Agroecology for producing goods and services in sustainable animal farming systems

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Editorial: Agroecology for producing goods and services in sustainable animal farming systems

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Agroecology was initially defined as a scientific discipline that applies ecological theory to the design and management of agroecosystems in order to enhance their sustainability (Altieri, 1987). It then gradually emerged both as a movement and as a set of practices, and moved beyond the agroecosystem scale toward a wider focus on the whole food system, encompassing food production, distribution and consumption (Wezel *et al*., 2009). The recent surge in academic literature on agroecology has ignored animal production systems despite their direct or indirect dependency on natural processes. Animal production systems have indisputable negative impacts on the environment, but as underlined by Gliessman (2006) the problem lies not so much with the animals themselves or their use as food, but with the ways animals are incorporated in agroecosystems and food systems. Animal agriculture needs to be reconfigured to minimize its negative impacts, produce food and other ecosystem services and increase their adaptive capacity to face an increasingly uncertain future (markets, climate change, demands for food security, shifts in dietary preferences in the developing world). The integration of animals in an agroecosystem can often make the difference in realizing long-term ecological sustainability and socio-economic viability goals. To extend ecological thinking into animal production systems, Dumont *et al.* (2013) recently proposed five principles based on the identification of key ecological processes that need to be optimized: (i) adopt management practices aiming to improve animal health, (ii) decrease the inputs needed for production, (iii) decrease pollution by optimizing the metabolic functioning of farming systems, (iv) enhance diversity within animal production systems to strengthen their resilience and (v) preserve biological diversity in agroecosystems by adapting management practices. In this special issue, 19 papers investigate how the issues above can contribute to the design of innovative, adaptive and resilient farming systems in ruminants, pigs, horses and aquaculture across temperate, Mediterranean and tropical areas.

Integration of cropping and livestock farming systems allows better regulation of biochemical cycles and environmental fluxes to the atmosphere and hydrosphere through interactions among farm units, and mobilizes biodiversity to supply ecosystem services. To reach these objectives, Moraine *et al.* (2014) propose a participatory design method that was implemented across a diversity of European case studies in which diversity of crops and grasslands interacting with animals appeared central. Cooperation and collective structuration between farmers and with other actors of territories reveal opportunities for smart social innovation. Veysset *et al.* (2014) and Ripoll-Bosch *et al.* (2014) analyze the economic performance of mixed crop-livestock farming systems in temperate and Mediterranean areas. Both studies find that the economic profitability of mixed crop-livestock farms is not related to the diversity of production or to animal productivity, the main driver of farm sustainability rather being the low dependency on off-farm inputs (feed self-sufficiency). However, the diversity of production enhances farm flexibility, with organic farms being the ones that exploit the diversity of herd feed resources (grasslands, cereals, legume crops) more efficiently.

Oosting *et al.* (2014) aim to analyze the constraints to production increases from the farm and the farmers' perspective in smallholder mixed crop–livestock systems in the tropics. They show that maximum herd output is not achieved at the highest production per individual animal. They also present a framework linking farming systems to value chains. The 'system jump' from subsistence to commercial livestock production would lead to lower prices, more competition and higher demands for product quality requiring investments that not all farmers can afford. Changing a system also requires a deeper understanding of the attitudes of farmers. For instance, Gizaw *et al.* (2014) show that collective breeding programs in Ethiopia lead to genetic improvement that cannot be achieved through individual efforts of smallholder farmers, and that the integration of farmers' own criteria (pelvic width, body length, color, horn) to select rams does not affect the program efficiency but makes it socially acceptable.

Latawiec *et al.* (2014) review the main constraints for sustainable intensification of cattle grazing in Brazil in terms of productivity, pasture management, socio-economic impacts and climate change mitigation. Adopting practices

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like rotational grazing, incorporation of legumes and integrated crop–livestock–forestry systems can enable higher yields and higher economic outcomes to be obtained while reversing degradation and protecting the environment. Technical assistance is however essential, particularly for small- and medium-scale farmers. An example also in Brazil is presented by Paciullo *et al.* (2014), who illustrate how organic dairy production that incorporates several herbaceous (legumes and grasses) and tree species in a silvopastoral system can improve animal nutrition, helping to reconcile animal production and environmental conservation.

Accatino *et al.* (2014) present a dynamic model of rangelands to which they apply the mathematical framework of viability theory to quantify the management adaptability of the system. They conclude that cattle grazing is viable only for high-rainfall regimes, and that the use of mixed herds composed of cattle and goats increases the adaptability of management. In tropical grasslands, combining goats and heifers offers a promising alternative for increased production of goats and overall animal production, and also represents an option for the lower use of chemical anthelmintics (d'Alexis *et al.*, 2014). In temperate conditions, Collas *et al.* (2014) analyze the consequences of suppressing energy complementation at pasture on the performance of saddle mares. Under high herbage allowance, the mare's adaptive capacities allow requirements to be met and produce foals with satisfying growth and conformation while relying on grass only. Supplementation should thus not be systematic, which appears an efficient way to increase farmers' incomes and decrease the environmental footprint of horse farming systems.

The use of forage plants as an alternative to concentrate feeds constitutes a relevant strategy to decrease the inputs needed for feeding pigs in tropical areas. Kambashi *et al.* (2014) review a number of issues related to the high fibre and low-energy contents of tropical forages and to the presence of plant secondary metabolites. They conclude on the need for a proper assessment at the farm level of the social, economic and environmental consequences of such nutritional changes. Agostini *et al.* (2014) illustrate how grow-finishing pig farms can increase their technical and economic performance by improving farm facilities and modifying batch management practices. Gilles *et al.* (2014) discuss how an integrated, self-contained, fish-plankton system can provide technical, environmental and economic advantages for fish aquaculture in Amazonia compared with the traditional outdoor production.

Innovative farming systems need to be evaluated for both their economic performance and their environmental footprint. Henriksson *et al.* (2014) and Sasu-Boakye *et al.* (2014) use Life Cycle Assessment (LCA) to quantify the impacts of various feed rations for dairy cows and pigs in Sweden. The carbon footprint varies according to cultivation practices and climate conditions. Authors stress that land use change must be considered in carbon footprinting as goal conflicts often arise. For instance, localising protein feed production reduces greenhouse gas emissions and improves some ecological processes (e.g. nutrient recycling), but at a cost of increasing land occupation for local feed production. Beyond the use of LCA, the five principles mentioned above can be used to setup multi-criteria evaluation methods. Botreau *et al.* (2014) identify a number of criteria and organize them to form the architecture of an evaluation framework for dairy systems in mountain environments, which measures the level of system compliance with agroecological principles.

Agroecology considers pasture-based livestock systems as multifunctional, delivering not only food and fiber but also a wide range of public goods. Rodríguez-Ortega *et al.*, (2014) review the Ecosystem Service framework for integrating market and non-market functions, which allows the multiple trade-offs and synergies that can exist to be considered. They point at the multidimensionality of livestock production and present different methodologies to value ecosystem services from the biophysical, socio-cultural and economic perspectives. An example of economic valuation of public goods associated to livestock production is the study by Martin-Collado *et al.* (2014) that calculate the Total Economic Value of an endangered breed, and propose considering the existence and cultural values associated to local breeds to inform conservation strategies.

We conclude this special issue by identifying key research areas on the technical and organizational innovations that are needed to scale-up the use of agroecology principles in livestock farming systems (Dumont *et al.*, 2014). Designing robust and resilient animal production systems able to face increasing uncertainty and handle various types of disturbances will demand a paradigm shift in many scientific disciplines. We should quickly progress toward holistic and interdisciplinary research methods, involving animal scientists, ecologists, economists and sociologists. The authors also call for a new approach for the whole research-development-innovation chain to bridge the gap between science and practice.

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