**Diversified farming systems for improved sustainability of agriculture: potentialities and challenges**

**Guillaume Martin1, Kerstin Barth2, Mathilde Blanc3, Bertrand Dumont4,** **Severin Hübner2, Marie-Angélina Magne5,** **Claire Mosnier4,** **Riccardo Primi6,** **Lisa Schanz7,** **Steffen Werne8, Christoph Winckler7**

1 AGIR, Université de Toulouse, INRA, Castanet-Tolosan, France

2 Johann Heinrich von Thünen Institute, 23847 Westerau, Germany

3 Swedish University of Agricultural Sciences, 90183 Umea, Sweden

4 Université Clermont Auvergne, INRA, Vetagro Sup, UMR Herbivores, 63122 Saint-Genès-Champanelle, France

5 AGIR, Université de Toulouse, ENSFEA, INRA-INPT-ENSAT, France

6 Università degli Studi della Tuscia, 01100 Viterbo, Italy

7 BOKU, A-1180 Vienna, Austria

8 FiBL, CH-5070 Frick, Switzerland

1 – **Introduction**

Responding to the many sustainability issues related to modern industrial agriculture (air, soil and water pollution, biodiversity loss, etc.), the diversity argument was brought forward by scientists (Kremen et al., 2012). Diversified farming systems intentionally include functional agrobiodiversity, i.e. crops, seeded and permanent pastures, rangelands and animal genotypes and species chosen by the farmer to manage his farm. These systems presumably provide ecosystem services while reducing the input needed for production. Agrobiodiversity is also assumed to strengthen the robustness and resilience of livestock farming systems.

Because of their inherent complexity, research on diversified farming systems is limited. Literature on the topic mainly consists of review articles that gather and integrate field- and herd-scale results at the farm level (Frison et al., 2011; Lin, 2011; Mijatovic et al., 2012) without addressing threshold effects driven by the scale change. Moreover, these articles largely focus on biotechnical issues and only take limited account of the socio-economic aspects of livestock farming (e.g. presence vs. absence of a local value chain) that contribute to the success or failure of diversified systems. The proof of concept thus seems rather limited so far.

We need to increase our understanding of the potential benefits and challenges of diversified farming systems. We focus on organic multi-species livestock farms, i.e. livestock farms integrating two or more animal species, possibly with integrated crop production. We review the theoretical advantages of mixed livestock farming and conclude on how studying diversified farming systems challenges the concepts and methods that have long been used to design and analyze conventional livestock systems.

2 – **Theoretical framework**

Sustainability in the context of organic multi-species livestock farms is understood as a multi-dimensional concept that involves trade-offs among the following dimensions: resource use efficiency, resource conservation, self-reliance, productivity, profitability, human welfare, animal welfare and resilience to hazards. In this paper, we review the literature according to these dimensions.

3 – **Results** **– Discussion**

The majority of papers studying multi-species livestock farming suggest that it improves productivity per animal and per unit area (d’Alexis et al., 2014). However, it is usually only one species that benefits from mixed grazing (e.g. lambs when grazed with cattle). Improved productivity is related to a higher resource use efficiency and to facilitation processes. Mixed grazing allows each species to express its food preferences and can enhance herbage use. For instance, sheep graze herbage close to cattle dungs that have high nutrient content and dry matter digestibility and is usually avoided by cattle (de Rancourt et al., 1980). In addition, multi-species farming systems may provide health benefits to the animals. It has been shown that mixed grazing of cattle and sheep reduces the number of strongyles well adapted for sheep (Arundel and Hamilton, 1975; Jordan et al., 1998) and thereby improve sheep performance and possibly sheep welfare. On the other hand, multi-species farming systems may increase the risks of transmission of bacterial and viral diseases, e.g. dermatitis (Rogdo et al., 2012). A special threat may arise from diseases with high mutation rates transmitted horizontally, e.g. among sheep and goats. Self-reliance is promoted when transfers of by-products occur from one farm enterprise to another and thereby avoid purchase of costly feed inputs. This is the case for piglets fed with whey from cattle, sheep or goat milk processing into cheese (Maswaure and Mandisodza, 1995). Despite these potential savings and above-mentioned benefits of multi-species livestock farms, their profitability is not necessarily higher than that of specialized farms. Economic results are, however, usually more stable thus improving farm resilience against economic or climatic hazards (Mischler, 2019).

4 – **Conclusions**

Based on available literature, multi-species livestock farming appears as a promising option for improved sustainability in agriculture. However, this literature remains rather limited and we have identified two main knowledge gaps which may hinder the upscaling of multi-species livestock farming. First, multi-species livestock farms may be much more complex to manage thus increasing workload and making farmer welfare more critical, but this aspect has been little studied so far. Second, little information is available on how interactions among species (or farm enterprises) are managed, although these interactions appear to be key drivers of farm efficiency and resilience.

Further research is thus needed to increase our knowledge of the technical, economic and environmental performances of multi-species livestock farms according to the management practices implemented. This research challenges the current concepts and methods of agricultural science that are mainly suited to specialized farms. Analytical frameworks to assess the integration among species or farm enterprises should better consider the farming practices but also how farm work is organized to deal with this diversity. Another key issue is how sales management does (or does not) take advantage of economies of scope allowed by the diversity of productions.

*Financial support for this project is provided by funding bodies within the H2020 ERA-net project, CORE Organic Cofund and with cofund from the European Commission.*

**References**

d'Alexis, S., et al., 2014. Mixed grazing systems of sheep and cattle to improve liveweight gain: a quantitative review. J. Agric. Sci. 152, 655–666.

Arundel, J.H., Hamilton, D., 1975. Effect of mixed grazing of sheep and cattle on worm burdens in lambs. Aust. Vet. J. 51, 436-439.

Frison, E.A., et al., 2011. Agricultural Biodiversity Is Essential for a Sustainable Improvement in Food and Nutrition Security. Sustainability 3, 238–253.

Jordan, H.E., et al. 1988. A 3-year study of continuous mixed grazing of cattle and sheep: parasitism of offspring. Int. J. Parasitol. 18, 779–784.

Kremen, C., et al. 2012. Diversified Farming Systems: An Agroecological, Systems-based Alternative to Modern Industrial Agriculture. Ecol. Soc. 17, 44.

Lin, B.B., 2011. Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. Bioscience 61, 183–193.

Maswaure, S.M., Mandisodza, K.T., 1995. An evaluation of the performance of weaner pigs fed diets incorporating fresh sweet liquid whey. Anim. Feed Sci. Technol. 54, 193-201.

Mijatović, D., et al. 2013. The role of agricultural biodiversity in strengthening resilience to climate change: towards an analytical framework. Int. J. Agric. Sustain. 11, 95–107.

Mischler, 2019. Desktop analysis of specialized and mixed organic livestock farms. Working document of the Core Organic MIX-ENABLE project.

de Rancourt M., et al. 1980. Measurement of animal grazing preferences. Cited in: Nolan, T., Connolly, J., 1989. Mixed v. mono-grazing by steers and sheep. Anim. Prod. 48, 519–533.

Rogdo, T., et al. 2012. Possible cross-infection of Dichelobacter nodosus between co-grazing sheep and cattle. Acta vet. Scand. 54, 19.