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THE ROLE OF CIRCULARITY IN MIXED FARM SYSTEMS

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Abstract

The paper aimed to present the practice of mixed farming systems which is based on circularity and proposes stronger links between crops and livestock. It aims to emulate the nutrient circuits resulted from food production based on those in natural systems, shifting from linearity towards cyclicity to reduce anthropic impact. The paper analysed the selected articles in order to identify strategies implemented in mixed farming systems which improve circularity and have positive effects on the environment and presented the results and discussions section in the form of guidelines and based our logic structure on the principles of circularity in agricultural systems. It is recommendable that farmers and stakeholders try to preserve and, where possible, increase the biotic diversity of agricultural landscapes, both in terms of crops and livestock (for example, by using cover crops and intercropping), but also in terms of habitats that can provide beneficial ecosystem services (such as: shelter for natural enemies, nitrogen fixing plants, etc.).

Key words*: circularity, livestock, recycle, waste management.*

INTRODUCTION

Predictions on the dynamics of worldwide human populations indicate a strong increase in the years to come (McKee et al., 2004). Additional food resources will be needed to support growing human populations, which will likely increase the anthropic impact generated by food production activities. The development of better conceptual and practical approaches is much needed for more sustainable food production.

Crops and livestock represent the principal means of food production and, also, some of the major contributors to ecosystem changes. Secondary products of these activities, such as greenhouse gases and other pollutants are known to have daunting effects on ecosystems, especially due to their long lasting and large-scale effects. Better management practices in agriculture are needed to reduce the impact of climate changes, without compromising socio-economic stability (De Boer & Van Ittersum, 2018).

In search of solutions, inspiration can be drawn from self-sustainable natural ecosystems that maintain their balance based on complexity and circularity. Mixed farming systems have been proposed as one of the viable solutions aimed towards sustainable food production (Oomen et al., 1998). The practice of mixed farming systems is based on circularity and proposes stronger links between crops and livestock. It aims to emulate the nutrient circuits resulted from food production based on those in natural systems, shifting from linearity towards cyclicity to reduce anthropic impact.

Mixed farming systems have been historically associated with subsistence farming that currently characterize underdeveloped or developing countries (Thornton & Herrero, 2014). The increased awareness of sustainability requirements and the possibility of reduced impact prompted more awareness and research on how this farming practice can be improved and implemented in the current context of food production, along with other environmentally friendly measures.

We adhere to this research direction and aim to better understand the issue of greenhouse gas emissions in mixed farm systems, in order to help structure the scientific knowledge on this topic and, ultimately, to contribute to the overall development of and ease of use for beneficial farming practices.

MATERIALS AND METHODS

We searched for articles related to the topic of greenhouse gases in mixed farming systems on

the Web of Science and Google Scholar platforms. We analysed the selected articles in order to identify strategies implemented in mixed farming systems which improve circularity and have positive effects on the environment.

We presented the results and discussions section in the form of guidelines and based our logic structure on the principles of circularity in agricultural systems (Oosting et al., 2021) and mainly focus on the research carried out in temperate regions.

RESULTS AND DISCUSSIONS

The concept of circularity in agricultural systems is based on multiple cornerstones. These represent concepts needed to be applied in order to reach a more sustainable agriculture and can be described as follows: (1) use arable land to produce food directly for human populations; (2) reduce food waste as much as possible; (3) recycle the by-products of agriculture and the use of animals with low opportunity cost as new sources of food, manure and for ecosystem services (de Boer & van Ittersum., 2018; Oosting et al., 2021). The implementation of these principles, along with other practices and methods, seem to have the potential to reduce greenhouse gas emissions resulted from food production activities. By definition, mixed farming systems already account, at least partially, to the aforementioned principles. We will further address how these principles could be further included in this farming practice, in order to benefit from a more sustainable way of food production.

The principle of using the land to predominantly grow food directly for human population (1st principle) could be applied in mixed farming systems at landscape scale, by partitioning the crop selection. Further efficiency might be achieved by an adequate rotation of the human consumption designated crops with high importance for the quantity and quality of the yield (Bowels et al., 2020; Shah et al., 2021) and by the practice of intercropping, which is also documented to increase the yield up by 20% (Yu et al., 2015). Large scale diversified crop rotation and intercropping were also observed to enhance crop resilience and soil biodiversity (Bowels et al., 2020; Yu et al., 2015), thus representing viable practices to be used in the context of climatic changes. Furthermore, mixing cereal crops along with legumes, especially N fixing taxa, has been documented to be efficient in fixing N in the soil and for reducing its emission into the atmosphere (Rauw et al., 2022). The principle of using agriculture to produce food primarily for human consumption is also inextricably linked to the feeding preference exhibited within societies (De Boer and Van Ittersum, 2018). For increasing the circularity in agriculture, it is recommended that consumers should adhere to a more plant-based diet, in order to reduce the greenhouse gas emissions resulted from animal breeding and consumption (Yue et al., 2017).

Reducing waste (2nd principle) is another principle which is important for reducing greenhouse gas emissions associated with food production and represents a basic, yet hard to reach desiderate. This principle can be applied for all the parties implicated in the cycle of food production, ranging from the producers to the intermediaries (processing units, markets) and the consumers. More research is still needed to increase the efficiency of nutrient enrichment, pest control and livestock waste management in agriculture and in mixed farming systems. With respect to the crops, so far, the best practices include the use of plants and cover crops in order to enrich the soil with nutrients which are beneficial for the quality and the productivity of crops (Snapp et al., 2005), and thus reduce nitrogen and phosphorous waste and further pollution. The use of green peas cultures, for example, along other crops can be used in order to fix N into soil and enrich it with certain nutrients. Research further suggests that cover crops can be beneficial for the management of agriculture derived N emissions, by reducing the leeching of NO_3 in multiple instances (Gabriel et al., 2012). The additional vegetal waste resulted from cover crops could be further used in accordance with the third enounced principle and be incorporated into the diet of the livestock. As such, the choice of suitable plants is very important in the waste reduction strategy. Pest control improvement represents one challenging aspect in the context of circular

agriculture, especially when discussing mixed farming systems. The traditional use of pesticides is associated, among other, with increased health problems in human populations, environmental pollution (the persistence of synthetic compounds into the ecosystem fluxes) and with the reduction of local and landscape biodiversity (including the decline of the useful group of natural enemies). Though advantageous in terms of pollution reduction, the use of biotic pesticides still poses inherent problems, with the most notably being the biodiversity reduction potential. On the other hand, the use of natural enemies is a practice with no significant deterrent side (Sunderland, 1999). Furthermore, this practice is closely linked to the concepts of circularity in the processes of food production, since there are no existing by-products. The efficient use of natural predators requires a landscape level approach and certain concessions in terms of land use, crop selection, cropping strategy and tillage practices. The diversity of natural enemies (both in terms of community structure and functionality) is important in order to efficiently prey on and control the variety of crop pests which may inhabit complex agricultural landscapes. Research documents that the diversity of habitats within agricultural landscapes serves to increase the diversity of natural enemies. This is achieved by increasing the natural vegetation strands, both forested and herbaceous (Zamberletti et al., 2021) and by increasing the diversity of different crops (Redlich et al., 2018). In addition to landscape heterogeneity, other agricultural practices, such as intercropping and cover crops were also documented to increase the overall predatory of invertebrate pests in agricultural landscapes (Boweres et al., 2021). The limitations in pest control exhibited by the communities of natural enemies could be supplemented by the use of pesticides. However, this aspect requires further research and developments, as it is widely documented that in multiple instances, the pesticide use has proven to be harmful to the natural enemies, in addition to the pests it is applied for (Beers et al. 2016).

The last principle of circularity and sustainability (3rd) in agriculture proposes the recycling of agricultural by-products and the use of animals with low opportunity cost, as new sources of food, manure and for ecosystem services. To account for the first half of the principle, the resulted crop waste (vegetal biomass) could be reincorporated into the food production cycles by various means, such as readily available compost or animal food. Soil nutrient enrichment can be achieved, at least partially, by applying compost resulted from the vegetal waste of previous crops, with possible even better applications in regions with lower soil quality (De Boer & Van Ittersum, 2018). Research suggests that in order to increase circularity of food production and consumption, it is beneficial to incorporate a medium amount of vegetal waste fed animals in our diet (Van Zanten et al. 2018). As such, the second part of the principle suggests that the increased use of low-opportunity-cost feed animals is linked to reduced supplemental consumption and residues linked to more expensive food. Multiple vegetal waste can be processed and incorporated in the diet of livestock. We consider that mixed farming systems provide an ideal platform for such practices, as they are very convenient for the construction of processing units that could transform vegetal and animal waste into food and fertilizers. Again, large scale project conception and management represents a perquisite for an efficient implementation of this principle and ultimately attaining more circularity in mixed farm systems. Additionally, more research and legislative developments are required to better use farm waste, especially for that of animal origin. The current EU legislation almost entirely prohibits the use of animal waste as a food source, with few exceptions for blood, in order to limit potential diseases (Zu Ermgassen et al., 2016). In order to avoid disease spreading, more research and investments are needed into processing and sanitation technologies, ranging from machine engineering to microbiology and chemistry. Strict control protocols and analysis should also contribute to safe use of waste and by-products. The capacity of farmers and control agencies to limit potential disease spreading is closely linked to the increase of circularity in mixed farming systems.

CONCLUSIONS

Large scale multidisciplinary approach is essential in order to attain a higher level of circularity in mixed and other type of farming systems. Though theoretically ideal, in practice full circularity, as encountered in natural ecological systems, cannot be attained in agricultural ecosystems and landscapes. Mixed farming systems represent a valuable platform for the research, innovation and improvement of circularity in food production. Using the residue and natural by-products resulted from crops and livestock in support of each other, can help reduce waste, especially in terms of pollutants resulted from fertilizers and pesticides. It is recommendable that farmers and stakeholders try to preserve and, where possible, increase the biotic diversity of agricultural landscapes, both in terms of crops and livestock (for example, by using cover crops and intercropping), but also in terms of habitats that can provide beneficial ecosystem services (such as: shelter for natural enemies, nitrogen fixing plants, etc.). Lastly, an increase in the research and technology, coupled with shifting preferences and expectations in food production and consumption can enable us to move towards more circular food production and sustainability in agricultural landscape management.

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