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Integrating crop and livestock beyond farm level: how serious games may help co-designing collaborations between neighbouring farmers.

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Crop-livestock integration is a theoretical ideal for sustainable agriculture. Albeit decreasing due to limiting factors at the farm level (e.g. work constraints), crop-livestock integration beyond farm level is seen as a promising option. However, local integration between neighbouring farms requires collective redesign to address organizational issues faced with increasing levels of spatial and temporal coordination (Asai et al., 2020). Specific methodologies are needed to co-design scenarios of crop and livestock coordination beyond farm level, involving a diversity of local actors.

We aimed to show how serious games can be used to cope with this challenge. We focused on supporting co-design of scenarios in two French regions considering neighbouring farm collaboration to reintegrate crop and livestock.

Two serious games, Dynamix and Oviplaine, were built using the same principles: i) a participatory approach taking multi-actor needs and objectives into account (e.g. livestock farmer, shepherd, crop farmer) (Barreteau et al. 2014) , ii) facilitate exchanges between farmers to build collective strategies, iii) consider technical changes at farm level and organizational changes at farmer group level, iv) include a spatially-explicit board game (map of the region).

Dynamix allows co-designing flows of grain, fodder and manure between neighbouring farms taking storage and transportation into account. Albeit Dynamix includes animal tokens, grazing on neighbouring farm is not its core. Oviplaine is an adaptation of Dynamix focused on cover crop grazing on crop farms. It allows to design day-by-day grazing itineraries for herds from plot to plot. Both games include simulation models allowing to consider supply-demand balanced for each type of crops and grassland, and seasonal variations in production. In Dynamix, a multicriteria evaluation of the co-designed scenarios allows to discuss benefits and trade-offs at the individual farm and group levels.

We applied the games with two groups of farmers: i) Dynamix in south-western France, with 4 crop aiming to diversify their cropping systems and to sell grain and fodder to livestock farmers and 5 livestock farmers interested in local and non-GMO feed for their animals; ii) Oviplaine in a specialized crop area, in the Parisian Basin with 4 crop and 1 livestock farmer aiming to build an itinerary for the herd.

Dynamix helped to quantify technical scenarios for each farm and equilibrate a local supply-need balances with 81.4 tons of cereals, 25.6 tons of protein crops, 120 tons of hay and 154 tons of manure. As crop farmers did not want to spend time dealing with storage and transportation of exchanged materials, two complementary organisational options were considered: i) plan one-on-one collaborations with individual livestock farmers able to store grain and fodder and ii) involve a local cooperative to facilitate logistics and agreements, anticipate needs and find more farmers if necessary.

Oviplaine helped the participants to build an itinerary from September to February. Some plots could be grazed during a few days, others for a few weeks. Seasonal availability of resources was estimated according to climate and crop farmers practices. The map helped to discuss the possible routes, access to water, possibilities to fence the plots, escape risks and eventual fallback zone in case of raining and damages on fields.

Both approaches confirmed the importance of working with spatially-explicit board games, tokens and maps to facilitate discussions and planning between participants. They allowed taking into account the spatial, temporal and organizational aspects. Both approaches are complementary. While Dynamix considers a larger diversity of actors, including famers and possibly third-party to organize logistical aspects over a year, Oviplaine focuses on the technical aspects of day-by-day cover crop grazing to follow the herd's itinerary. Applying the serious games on two case-studies with different contexts, actors and challenges revealed their strong potential. Games can easily be scaled-out to other agricultural contexts.

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