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Mixed crop-livestock systems[1]

1 Measure definition

Mixed crop-livestock systems refer to farm-scale systems where livestock and cash crop production are combined to optimise resource efficiency (FAO 2001; Ryschawy et al. 2012; EIP-AGRI Focus Group 2017). Different types of integrated crop-livestock systems exist with varying degrees of integration of crops and livestock, and the volumes of external inputs, outputs and losses, including GHG emissions. Traditional mixed systems rely on low external inputs and often involve grazing on pasture, while modern systems seek to maintain high productivity with low inputs by increasing efficiency through synergies between crop and livestock systems (Garrett et al. 2020). Typical elements of mixed farming systems are organic matter recycling and forage legumes in the crop rotation. Livestock keeping is area-based, meaning that the organic fertilizer applied to one hectare corresponds to the manure of one livestock unit and livestock can be fed by on-farm products only (Gattinger et al. 2012).

Integration of animals and plant production was common throughout agricultural history but ongoing agricultural specialization and intensification leads to a separation of crop and livestock production (Schut et al. 2021). At present, mixed farming systems account for over 60% of animal production in Europe and worldwide (Herrero et al. 2013). However, taking into account all types of farming systems, i.e. cropping only, animal husbandry only and mixed farms, integrated systems make up only 10-20% of farms in Europe (Garrett et al. 2020). This indicates the dominance of farming systems with crop or animal production only nowadays compared to integrated crop-livestock systems. A shift in farming systems towards mixed farming could close nutrient cycles and reduce the number of animals in large industrial production, but must be combined with a paradigm shift in food and dietary systems.

A regional or landscape-scale integration of crop production and livestock husbandry can be an alternative to integration at farm level. According to this approach, income streams would be diversified while keeping costs down by economy of scale via specialized land use (Garrett et al. 2020). However, it requires strategic top-down planning and is currently not pursued as an explicit objective in EU agricultural or land use policies.

Geographical and biophysical applicability

- **Suitability to different biophysical conditions:** Integrated crop-livestock systems are generally applicable across landscapes and regions; mixed farming is typical for organic agriculture, but can be applied in any agricultural production system (Gattinger et al. 2012).
- **Suitability to EU/German conditions:** European landscapes offer great potential for mixed farming because of the climatic suitability to grow a variety of crops and forage. Farms with heterogeneous and small field sites as in many landscapes throughout Central and Southern Germany often have fields unsuitable for cropping and can use these as pasture for livestock.

[1] This factsheet was developed as part of the research project "Naturbasierte Lösungen (NbS) im Klimaschutz: Marktanreize zur Förderung klimaschonender Bodennutzung" (FKZ 3721 42 502 0) and is also published as part of the Annex to the UBA report "Role of soils in climate change mitigation", see www.umweltbundesamt.de/publikationen/Role-of-soils-in-climate-change-mitigation.

Fit with NbS definition

Mixed farming systems are in alignment with all aspects of nature-based solutions as in the working definition for this research project defined by Reise et al. (2022). The integration of livestock husbandry in cropping systems enhances natural cycling of organic matter and nutrients within the farm, diversifies natural habitats across the farm landscape for wildlife conservation and improves microbial activities due to improved crop rotation and fertilization with farmyard manure. Several ecosystem services are provided benefiting natural environment, farmers and society.

2 Mitigation Potential

2.1 Carbon sequestration

In mixed farms, livestock manure is applied as fertilizer on organic matter basis. A cumulative C-input to the soil by farmyard manure increase the SOC stock by factor 1.26 (Maillard and Angers, 2013). Additionally, forage legumes and perennial grasses are key elements in the crop rotation of mixed-farms. They can lead to C accumulation in the soil with annual SOC sequestration rates of 0.11 t C/ha/year (Lugato et al. 2014). Organic matter recycling by manure application and an increase in SOC stocks was especially confirmed for organic farms (Gattinger et al. 2012).

2.2 Total climate impact

Agriculture accounts for approximately 11% of the total GHG emissions of the EU-KP[2], with almost half of the agricultural emissions come from enteric fermentation and manure management. The agricultural sector is responsible for around 49% of the total EU-CH4 emissions (deriving mainly from livestock) (EEA 2022). The share of total EU emissions from enteric fermentation in 2020 ranges between ca. 18% in France, 13% in Germany, 4% in Netherlands and 0% in Malta (EEA 2022).

Dairy farms and mixed farms have a similar amount of annual GHG emissions (5.5 t CO_2-eq ha^{-1} $year^{-1}$), mainly from enteric fermentation of the cows (Schader et al. 2014). Conventional farming with the use of farmyard manure also results in higher N_2O production compared to conventional farming with mineral fertilization, both per unit of yield and unit of area (Skinner et al. 2019). Nevertheless, re-integration of livestock with crop production closes farm-gate nutrient cycles. This closed-loop idea of crop-livestock production can reduce GHG emissions from livestock manure at farm-scale when integrating cropping fields beside livestock husbandry, where the manure can be recycled rather than wasted (Li et al. 2012).

Beyond farm-scale, additional GHG emissions from off-farm fertilizer production as well as transportation will be reduced by direct application of manure produced at the same farm. Finally, mixed farms with an equilibrated land to livestock ratio are producing also the fodder for their livestock on-farm, thus reducing GHG emissions from off-farm fodder production and transportation (Schader et al. 2014). Of course, the choice of fodder crop and the way of production, e.g., perennial grass in a crop rotation with a high mitigation potential versus intensive maize production (Christenson et al. 2021), offer further impact on GHG emissions that are closely linked to farm management practices, e.g. improved crop rotations.

2.3 Limitations on the mitigation potential

The climate mitigation potential at farm system level remains unclear. There is a lack of knowledge on the actual amount of GHG emissions that can reduced by (re-)integrating livestock

[2] EU-KP = EU-27+ISL+UK.

and crop production, or the amount of SOC that can be sequestered using mixed farming systems (EIP- AGRI Focus Group 2017).

Achieving positive environmental performance on a mixed farm is closely related to the level of physical integration and complementarity between crop and livestock (home-grown feed, recycling of waste as fertilizer), thus relying on synergies, not just the coexistence of both on a farm (Leterme et al. 2019). Manure management and fodder production are key elements here to close the nutrient cycles. This is closely linked to improved crop rotations by higher diversity and length, and the grazing intensity (Garrett et al. 2017). Furthermore, management factors such as the degree to which farms rely on external inputs to intensify their operations such as N and P fertilization, the tillage/ploughing intensity or the addition of nitrification inhibitors impact the mitigation potential at farm scale.

3 Adaptation and co-benefits

- **Yields**: Integrated crop-livestock farming show no declines in profitability or yields (Garrett et al. 2020). The integration of grasses and forages into cropland can even increase yields in subsequent crops as well as livestock profitability (Garrett et al. 2017).
- **Environment**: Mixed farms in commercial agricultural landscapes are associated with lower environmental externalities than specialized crop production and enhanced ecosystem services (Garrett et al. 2020).
- **Climate impacts:** The diversification of mixed farms, including a share of permanent grassland and forage legume production for the cattle, improves sustainability and resilience to inter-annual weather variability due to risk distribution (Regan et al. 2017; Garrett et al. 2020).
- **Soil and biodiversity**: Integration of grasses in the crop rotation (Garrett et al. 2017) and application of farmyard manure (Lori et al. 2017) from livestock integration rather than the use of synthetic fertilizers increase soil microbial activity and soil carbon sequestration. Due to their positive impact on beneficial soil biota, mixed farming is a measure of sustainable soil fertility management (Barbieri et al. 2017; Gattinger et al. 2012).
- **Biodiversity:** Mixtures of crops and pastures diversify the farm landscape and increase habitats for local wildlife, heterogeneity of species within patches (β-diversity), and related ecosystem services such as pollination and biological pest control (Garrett et al. 2017).
- **Nutrient management**: Separation of crop and livestock production increases slurry from livestock, with high GHG potential. Due to the EU-Nitrate Directive (91/676/EEC), manure is often transported from specialised animal production areas to other regions (Schut et al. 2021). The emissions from large distance transportation outweigh the emissions saved by its reuse. In mixed farms, the manure can be recycled by directly returning it back to crop production (Gattinger et al. 2012). Nitrogen pollution due to nitrogen surplus can be reduced compared to crop and dairy farming systems (Ryschawy et al. 2021).

- **Resource efficiency**: Land resources in mixed farms with fodder crop production are more efficiently used and can support more animals per hectare than farms relying solely on extensive grazing (Regan et al. 2017).
- **Costs**: Fodder and manure production at mixed farms reduces purchase and transportation costs and improve feed and fertiliser autonomy (Ryschawy et al. 2012; Regan et al. 2017).
- **Economic resilience:** Mixed farming can provide a more stable and diversified source of income, which helps farmers to reduce their risk major changes in prices (Ryschawy et al. 2012; Garrett et al. 2017).

4 Trade offs

- **Costs:** Diversification of farm production means higher upfront costs, e.g. for machinery (Garrett et al. 2017).
- **Economic dependencies:** Crop and livestock production requires dependency on a greater diversity of agricultural supply chain infrastructure, e.g. processing facilities, marketing channels and transportation routes (Garrett et al. 2017).
- **Management:** Re-integrating livestock in agricultural systems may lead to a loss of cropland due to conversion to pasture. If conversion of grassland to arable occurs (within the limits, e.g. set by the cross-compliance/conditionality under the Common Agricultural Policy), this can lead to loss of soil carbon.
- **Labour:** Better utilisation of labour throughout the year (Schut et al. 2021) is counterbalanced by the need for more or skilled labour. The year-round attention the livestock requires more labour compared to seasonal crop production (Garrett et al. 2017).
- **Nutrient management**: Livestock integration enhances nutrient cycling but the impacts on carbon and nutrient accumulation remain strongly influenced by co-management factors such as N and P fertilization intensity, tillage intensity, crop rotation length and grazing intensity (Garrett et al. 2017).
- **Policies**: Supportive policy environments and policy incentives for crop-livestock integration are limited (Garrett et al. 2017).

5 Implementation challenges

For practitioners used to segregated farm types, the integration of either livestock or crop production can be very challenging, labour-, planning- and cost-intensive, e.g., by infrastructure and further land necessary for the implementation. An alternative could be the unification of two formerly separated farms. This, however, is still challenging. Policy restrictions or non-supportive environments can be another limitation for the (re-)establishment of mixed farms across regions.

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