Analysing farmer biomass, product, labour and land exchanges in a range of European landscapes.

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In landscapes, interactions between farmers, *i.e.*, coordinated actions (e.g., exchanges of biomass, livestock, labour, or land), can lead to agronomic benefits, ecosystem services and close the nutrient cycles. We aimed at exploring the types of interactions among farmers and their effect on landscapes, identifying, among them, those leading to improved circularity. We analysed interactions in six farmer networks: crop-livestock landscape in France (FR); Montado in Portugal (PT); small-scale mixed farms in Romania (RO); farms and biogas plant in Denmark (DK); sheep and arable farms in Scotland (UK); arable and dairy farmers in the Netherlands (NL). Interactions were manure-feed/straw exchanges between crop and livestock farmers (FR, UK, NL); livestock transfer for grazing to other farms (PT, RO, UK); biogas-plant mediated nitrogen redistribution (DK); land parcel exchanges for optimizes rotations (NL); product exchanges between farmers and agrotourism facilities (RO). Most explored interactions require mutual trust as they were often informal and not regulated by contracts. Advisors play (FR, DK) or are advocated to play (NL) a (stronger) role in mediating. Not all interactions promote landscape-level nutrient recycling; land exchange aims for optimization (NL); in RO, interactions focus on economic mutual aid. Manure-for-feed/straw and livestock transfer enhance circularity.

Keywords: farmer interactions, ecosystem services, circularity, biomass exchange

1. Purpose

Mixed agricultural landscapes integrate different interacting agricultural components (for example crops, livestock and trees) in a way that they can recycle nutrients at different levels and provide ecosystem services (e.g., biological control for reducing the need of pesticides) (Martin et al., 2016). In some cases, individual farms might be specialised or might not be able to close the nutrient cycle within the farm. In this case, in order to achieve integration and nutrient recycling at the landscape level, it is fundamental to have interactions among farmers or between farmers and other actors (Martin et al., 2016). However, interactions occur in many different types and formats (Asai et al., 2018), especially given the diversity in European mixed farming systems and *the interaction does not necessarily result in integration of components in the landscape and nutrient circularity*. In this study, we addressed the following questions: what are the main types of materials exchanged among farmers? In what way do these exchanges occur? Finally, we reflect on whether there are some interactions are more important than others in developing integration and interaction of components and nutrient recycling in landscapes.

2. Design/Methodology/Approach

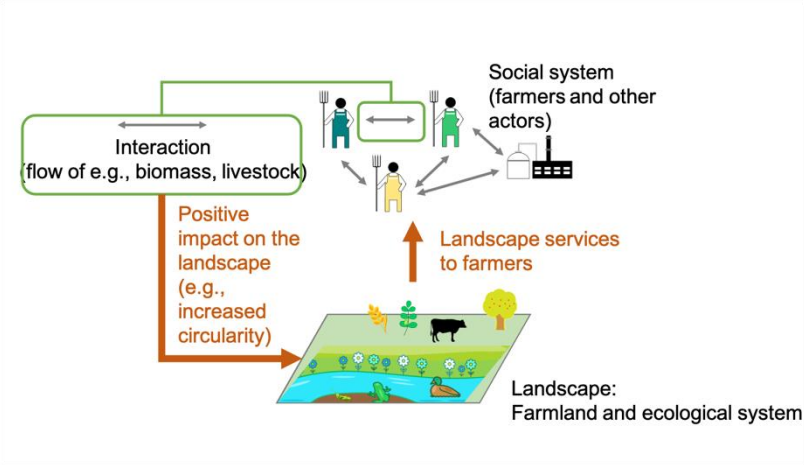
We considered six European farmer networks (Table 1) extending over an area of a NUTS3 or smaller and characterized by different agricultural activities. All the networks include farmers that are either interacting directly with other farmers or with other actors in the landscape. The number of farmers in each of the networks varies. Some networks have been in existence for many years, while in others, the interactions have only occurred relatively recently.

Table 1 – Description of the networks

Country	**Short name**	**Description**
France	FR	13 farms located in uplands (ruminants) and in lowlands (cereals) in Ariège
Portugal	PT	15 farms in the montado (tree-grass) system in Alentejo
Romania	RO	8 small-scale farms combining mixed agricultural activities (fruit, dairy cattle, sheep) and agrotourism
Denmark	DK	11 specialised farms (pigs, dairy cattle, other cattle, stockless) and a biogas plant
UK	UK	Farms involving sheep coming to graze winter cereals
The Netherlands	NL1	Four farms (2 mixed (dairy-arable), 1 dairy, 1 arable farm)
	NL2	Two farms (1 arable, 1 dairy)

The network facilitators were asked to describe the coordinated direct or indirect (e.g., via intermediaries) interactions action between two or more actors (at least one is a farmer) that leads to exchange of resources or animals having some landscape services (e.g., improved soil conditions, animal welfare, increased nutrient recycling) (Fig.1). This excludes pure buying or selling of products or services without agronomic consequences for both parties. In order to analyse interactions within the networks, the idea was that each network could identify farmers interactions and describe them among pre-defined axes, in order to allow cross-network comparability.

Figure 1. Within a landscape, actors (forming the social system) interact within an ecological systems. An interactions among two actors (actor 1 and actor 2) is defined as an exchange of resources (from actor 1 and actor 2 and vice versa, excluding money). This exchange leads to landscape benefits, including ecosystem services, decreased imports, nutrient recycling.



In each of the networks, a common set of over-arching questions were addressed, which were aimed at identifying the resources exchanged in farmers interactions and the benefits these exchanges provide to the landscape. Questions were addressed with focus groups (PT, RO), with focus groups integrated with expert knowledge (UK, NL), with data analysis and expert knowledge (DK), or with a series of in-depth farmers interviews (FR). Because of the heterogeneity of the protocols implemented and of the type of information collected across case studies, network facilitators were asked to fill a common table (Table 2) in which interactions could be described homogeneously across common, standardised, dimensions: 1) actors involved (in this sense it was important to distinguish the type of farmer (e.g., cereal, cattle), so that we could make considerations about complementarities among farmer types), 2) resources or livestock exchanged, 3) perceived benefits to the landscape, including ecosystem services, reduced need for importations, increased nutrient circularity. Interactions could involve some monetary flow, however we excluded pure purchases without non-monetary resources flows in both directions. The benefits to the network (point 3) were either identified through discussion with actors in the focus group or inferred by researchers. Further discussions between the actors and the researchers allowed insights to be gained about relevant strategies for facilitating interactions and on whether these interactions led to increased nutrient recycling at the landscape level.

3. Findings

The focus groups revealed a diversity of interactions with different modalities, involving farmers, and in some cases other actors. The intensity and frequency of interactions could not be quantified consistently among case studies; therefore, we have only compared the types of interactions according to the dimensions of Table 2.

Table 2 - Interactions observed in the case study networks. Each interaction, assigned an ID, is associated to two types of actors interacting ("Actors"), which deliver certain resources ("Resources delivered in the interaction"), giving rise to the specified benefits to the two actors and/or to the network as a whole ("Benefits in the network").

ID	Actors	Resources delivered in the interaction	Landscape benefit
IntFR1	Cattle farmer	Manure	Feed self-sufficiency; reduced synthetic fertilizer
	Cereal farmer	Feed	
IntPT1	Pig farmer (outside)	Pigs	Good quality feed and welfare for pigs; soil improvement through manure
	Montado farmer	Acorns, grazing area	
IntPT2	Sheep farmer	Sheep (goats)	Feed and welfare for sheep, weed control and decreased need for machinery, reduced synthetic fertilizer
	Orchard/vineyard farmer	Graze feed and area	
IntRO1	Mixed farmer	Sheep, dairy products	Pasture maintenance; feed for sheep in spring/summer months, employment creation
	Shepherd	Specialised labour	
IntRO2	Farmer	Dairy products, fruit, manure, calves	Manure for fertilization in orchard, employment creation, agro-tourism development in the region
	Agro-tourism facility	Products	
IntDK1	Mixed farmer	Manure	Nitrogen redistribution; reduced synthetic fertilizer, higher nutrient efficiency and gross margins.
	Biogas plant	Digestate	
IntUK1	Beef/sheep Farmer	Ruminants	Pasture maintenance, feed for sheep over the winter months
	Arable farmer	winter cereals	
IntUK2	Beef/sheep Farmer	Manure	Feed self-sufficiency; reduced synthetic fertilizer
	Arable farmer	Straw	
IntNL1	Arable farmer	Land	Improved rotation; increased production
	Arable farmer	Land	
IntNL2	Dairy farmer	Manure	Feed self-sufficiency; reduced synthetic fertilizer
	Arable farmer	Feed	

One set of interactions reflected exchanges of manure and feed/straw among specialized crop and specialised livestock farmers (IntFR1, IntUK2, IntNL2), taking advantage of their complementarity, and therefore allowing the increase of regional feed/bedding self-sufficiency and decreasing the need for synthetic fertilizer. A second set of interactions regarded the transfer of livestock from one place to another for a certain period in order to satisfy livestock needs for certain types of feed, increasing the carrying capacity on the livestock farm and pasture maintenance on the other: in IntPT1 pigs come from outside the region to spend time in the Montado feeding on acorns bringing benefits to Montado soils; in IntPT2 sheep come from farms with olive orchards or vineyards

(outside the network) to graze, therefore helping to control weeds; in IntRO1 sheep are sent to mountain pastures with a shepherd in the spring and summer months (traditional transhumance practice) and calves are grazing in orchard; in IntUK1 sheep, from livestock farms, are grazed on winter cover crops or winter cereals on arable farms. In IntDK1, IntNL1, the interactions do not involve the transfer of goods between livestock and arable farms. In IntDK1, the farmers send their manure to the biogas plant and receive digestate. Some farms pay for receiving more digestate than equivalent to the manure they sent: this leads to indirect interactions among farmers mediated by the biogas plant, leading to a nitrogen re-distribution in the region, reducing the need for synthetic fertilizer. In IntNL1, the arable farmers exchange land parcels in order to optimize rotation and therefore increase their productivity. In IntRO2, dairy products are exchanged between farmers and farmers with agro-tourism facility, therefore helping each other economically and developing agro-tourism in the region, which creates as well jobs locally. The negotiations between the farmers may also involve bartering and include the sharing of labour and resources. In case money transfer is involved, the interaction has a higher benefit to one of the two actors involved. Interactions occur mostly on a bilateral basis on the principle of a (more or less consolidated) mutual trust and do not typically involve legal agreements. However, in France (IntFR1), it is legally required that cooperatives play a role of mediation and facilitation for exchanges involving the exchange of feed. The other exception is DK1, where the biogas plant plays the role of mediator in the network.

4. Practical Implications

Many of the interactions are agreed upon informally, which may be why they are often not included in policies. It would benefit farmers if policies were implemented that not only focused on the individual farmers, but valued the interactions among farmers. This would help to facilitate the emergence of good relationship between farmers. This can also be achieved by means of intermediary agents or cooperatives. Considering the DK network, the integration with a cooperative facilitates farmer (indirect) interaction, so the intermediary role of the biogas plant is beneficial for interactions. In FR and the UK, advisors are already playing a role (organisation of training for crop-livestock interactions, playing an intermediary role). NL farmers advocated for advisors who are not experts in specialised farms (crop or dairy) but have expertise in facilitating interactions among farmers. Formal agreements between the farmers and the other actors would help to protect these bilateral relationships.

5. Theoretical Implications

Not all the interactions explored led to nutrient recycling in the landscape. For example, IntNL1 is focused on optimising the production of the cooperant farmers; however, this interaction does not lead to integration of components and nutrient recycling. IntRO2 interactions are focused on economic mutual aid, while nutrient circularity is limited. IntPT1, IntPT2 and IntUK2 involve farmers outside the network. The exchange of manure and feed (IntFR1, IntUK1, IntNL2, IntRO1) will promote nutrient recycling.

6. References

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