landscapes are frequently the ideal level for facilitating an efficient transition to agroecology. In order to facilitate the implementation of agroecology at the landscape scale, biosystems engineering would perform a primary role, taking care of the essential stages of development, which enable an integrated system approach. To this aim, the following research activities would be further implemented by experts in Biosystems Engineering, to foster the implementation of the concept of Agroecology at landscape level and protecting the rural environment:

- provide methods for redesigning agroecosystems at the landscape level, taking into account the ecosystem services and additional advantages of agroecology at this geographic scale; improving and enriching biodiversity; creating ecological corridors; safeguarding water; combining crop and livestock production to close energy and nutrient cycles; cutting back on the use of agrochemicals; lowering pollution; and enhancing the contribution of farming practices to climate change adaptation and mitigation;
- create plans which integrate territorial planning, promote agroecology at the landscape level, improve the coherence of environmental and agricultural policies and regulations within a specific landscape or territory, and encourage the development of new governance structures;

- design strategies aimed at using locally available renewable resources, trying to keep the cycles of biomass and nutrients as near to home as possible, while enhancing recycling practices;
- valorizing natural solution for anthropic interventions (on buildings, *etc*.), so as to maximize the use of local traditional materials, technical solutions based on natural elements, fully biodegradable materials, *etc*.
- Improve landscape and natural resource governance, by suitably integrating remote-sensed data, GIS and LIM, to play a key role in supporting comprehensive assessments of agroecological systems, offering a valuable approach for sustainable agricultural resource management and rural landscape protection.

Conclusion

The interactions between agroecology and the rural landscape are fundamental to understanding and promoting sustainable agricultural practices and environmental conservation. The practice of agroecology tends to foster agricultural biodiversity by promoting the presence of natural habitats, ecological corridors, and wildlife refuge areas within the rural landscape. This might lead to greater resilience of agricultural ecosystems and benefits for agricultural productivity in the long term. An improved contribution by researches on Biosystems Engineering may enhance the co-creation and horizontal sharing of knowledge, to reduce pollution from agriculture and to protect the rural landscape.

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Souhrn
Význam agroekologie dokládá nárůst vědeckého výzkumu na toto téma v bibliografii. Vysoká multidisciplinarita inženýrských biosystémů umožňuje výzkumníkům v této oblasti zabývat se různými výzkumnými tématy. Kromě toho hrají inženýrské biosystémy v agroekologii zásadní roli, neboť přispívají k navrhování a zavádění udržitelných a ekologicky šetrných zemědělských postupů. Tento obor integruje inženýrské principy s ekologickými a agronomickými znalostmi s cílem vyvinout potravinové systémy, které snižují dopady na životní prostředí, podporují biologickou rozmanitost a zvyšují odolnost zemědělských ekosystémů. Biosystémoví inženýři uplatňují své odborné znalosti při navrhování a optimalizaci systémů chráněných plodin, které snižují plýtvání vodou a minimalizují znečištění. Biosystémové inženýrství hraje také klíčovou roli při vývoji a zavádění pokročilých zemědělských technologií, jako je přesné zemědělství a využívání dronů a senzorů k účinnému a udržitelnému monitorování plodin. Souhrnně řečeno, zemědělské inženýrství poskytuje nástroje a řešení nezbytná k převedení zásad agroekologie do praktických činností, čímž podporuje udržitelnější a odolnější zemědělsko-potravinářskou produkci.

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