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Wildlife and agricultural production

MINI-PAPER: Managing farmers-wildlife relationships under a territorial framework, recommendations for European countries

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Scope and aim of this mini-paper

This mini-paper is part of the work of the EIP Focus Group on Wildlife and agricultural production. It is focused on the territorial aspects of the relationship between agriculture and wildlife, complementarily to on-farm actions and other technical and policy solutions. This document intends to analyse the current performance of land planning and management tools about wildlife issues, looking for good practices and working tools that may help reduce damages caused by wildlife and improve coexistence with farmers. This overall goal can be addressed by:

- 1) Analysing the territorial aspects of the relationship between farming systems and wildlife.
- 2) Addressing social conflicts between stakeholders (farmers, hunter, foresters, conservationists, NGO...), especially those involving wildlife issues
- 3) Promoting agreements and collaborative tools that deal with these problems while respecting the main actors and interests at stake
- 4) Improving land planning and management to balance wildlife's needs with farming security and performance.
- 5) Integrating wildlife-human relationships in land management & planning tools

Introduction: wildlife, agriculture and territory

Human-wildlife relationships are extraordinarily complex and sometimes they could be damaging for both sides. As agriculture is the most land consuming human activity it is frequently a source of serious coexistence problems (Nyhus, 2016). Those interactions have a strong link to the land where both cycles develop simultaneously. Besides, not only agriculture but other outdoors activities are also involved in those problems, including hunting, sports, tourism, or nature protection. Other land uses are also responsible for strong interactions with wildlife: transport and communications, urbanism, water management or energy production.

These interactions raise unanswered questions about the role of human-wildlife relationships in an increasingly humanised biosphere (Lorimer, 2015). Wildlife-related problems make us aware that our efforts to segregate humanised areas (such as urban, agricultural and industrial areas) from natural areas usually end in coexistence failure. Fencing, deterrents, monoculture, urbanisation and strict construction of city centres do not eliminate the presence of nature in these places, just drives it through alternative ways. Wildlife adapts and take advantage of new opportunities, under man-made conditions. Consequently, the society is compelled to manage these relationships, which necessarily bring the need to address human expansion and footprint on the landscape, recognising that the presence of natural capital is essential for our health and development. Anyway, in this complicated human-wildlife coexistence framework, farming and forestry are the most affected human activities and at the same time, the most suited to develop a territorial action to establish a common ground where coexistence could be developed (Tschartnke et al, 2012).

Under this background, land acts both as the scenario where wildlife-agriculture relationships happen and as a provider of most elements they both need to develop (Carter et al, 2019; Wright et al, 2012). On one hand, as a scenario, its actual configuration has a strong influence on where and how human activities and wildlife converge and interact. On the other hand, as a provider, it is changing and evolving, hosting fluxes of materials (including animal movements), energy and information, influencing the occurrence, intensity and evolution of human-wildlife interactions. Consequently, understanding the territorial structure and dynamics related to the interaction between human activities and wildlife becomes a necessary step to manage those relationships in a positive way, which may simultaneously reduce losses and maintain agricultural production, while protecting key natural elements and processes.

However, current territorial and landscape trends show evidence of an increasing polarisation of land-use and settlement in European landscapes towards a global process of urbanization (Primdahl et al., 2013; Plieninger et al., 2016) that is making people leaving the countryside while agriculture gets concentrated and intensified. Urbanisation and abandonment are currently driving European landscapes, redefining the relationship between European cities and countryside (Antrop, 2004) and affecting the structure and population numbers of wildlife species, such as carnivores or wild ungulates. Remote rural areas with poor accessibility befall on

abandonment, losing to fragmentation and homogenisation of highly valuable traditional landscapes, getting primary agricultural fields occupied by wildlife, and gradually losing their identity. On the other hand, urban-influenced environments and metropolitan areas becomes a complex, multifunctional and intensively used space within a larger urban network frame where industrialised crops and intensive livestock farms occupies large surfaces of the remnant accessible and productive land, which loses biodiversity and landscape features (van Vliet, 2015). In this scenario problems linked to interaction with wildlife are more probable to happen and much more difficult to solve (Tsunoda, 2020), impacting in the complex matrix of multiple interests shown in progressively urban areas or with an increasingly abandoned (though with natural values strongly defended) rural landscapes.

Failure to properly address these problems is causing deep trouble to farmers and other stakeholders in rural territories that need urgent and sound policies to support their livelihoods. Besides, lack of coordination between land planning and sectoral policies makes the implemented measures inefficient, driving farmers to apply individual solutions, which often are ineffective, and drive them to clash with other people and interests. Thus, the most affected people are left lacking capacity, resources and support to improve their situation, which leads to conflict and misunderstanding, ineffective governance and often contradictory action. Correcting this situation implies developing land-based policies and strategies that could provide better tools to manage human-wildlife relationships in agricultural landscapes.

Often, preserving biodiversity while protecting agriculture from wildlife damage feels overly contradictory, becoming, for many managers, a win-lose situation. Either the goal is set on protecting biodiversity and consequently assume wildlife damages or, conversely, prioritise agriculture production or other industrial activities with disregard and marginalisation of wildlife. This dual attitude towards land management is often shown in rural areas, resulting on an overload of extreme measures that may solve temporarily the problem but are proven ineffective on the long term. Examples of it are the combination of fencing and culling in certain areas suffering pressure from wildlife species considered potentially damaging, attitude that can be upscaled to full countries or regions. An example is the territory of Denmark, where there is a huge concern about wild boars and its role in disease transmission towards Danish hog business. Accordingly, the presence of wild boars is not easily tolerated (Jordt, 2016) and wild boars crossing the Germany-Denmark (Land Schleswig-Holstein) from the south have been regularly eliminated by shooting. Currently, the spread of African swine fever (AFS) on the German border led to building a fence to prevent infected individuals from reaching Denmark. A similar perspective was applied to shoot, in 2017, a European Bison that crossed the Polish-German border near Lebus (Germany). Whilst reintroduction of European bison has been promoted to enhance biodiversity and natural habitats of Western European countries, it also has been seen for years as a threat to forest and agriculture.

Farmers often feel the presence of wildlife species on agricultural fields as fearful, leading to a widespread belief that there should be separated areas and no wildlife should be allowed in the crops. On their own, farmers usually solve this kind of problems at the field level. Wildlife issues are seen as a technical problem like insects, weeds or diseases that could be solved with the appropriate tool. Often, these isolated actions do not solve the problem but simply move it to other farms in the surrounding area. Often, as damages result from animals moving between agricultural and non-agricultural fields, trying to apply on-farm solutions can be ineffective. Conversely, when considering the territorial level and the ecological processes involved, the coordination of different types of measures is a better guarantee of effectiveness.

Finally, the agroecological perspective seeks for wildlife-friendly models of agricultural production (Tscharntke, 2012) arguing that a biodiversity conservation strategy based on spared natural land whilst agricultural land is intensified and its wildlife evicted is neither viable nor acknowledges the mandatory complexity needed to protect most species or habitats of interest. Agroecology aims for efficient farming practices and land management tools that intentionally include functional biodiversity at multiple spatial and temporal scales, seeking for a productive coexistence with wildlife that could maintain key ecosystem services for agriculture, such as soil fertility, pest and disease control, water use efficiency, and pollination (Kremen et al, 2012).

Problems between farming and wildlife do not arise only in marginal areas, mountains or protected lands. Often, all these marginal territories are better adapted and have better tools at their disposal to manage those

contingencies. Conversely, intensive agriculture developing in deeply transformed landscapes face increasing problems related to wildlife (Fischer et al., 2017). Accordingly, the presence of wildlife is also triggering conflicts at the city's meeting point with forests and fields.

This kind of problems can usually be addressed using proper tools. Often, land-based activities are ruled by a set of land planning and management plans and tools running under different governance models. Besides, they are often linked to comprehensive development frameworks. In any case, problematic relationships between wildlife and agriculture are rarely accounted for in land planning, so it is really important to build proper guidelines to help planning tools to address them and contribute to coexistence.

This mini-paper analyses the potential of territorial approaches to address the rising problems between wildlife and farming, making a series of recommendations to improve the way wildlife issues are addressed in land planning and management tools, focusing specifically on territorial aspects and aiming to reduce conflicts and develop a farmer-friendly scenario of human-wildlife coexistence.

The territorial approach to coexistence

The territorial perspective consists of considering the spatial dimension of those problems, analysing how wildlife uses the whole territory (not just the problematic areas), and applying solutions based on coordinated, and multi-agent action implemented over wider territorial units. This approach can be implemented at multiple scales and levels, but these two characteristics, i.e. landscape and multiple actors, define the territorial scope. Consequently, applying a territorial approach demands wide political competences, coordination between different actors including government agencies, municipalities, stakeholders and private organisations and common goals for a given territory, which makes the implementation of those tools quite difficult. This chapter offers some ideas to help develop innovative land-based planning and management tools or update the existing ones to deal with wildlife-agriculture relationships under complex political and territorial backgrounds.

Land planning and wildlife management

Ideally, land planning addresses natural resources, land uses, nature conservation, sustainable development, landscape, climate adaptation and sectoral planning (agriculture, forestry, hunting, communications...) under comprehensive instruments, which should consider together all interests at stake. This kind of planning tools, when properly used, are adequate to deal with relationships between farming and wildlife at a landscape level.

In any case, the reality of European countries is that comprehensive land planning is rarely developed under a single governing body or a strong institution that coordinates different topics on the same territory. Only some European areas, for instance those under strong protection regimes (such as National parks) have a coordinated political direction and strong planning tools. Most other protected areas (such as the Natura 2000 network or Biosphere Reserves) develop land planning and management tools that mostly rules nature protection and land uses, but under heavy influence of sectoral policies, which not necessarily account for global objectives. This is the case of France, where water is managed by catchment basin, hunting by administrative units, crops by grain collection basin, etc.

Other countries, like Spain, add to this situation the federal-like competence distribution, which gives the regional governments state-like powers in agriculture, nature protection and land management.

It is possible to address farming-wildlife situations under a territorial perspective when there is already a territorial framework to manage them. When these tools are not available or not well adapted to local situations, we still can apply a territorial perspective but, first we should build up the dialogue ground, the multi-actor involvement and the capacity of action with the stakeholders involved. Consequently, we need to convince people, institutions (and funders) of the usefulness of working on a territorial scale to manage wildlife issues.

Conversely, as human-wildlife relationships are complex, affect different sectors and they are often linked to conflict situations, to deal with them it is necessary to develop and optimize proper planning tools, and prepare people to use them in this kind of situations. To this end, the first step is to develop a comprehensive framework addressing relationships between farming (in a wide sense, including crops, livestock and forestry) and wildlife, also including other human activities and interests.

Eco-systemic approach as a planning basis

The management of farmers-wildlife relationships under a territorial perspective should rely on scientific information and addressed under an eco-systemic approach, working in the same direction and with the same processes than natural ecosystems do. This section gives some perspective on how to develop strategic land plans better suited to manage coexistence and interaction with wildlife.

As a first step, we need to establish a common ground for these relationships to happen. Anyway, rural space, as a habitat for humans and wildlife can be considered as a social ecological system, including a community of living organisms and people, relationships, space, fluxes of materials, information and energy all of them interacting as a system with stronger internal links that those related to other ecosystems or the environment.

A key practical question about systemic approach to managing those interactions is the role of science and research. The Rio de Janeiro Convention on the Protection of Biological Diversity, which has been ratified by 196 countries to date, obliges most European countries to apply an ecosystem-based approach to biodiversity protection, that should also be acknowledged when dealing with wildlife-related problems. The management of agricultural areas where wildlife species occur refers to the application of mechanisms of functional ecology related to interactions between all components (Preise et al., 2018). Accordingly, the use of scientific tools in territorial management at the ecosystem level is not only an appeal, an incentive, but something necessary. Science creates a framework within which land planners and managers will navigate. Consequently, they should have access to enough sources of knowledge and support to plan consistent territorial management actions.

Moreover, ecological processes are nested on increasing time and space scales (Allen & Star 2017). According to this “hierarchical principle” (see fig.1) higher scales action can constrain the success of strategies implemented at lower scales. Meaning that, in our case, a territorial plan can hinder farm-level wildlife damage prevention measures. For example, the damage on a raided crop field will not depend on the food resource on the field itself, but also on the relative interest of the different resources in the landscape. Some bird species like woodpigeon are known for their demographic dynamism in cities, which condemns to failure the regulation strategies in the neighbouring countryside. As the species in question often have significant dispersal capacities (wings, for instance) this principle implies the mandatory need of coordinating the actions carried out at the different levels: field landscape and region to be able to control the problem.

Anyway, mammals and birds causing agricultural damages have sophisticated behaviours. Animals develop on the field behavioural adaptations such as the exploitation of new resources and habitats or the habituation to scaring methods. Management should therefore be adaptive, nonetheless as climate, landscapes and biological communities are also quickly changing, making knowledge become outdated. Particularly, some key species and populations, such as invasive species must be closely monitored. This need for change and adaptation raises another key issue: that science does not have all the answers. Sometimes knowledge is outdated, poor or inaccurate, as happens with the biology of certain species (especially common or non-charismatic species) so the predictive capacity of ecology can be insufficient for choosing management strategies. Therefore, it is important to accept uncertainty and to collect data in order to re-evaluate knowledge and assess management strategies in a data-driven approach.



Figure 1: multiscale framework for the analysis of wildlife agriculture relationships

Mapping and monitoring: a keystone for success

Establishing a rationale, scope and foundations of land planning instruments that should be used to address human-wildlife relationships, is a first step, and a key conceptual one, to address wildlife-agriculture issues from a territorial perspective. However, we cannot address such complex issues without proper knowledge of the actual situation where they develop. We need knowledge, we need facts, we need data to be able to plan for the future, establish a land-based strategy or implement useful measures. Logically, territorial perspective on solutions demands territorial perspective on information and data compilations. Assessing the situation under this perspective relies on two key processes: mapping and monitoring.

Mapping consists basically on graphically displaying phenomena over a land representation at a defined scale, while monitoring provides actual data about those phenomena, measuring its main characteristics, magnitudes and change. Mapping focuses on space change, while monitoring deals with change over time, so both are complementary and needed as key assessment tools for developing strategies to cope with wildlife issues.

Ecosystem mapping as a basis for the establishment of a rural development plan

Mapping, as it links a situation to an explicit area of occurrence is the first step to characterize a problem under a territorial perspective. Anyway, mapping doesn't mean drawing a static line on a map, but giving territorial sense to changing, flexible and adaptive situations. It is very important to acknowledge that while maps are static the reality of human-wildlife interaction is very dynamic and voluble, consequently accurate decisions have to be made over a reality that changes so much faster than maps. Anyway, despite this underlying contradiction it is possible to represent, if not the dynamics themselves, at least some of the factors that influence those dynamics and represent a real scenario that helps decision-making. Conversely, out-of-date cartographic information makes these tools useless and often constrains the whole effectivity of land-based tools. This section offers some mapping ideas to help deliver accurate measures to address agriculture-wildlife issues.

Mapping starts by establishing and defining the boundaries of the territory we are dealing with. Multilayer GIS are instrumental for developing operational maps representing the different factors influencing this problem, including the different habitats, land uses and local dynamics. The basis for this implementation could be established upon agricultural mapping designed for the management of Common Agricultural Policy, which collect the main agricultural lands and their characteristics. Besides the usual features displayed in any spatial planning GIS, specifically a detailed land-use layer, any map intended to deal with wildlife issues should also represent some items related to coexistence such as the habitats and areas used by each target species. Animals often use a matrix of different lands (which can change over the year or lifecycle) to fulfil their requirements, so it is difficult to represent their features.

Connectivity is, for instance, an important issue, which can be addressed using multipurpose or species-specific map models designed for spatial planning (Ganges & Herrera, 2013). Sometimes low connectivity pushes constrained populations of wild species to use agricultural fields whether like it or not; some other times, good connectivity allows specific groups to access agricultural fields and profit from temporarily high availability of resources. Either way connectivity is key for wildlife movement behaving sometimes in different ways than expected: e.g. rabbits in central Spain are attracted to roads, specially fenced highways that provide shelter and mobility across the landscape (Barrientos, 2009; Planillo & Malo, 2013) becoming far more problematic for adjacent crop fields that those isolated in the landscape. Also, fragmentation is another feature influencing coexistence. Infrastructures (roads, energy lines...) intensive land uses, fencing and other activities are actually fragmenting the landscape, reducing wildlife mobility. Fragmentation also influences the way wildlife access and uses the land leading to undesired situations. Additionally, layers displaying damages and other interactions between wildlife and agriculture are also necessary to assess the risk (the probabilities of having problems and their magnitude). Moreover, some social-economic factors that also could influence damages, such as property and access rights, livestock paths, hunting areas... should be displayed. This way we can unravel underlying patterns that help understand the problem.

Maps can also support key planning tools, such as zoning, which implies organising spatial information to define specific areas where different approaches or measures should be undertaken. Finally, maps are powerful tools to display and analyse reality, but they also play an active role in actual planning and decision-making. Predictive maps of risk can help to be prepared for problems and try to prevent them. Participatory mapping can facilitate local stakeholders to give accurate information on damages, to assess different future scenarios or planning for implementing specific measures and innovations to reduce damages. Despite all this power, maps are just representation tools, as useful as the data they rely on. Accordingly, they should be founded on sound data obtained through monitoring. To this end, this map should be understandable by its end users and displayed in terms they could manage, but once accessibility is accomplished it can be extremely useful.

Monitoring farmers-wildlife relationships under a territorial framework

Monitoring is essential for the implementation of an adaptive management, following a principle of progress loop. Its purpose is to provide sound data to characterise the damage and diagnose its causes, and then to evaluate the effectiveness of the management measures implemented. It should enable a shared vision and constructive discussions between stakeholders. If possible, data should be quantified and spatialized (mapped) so that zoning can be carried out. Data collection should in principle be carried out on an annual basis, which corresponds to agricultural production cycles.

Data to be collected

Monitoring systems for adaptive management of farmers-wildlife relationships generally require three types of information:

1. An objective assessment of the damage is important in order to dimension the responses to be provided. The strategy will be to rely on voluntary declarations or to carry out randomised surveys. In the first case, the total amount of damage will be inaccurate and will be reduced if respondents are not motivated to report the information (in particular if no financial compensation is foreseen). The second case is more suitable for obtaining an accurate estimate but requires more resources.
2. The status of wildlife is important in understanding the origin of damage and establishing management plans. The data may relate to the target species and possibly other species of interest, e.g. predators of the target species. Detailed information on the behaviour of the target species (photo traps, GPS tracking) can be valuable in case of doubts about the attribution of damage (e.g. symptoms that can be attributed to several types of pests, e.g. birds and slugs can cause similar symptoms on young plants).

3. Finally, information on drivers such as landscape and damage management and prevention practices should make it possible to assess their effectiveness, by linking them with information on damage and the status of populations. Practices should be considered at the field level (protection implemented by farmers), but also at the territorial level (crop areas, crop rotations, landscape elements, regulation of the target species).

This data should, as far as possible, be accurately located and have historical depth. The table 1 lists these main items, the generic methods used to obtain them and the data sources that can be used.

Table 1: main data required for monitoring farmers-wildlife relationships

Data		Sources and methodologies
Damage	Voluntary statement	Public collection for compensation (validation by experts)
		Insurance collection (validation by experts)
		Participatory collection (e.g. with collaborative mapping tools, citizen's science...)
	Randomized on field or on farm survey	With the support of research or advisory services (farming or hunting)
	Remote sensing (for ungulates)	Commercial services, research projects, public observatories
Wildlife status (target and other species)	Abundance	Standardized protocols
		Existing databases
	Species diversity	Standardized protocols
		Participatory collection
	Movements and plot frequentation	Via sensors (camera traps, GPS)
Opportunistic and participatory collection		
Drivers (both managed and unmanaged)	Land occupation (crops, hedgerow, forest...)	Open data
		Commercial products
	Farming practices	On farm survey
		Participative collection (e.g. with collaborative mapping tools)
	Hunting and regulation practices	Compulsory data collection (kill count)

Methods and tools

Monitoring for territorial planning must be designed in a participatory way. The objective is for the stakeholders to agree on the dataset to be collected and the indicators that will be derived from it. This work must benefit from the expertise of stakeholders and possibly researchers when the processes at the origin of the damage are poorly known or controversial.

The reality of damage may be a subject of dispute between stakeholders. Damage is determined after it has occurred on the basis of characteristic symptoms. Some are ambiguous and must be agreed upon in advance. The link to economic damage may be indirect. For example, the link between losses of emerged plants and commercial production depends on many agronomic factors. Again, agreement among stakeholders on the estimation methodology is important.

The design of the monitoring activity is important to reduce costs and guarantee interoperability with other national or even international information systems designed to guide public policies. It is indeed important that data from different territories can be aggregated and processed. Therefore, we propose the following recommendations:

- Use as far as possible existing data sets already collected by the government or other stakeholders. Some resources are available at EU level for land occupation (e.g. digital land parcel identification system for crops - LPIS) biodiversity monitoring (e.g. Pan-European Common Bird Monitoring Scheme) etc.
- If new data collection is needed, use standardized national or international protocols whenever possible.
- Choose open data and open formats, which guarantee cost reduction and better use of data within the project and beyond.

The development and democratisation of digital technologies are nowadays favourable to a reduction in the costs of data acquisition and processing. They enable ambitious and collaborative projects, in particular:

- Satellite imagery provides free high-resolution products for land use planning (e.g. the EU Copernicus programme provides free access to high resolution satellites images. See Inglada et al., 2017 for an operational land cover map derived from Sentinel 2).
- The internet of things (IoT) and the lower cost of sensors allows precise tracking and location of wildlife via connected cameras or GPS devices adaptable to both large vertebrates and birds like corvids and pigeons.
- Unmanned aerial vehicles (UAV, i.e. drones) coupled with image recognition allow the detection of crop damage at low cost e.g. (Rutten et al., 2018 for an application to wild boar damage).
- There are now a large number of tools available to integrate data collection, sharing visualization and processing. The implementation of these tools requires less and less specialized computer development skills. Some are specifically oriented for collaborative projects, e.g. to support "volunteered geographic information" obtained by citizen science.
- The development of open data, supported by public policies, facilitates access to many datasets via national or international platforms (e.g. EU Open Data Portal).

This generic framework for data management allow different treatments of spatial data:

- Locating areas at risk of damage according to observed spatial patterns;
- Identifying risk factors (extraction of knowledge by correlating drivers and damage);
- Predicting and mapping risk areas according to the present situation or to future actions (models).

Some treatments are simple, others require specific competence in data science.

Temporality of the monitoring

Monitoring should be stable and permanent. It is indeed important to listen to weak signals and to anticipate problems. For example, the control of voles must be carried out before the outbreak, i.e. when monitoring reveals demographic trends that are invisible without a standardised survey. Stopping monitoring because the problem has been recently solved can have serious consequences. Invasive species also demand sound monitoring before problems occur, even if this may provoke scepticism.

Tools to deal with wildlife issues through a territorial framework

The previous sections show why a land-based perspective is so necessary, but the real actions that can be performed under spatial frameworks are sometimes poorly defined and difficult to plot in advance. Besides, territorial measures designed to address wildlife-agriculture issues are highly specific depending on the target wildlife species, agricultural activities and landscape structure and dynamics, so it is really difficult to pre-compile a list of the particular actions to be developed. Anyway, to complete the perspective of these tools, the following list introduces some powerful territorial tools that could be applied depending on each situation.

First of all, the main advantage of territorial approach is basically coordination between actors to achieve a common goal. Coordination implies a leadership (individual or collective) widely accepted and supported and a sound governance model. Anyway, territorial coordination can develop at different levels and with different actors. Bottom-up coordination starts with collaboration among farmers to pool resources and synchronise actions to enhance their impact and performance, for instance using dissuasion methods simultaneously and on the right timing. They also can partner with hunters to coordinate hunting plans with farmers demands, with environmentalists to install refuges for pest predators, with shepherds to graze and control abandoned lands, etc. Upscaling this coordination should lead to active policy-making dealing with those problems. Coordination between government bodies is also a must in the territorial approach.

Besides coordination and governance, territorial action targets habitats, resources, mobility, populations and relationships of species as seen on-farm measures (COAG, 2010). Interventions over habitats can include changes in agricultural activity such crop rotation, scheduled grazing, fallows, woody cultures, etc. Also, spontaneous vegetation could be managed with treatments like grazing, controlled burning, cuts, plantations, etc. Soil and other factors can also be targeted, with ploughing, seeding, fertilization, watering, etc. Besides, mobility and connectivity can also be addressed by managing landscape features (waterflows, patches of vegetation, groves, forests, pastures, etc), infrastructures (channels, paths and roads, fences, walls, hedgerows, tree lines, crop edges) and land uses (forests, crops, urban, industrial, etc).

Finally, land-based interventions can manage wildlife populations and their relationships coordinating actions potentially carried at farm and local level plus incorporating specific measures carried upon non-agricultural land units. Besides, populations can be influenced through resources management, which implies creating, removing, displacing or adapting shelters, food, mating grounds and other specific needs (holes, hosts, rocks) for targeted species or their predators or parasites. Management of predators is an important tool at territorial level, not only for controlling the population of species causing damages, but also for their role as deterrents. The management of population dynamics demands a deep knowledge of the species and its behaviour, along with detecting seed populations to provide individuals willing to adapt to agricultural environments and preventing population sinks and barriers. As an example, country voles (*Microtus arvalis*) in Castilla y León (Spain) was a huge problem in 2007, with 200.000 ha affected and losses estimated over 15M€. These invasions have been detected since the 1990s, and correlated with agriculture expansion, climate change and tularemia disease outbreaks (Jareño; 2014). Environmentalists have been working in cereal crops implementing a biological control system of voles providing shelter for kestrels, barn-owls and other predators, with very interesting results (Paz et al, 2012). The organisations behind this project have strongly advocated for a territorial strategy to enhance those measures and adopt a real land-based strategy.

To our knowledge, the principles mentioned above have not been implemented throughout the entire sequence from diagnosis to assessment. They should be seen as guidelines. On the other hand, some territorial diagnoses based on these general principles were carried out with the support of research teams. The table 2 gives a few examples.

Table 2: examples of territorial diagnoses and strategies

Species	Region	Governance	Data	Output	Reference
Wild boar (<i>Sus scrofa</i>)	Basilicata region, Italy	Research project	Existing survey on localised damage (2007 to 2012) Geographical drivers (human density, vegetation, distance to road...)	Prediction Map of risk Ex-post assessment of 2 management scenarios: integrated prevention and control action on delimited areas vs. compensation	Cozzi et al., 2019
Bulbul (bird) (<i>Pycnonotus jocosus</i>)	La Réunion, (French overseas department)	Working group led by agricultural organisations and public authorities, including research institutes and an environmental protection association	Existing data PhD Thesis for linking birds and landscape (radiotracking, abundance...)	GIS for analysis and decision making Integrated multi-scale management plan	Clergeau et al., 2002
Voiles (<i>Microtus arvalis</i>)	Castilla y León (Spain)	Research and action projects led by NGO and research groups	PhD Thesis , Degree thesis Manual for biological control of voiles	Large scale nests and posts for predators were installed Promising results at scales of 1 nest for kestrel and 1 for barn-owls for each 20 Has	Paz et al, 2012

Limits and difficulties of adopting a territorial framework

The adoption of a territorial framework, although necessary to implement strategies above farm level, faces several difficulties to be successfully developed and won't always be possible or easy. In any case, there are areas better suited than others to implement pilot territorial frameworks to address wildlife problems. As said, protected areas (Biosphere Reserves or National Parks for instance), usually have developed specific spatial tools for their planning and management and also develop monitoring and conservation programs for endangered species. Under such conditions, those areas should be more prepared to implement demonstrative monitoring and management plans dealing with wildlife damages. Consequently, they can act as pilot areas for implementing this territorial framework. A similar role can be undertaken by other land-based figures, such as metropolitan areas, controlled appellation of origin, etc., if they have access to certain

tools such as spatial planning instruments, GIS or research units. Adopting this approach in already highly developed areas may limit, to a great extent, the ability to analyse and program in advance concrete preventive actions, though their higher availability of resources may help overcome these constraints.

This section lists some of the main constraints for using a territorial approach. Some of them (as absence of strong land institutions and lack of coordination between government agencies) are structural and demand stronger and deeper political commitment. Generally speaking, those constraints are out of the scope of this paper and won't be dealt with specifically, although some recommendations set the focus on policies and participatory institutions supporting territorial initiatives.

The systems of beliefs of the different stakeholders need to be taken into account. Social and cultural issues are key with dealing with wildlife issues. Stakeholders do not easily give up some of their beliefs, even if they are contradictory with evidence or research. Environmentalists, sometimes allied with hunters, often dispute the reality of damages, diminishing them or blaming bad practices. On the other hand, farmers, sometimes allied with hunters, usually see no other solution than culling and population control. Besides, conflicts often arise from a clash of beliefs even if objective interests could be harmonised. Anyway, while participating in territorial actions supported by a monitoring system means taking the risk of seeing those beliefs challenged, the results of collective action can be much more effective and supported by the community.

Land planning for complex territories is difficult and can delay solutions. Adopting this approach in already highly developed areas with complex dynamics (metropolitan and peri-urban areas, industrial regions, etc.) may limit, to a great extent, the ability to analyse and program early action. On the other hand, those territories can mobilise more resources to address the problem, so the challenge here is to make the agriculture-wildlife relationship a priority issue for land planning.

Governance can be complex and difficult to establish. There are many stakeholders interested in agriculture-wildlife relationships at the territorial level. They belong to the agricultural, hunting, tourism or nature protection among other sectors, and their interests are often contradictory. When a wildlife issue becomes visible, each stakeholder considers itself legitimate to give its opinion, but not to lead and coordinate a project or a solution. This way, conflicts often arise blocking solutions and demanding the intervention of the government agencies, imposing solutions or bringing back stakeholders to the table. This vertical mode of governance makes it possible to go ahead and provide substantial resources and actual interventions on the problem, but it also presents risks such as lack of trust and commitment. The challenge here is to develop horizontal and bottom-up governance models for those projects, facilitated to be carried by all the stakeholders under prior and honest agreement, in order to achieve a common objective.

The delimitation of territory to establish this spatial framework poses another problem. Governments are organised on different levels (municipality, region, etc.), which may or may not coincide with affected territories, or with the scope of stakeholders' organisations. Besides, wild species are not aware of these constraints and are distributed according to ecological criteria that are not always well known. There is a risk of working on too small territories that will cause failure because of external constraints or too large territories with a dilution of resources.

The required skills are not always available. Data management is a keystone of monitoring. To be efficient (maximum output at low cost), it requires skills that are not always available. Some projects may require full-time data managers, but for others, volunteer "geeks" familiar with open data platforms may be of great help. A good data treatment will be instrumental for gathering useful intelligence, so projects need to be aware of this.

Territorial projects often lack continuity, stability and long-term perspective. Land-based programs have their own timespan that need to be respected. First, land planning is a time-consuming activity, so there is a need of time to design and implement the plan. Then, implementation should be considered and scheduled to last and prolong the solution over time. Besides, monitoring schemes need to be running under schedule, and be sustainable to anticipate problems and to allow time for actions to take effect. However,

projects often rely on temporary funding that are assigned over a few years, on annual budgets from government agencies (affected by political changes) or on public interest that fades away when it is more important to take preventive measures. Setting up a long-term prevention project is really a challenge for most actors engaged on land-based issues.

Innovation and knowledge gaps

Farmers often lack effective and certain means to protect their crops against vertebrates, as it is the case for the other bio-aggressors that are usually treated with effective methods used under strict protocols. Even if those methods are discussed and there is public controversy and collective action against their use (as happens with herbicides and pesticides affecting pollinators) farmers are supported and supposed to act against those pests. Conversely, science and research is not helping enough with wildlife issues. Vertebrates are traditionally out of the scope of agronomy which mostly deals with weeds, insects and diseases. On the other hand, agriculture is out of the scope of ecology which traditionally deals with a “nature” made of undisturbed habitats. Lately, agroecology, as science, social movement and agricultural practice, has started to apply a wider perspective to coexistence, but in-between farmers feel helpless and frustrated, and coexistence with wildlife is not getting better.

Anyway, we still lack critical knowledge to manage those problems. This gap is especially visible for bird species, for which scientists are in most cases unable to understand the spatial and temporal variability of damages. Birds behave in a complicated way, so we still do not know well which are the cues for the selection of food items within a field, between fields in the landscape, or landscapes in a given region. Besides, it is difficult to know what are the vital areas for bird species and how they move or how they adjust food supply and demand throughout the crop growing season. Without proper hypothesis and research, stakeholders are condemned to blind empirical tests which may be costly. For example, it is not possible to assess, in a given spatial and temporal context, if the balance between the positive effect and the negative effects of semi-natural landscape elements is in their favour or against them. To date, no insurance system allows the tests to be carried out on this large scale. In other words, farmers have to bear the risk of loss in case of failure.

The same happens for mammals, as have been seen in the case studio of country voles. There is, still, a great controversy about some traditional management tools such as poisoning, burning stubbles or erasing landscape features, that generates conflicts between farmers, governments, researchers and environmentalists, muddling the waters and preventing proper research and collective action to be implemented.

Surprisingly, there is still no sound proof about if enhancing landscape elements are good or bad to prevent and manage damages. On one side, landscape elements are considered key for ecosystem regulation helping to stabilise populations and preventing demographic explosions, on the other hand they are considered as reservoirs, where damaging wildlife can shelter and restart their cycles, even after successful interventions. This controversy is the same with pest insects: landscape features (flowers, trees, pastures, shrubs...) usually help effectively to regulate their populations but the variations in local conditions (crop, landscape, communities) may lead to failure (Tschardt et al. 2016). The relationship between landscape elements and wildlife causing damages remains blurry, and probably it will need to be analysed and monitored specifically for each species causing trouble and each agricultural area suffering them. The treatment of these features in both CAP and other local policies is generalist and not linked to the specific context. It can be more or less successful promoting biodiversity in agricultural fields but, to this moment, is nearly unknown its effect dealing with wildlife issues. Nevertheless, research on those elements should be included in CAP-related analysis to be properly addressed in payments and regulations.

Summarising, there is a great need of knowledge, including data & info about biology and movement of target species, which can be obtained through monitoring tools and more research about ecological processes. There is also a need for historical data that are hard to find, update and optimize. Besides, dealing with wildlife specimens could demand specific skills that only farmers and trained people have been able to obtain from peer to peer transmission. Stakeholders, farmers and other actors should be involved also in data gathering

applying a participatory approach to gain knowledge, including participatory surveys, citizen's science and participation on data monitoring or early alert systems.

The key for an effective field intervention at a territorial scale is being able to gather enough knowledge from researchers, managers, farmers and other stakeholders. But it is difficult to combine different models of knowledge into actual capacity of action. Co-construction of knowledge (Morais, 2016) is a tough and undeveloped, although powerful tool for managing complex systems and complex problems. Scientific knowledge of ecology and ethology, supported by actual data, is essential. Research intervention has the advantage of elevating the debate by getting participants to imagine solutions "out of the box". But field experience is a key tool to determine if a specific solution will be useful or not and developing technical approaches to specific problems. Moreover, there could be an additional need for professional support and consulting right on the field, which can help to assess the performance and cost-effectiveness of the solutions proposed.

Anyway, there are some additional barriers for this co-construction of knowledge. Language is one of them, different social groups have different languages. Some of them can be obvious, like different languages in different countries or regions, or scientific and technical literature being inaccessible to local stakeholders. But some other language barriers are hidden and very effective in preventing good communication. Farmers and environmentalists, for instance, do not mean the same when they talk about protection, predation or losses. Experts often use complex and barely understandable language to explain their concepts, and people not used to talk in public may experience difficulties in transmitting their thoughts. Additionally, technical and geographical differences also can make data sharing difficult, as when available geographic data are not in the same platform or projection as the main map, so they are not directly usable.

Finally, information gathering is not enough to gain capacity of action. This information should be accessible and transparent, organised in a way compatible with several information systems (open data, good metadata, friendly user interfaces, technical support), stakeholders should have all the help they need to interpret and act upon it and government should have available technical consulting ready for working with farmers and other final users.

Recommendations to address wildlife-agriculture relationship from a territorial approach

The next recommendations are meant to be practical and useful to land planners, researchers, decision-makers, technicians, development and innovation brokers, farmers and other stakeholders involved in land-based activities.

Recommendation 1: Address human-wildlife relationships with land-based tools.

The first recommendation is effectively including these problems to land planning tools or to create new specific spatial tools to deal with them. To this end it is recommended to use an ecosystem-based approach. These tools are fed by data and information and displayed over maps, so it is possible to use existing available research and accurate data, try to improve field information on the subject and use and share knowledge from local agents. This information needs to include a good assessment of wildlife damages. In any case, all this data should be displayed in maps, using a well implemented and frequently updated GIS. Other tools, like rural development programmes (RDP), for instance, should include coexistence with wildlife, taking into account the needs of all participants managing natural resources. At the same time, RDP can apply a wider perspective over territorial elements and strategies needs while support can be provided to test innovative/collaborative solutions at the territorial level (for example under the cooperation measure and more particularly via EIP operational groups).

Recommendation 2: Promote farming as an accurate and powerful land management tool

Farming is one of the most powerful ways to manage a given territory and provide good support for outdoor activities while improving biodiversity. Farming based on territorial resources can help control and improve primary production, vegetation, soil quality, landscape features, and fluxes of water and materials at a territorial scale. This way, better farming becomes the main tool for landscape interventions and consequently for preventing and managing wildlife damages. That capacity is especially evident in high nature value (HNV) systems and agroecological farming, including systems such as organic farming or pastoralism. HNV agricultural systems provide quality production compatible with high levels of ecosystem services and wildlife coexistence. Besides being often affected by wildlife related conflicts, those systems also hold knowledge and capacity to implement suitable solutions, protecting their activity and improving their sustainability.

Recommendation 3: Improve connectivity while controlling accessibility.

Connectivity, is a key territorial issue to allow ecosystem services of control and wildlife movement at territorial scales. As contradictory as it could seem, reduced wildlife mobility can help concentrate the damages and increase its intensity. Enhancing connectivity helps wildlife to move between suitable habitats, accessing more resources and spreading their effects. It also allows movement for their natural controllers, helping to adjust the size of their populations. Anyway, whilst overall connectivity should be enhanced to improve ecosystem dynamics and help stabilise wildlife population, access to fragile sites or areas especially vulnerable to damages should be managed by using appropriate fencing, landscape features, dissuasion tools, repellents, dogs and other deterrent measures. In the same line, some specific situations may be addressed by segregating potentially damaging wildlife from farming and keeping at a minimum the interactions between them (especially vectors of disease and predators), for instance limiting accessibility to features used by both domestic and wild animals (salt rocks, water sources, shadow trees...) and limiting provision of resources for wild animals close to vulnerable sites. Large-scale fencing of fields and forests should be used with caution in territorial management. It disturbs animal migration routes and encloses populations. At the same time, it is expensive and does not provide full protection against other animals. Anyway, these measures do not contradict the agroecological approach promoting close interactions between agriculture and wildlife, especially beneficial fauna, as those agricultural activities can still be HNV systems, organic or wildlife friendly.

Recommendation 4: Use zoning as an adaptive tool to set priorities for each area

Zoning, as assigning each patch of land with specific treatments and measures is one of the most important tools on land-planning. Zoning doesn't mean fencing or enclosing but adapting measures to the characteristics of each area. Besides, different land categories may be instrumental to seek wide agreements on priorities for each area to dealing with wildlife. This way, when wildlife is prioritised, for example in a protected area, farmers and people traditionally using these areas should get recognition and proper support for their work. Although zoning is a powerful tool, it needs to be flexible and adaptive. Wildlife is mobile, as pastoralism, hunting and other activities. Consequently, regulation and management of these areas need to acknowledge change and uncertainty. Fortunately, there is great traditional knowledge stored on rural communities of strategies to deal with changing environments.

Recommendation 5: Harmonise the different tools, land uses, rights and resources into compatible frameworks seeking for multifunctionality to help balance damages.

Territorial planning should seek to harmonise all uses and elements in a given territory, both natural and anthropic. The controversy here hangs between two management models land-sharing and land-sparing. Land sparing on the one hand plans for agriculture to be as intensive as possible, releasing as much land as possible to be used exclusively as natural spaces for wildlife and biodiversity with the lowest human interference possible. Land-sharing, on the other hand promotes better agricultural production systems, integrated with the ecosystems in a territorial model fit for coexistence. While movements as rewilding are pressing for the first option, agroecologists and rural experts strongly advocate for ecosystem-based production models that combine high efficiency agriculture with biodiversity, provision of ecosystem services and healthier environments. In any case, right now it is impossible to fully separate humanised from natural areas, especially in Europe, so we need proper coexistence tools. Either way, urban development should avoid dispersed developments and diffuse impacts, for sustainability reasons but also from a wildlife coexistence

point of view. Sprawl, especially in high natural value areas, put pressure on wildlife populations and change their dynamics. At the same time, it attracts further development, buildings and infrastructures, multiplying the impacts. On the other hand, abandonment of traditional agricultural sites is a source of wildlife related problems with the remaining activities. Farmers feel invaded by an uncontrolled and damaging process that is also destroying valuable habitats, incrementing risks of forest fires and reducing biodiversity. Other challenge is to harmonise the different uses of land and resources into compatible frameworks. The same land can support different activities and still be suitable for biodiversity and wildlife.

Recommendation 6: Manage landscape features in a way useful to deal with wildlife problems

Landscape features are a key issue in managing agricultural fields. One way or another, they are important in managing wildlife in crops, and key in preserving agricultural biodiversity. Consequently, they need to be part of any solutions to deal with wildlife issues, so landscape features including all kind of mid-field shelters for wild animals such as hedgerows, plant boundaries, groves, fruit tree plantations, pastures, shrubs, water holes, sources, tree lanes, flower strips and other spots of wilderness, need to be promoted, improved and preserved. This way, the territory would provide support for key ecosystem services that help regulate and balance wild species population. Besides, they may have additional benefits for farmers, such as protecting the land from winds and drying out of soils, and to interrupt floods and erosion processes, preventing desertification. The challenge is how to manage these features in a way that prevents and help controlling wildlife damages.

Recommendation 7: - Implement a monitoring system

Monitoring is key to implement efficient, suitable and well-designed measures. A sound monitoring system is instrumental to: 1) feed the adaptative management with sound data and; 2) enable a shared vision and constructive discussions between stakeholders. For monitoring systems to be fully functional it is convenient to deal with both existing and new data. First, it is recommended to use as far as possible existing data sets already collected by the government bodies or other stakeholders. When new data collection is needed, it is important to use standardized national or international protocols whenever possible. Anyway, the choice is always on open data, open frameworks and open formats, which guarantee cost reduction and better use of data within the project and beyond.

Recommendation 8: Analyse and address conflicts related to land and natural resources and connect them to human-wildlife relationships.

Wildlife-agriculture issues are related, in fact, to human-human relationships, usually between groups of people with different interests. This is why conflict often arises over these problems and solutions are so conflictual. Consequently, conflicts need to be addressed before setting the focus on improving coexistence with wildlife. Human issues come first than technical solutions. To this end, scan for actual and latent conflicts and characterise them as deeply as possible. Often human-wildlife relationships are closely linked with other conflicts, which often make solutions difficult. Anyway, be aware that most stakeholders, even those leading the effort to deal with wildlife related problems, can be involved in the conflict, or be seen as part of it by the other side. Land planners, researchers, decision-makers, technicians, development and innovation brokers, farmers and other stakeholders can be perceived as non-neutral, so sometimes neutral third parties are necessary to reduce conflict and boost solutions.

Recommendation 9: Include all participants in programming measures but raise awareness on each one about the consequences and responsibility of the decisions made.

The implementation of the above described ecosystemic model of management of rural areas is possible only by combining the efforts of all rural management entities, i.e. farmers, agricultural organisations, hunters, foresters, local administration or non-governmental organisations that need to be working together. Social sciences could be a unvaluable tool to help seek deeper agreements. Anyway, responsibility is key when developing land-based plans. As coordination and leadership is complex when dealing with multiple interests, and opinions are free and encouraged under participatory frameworks, it could be challenging to determine

who is responsible for designing, implementing or monitoring a specific action. Besides, there also needs to be an agreed responsibility for developing any action designed in the plan. Negotiation between all stakeholders and responsibility-sharing will be core to succeeding in applying these plans, while scientific and research institutions would assist the plan design and development. Moreover, there is also the question of who should bear the risk for any measures implemented, and whether people with actual problems and losses due to wildlife interaction (farmers, shepherds...) should carry on the consequences of failure or bad judgement. On the other hand, stakeholders whose livelihood won't be affected one way or another, sometimes exercise strong pressure for adopting difficult measures, without enough consideration or support to farmers' problems. These are common issues in participatory processes, and proper facilitation could be a great asset to ensure dealing with these issues in a fair, inclusive and supporting way.

Recommendation 10: Use a social and participatory perspective to integrate human-wildlife relationships in sustainable planning tools

The best way to plan for a territorial-based action plan to deal with wildlife is to implement participatory processes to incorporate all stakeholders to land planning tools. Participation may be used to establish overall objectives and priorities for coexistence or any other sustainable development issue under a territory approach for each area, sector and activity concerned and harmonise them under global and sectorial policies. Anyway, these processes should imply deep work with stakeholders, enhancing social interaction between them along the planning process. It is also important to listen carefully to them, understand what they are saying and use their knowledge as a source of innovation. Also, it is necessary to understand that participation is time consuming, and farmers often do not have enough time to dedicate to those processes, especially if results are not foreseen. So, it is important to assign enough resources and incentives. Moreover, communication between stakeholders along planning process should be improved by creating spaces for dialogue, organising collective activities and opening channels for fluid and immediate communication. Often, damages caused by wild animals are only the tip of the iceberg, and farmers and other stakeholders are affected by other problems. Damages are not only economic: insecurity, risk perception, lack of confidence, helplessness, marginalisation or abandonment could be more disturbing than the economic cost of damages. Participatory processes should aim for improved governance institutions ruling human-wildlife coexistence in each territory. A good governance framework, with participation of stakeholders, able to make well-founded decisions, holding proper technical support and enough resources to produce the flexible, adaptive and immediate measures that would help control wildlife damages, and address coexistence-related conflicts.

Conclusions

Territorial perspective is a necessary approach when dealing with widespread problems related to agriculture-wildlife coexistence. Although it requires an adequate level of coordination, time and resources, some case studies show that it is possible to reach collective action that contributes to solve these problems.

Anyway, territorial approach on dealing with wildlife issues is still in an early development stages, and there is some gaps and constraints actually preventing its development, specifically some questions related to data-gathering, monitoring and co-construction of knowledge.

The paper contains a set of recommendations that should help any core group interested in promoting a territorial basis to deal with agriculture-wildlife relationships to get stakeholders together and design, implement and monitor a land-based plan to face those problems. Among the 10 recommendations included, some of them are methodological about the broad perspective of ecosystem approach and spatial planning, others are technically-oriented, improving monitoring, mapping and other tools, and, finally, other are focused on conflict and social issues incorporating social innovation as a key element for success.

There is enough potential to apply a wide spectrum of innovations to deal with agriculture-wildlife issues at a territorial level. First of all, applying social innovation to incorporate all stakeholders to land planning and land management tools, using participation as its main gear, for instance promoting new institutions and bodies of governance, enhancing extension and AKIS (Agricultural Knowledge and Innovation Services), facilitating access to ITC or solving underlying conflicts that difficult understanding. Second, to implement monitoring

systems to assess population dynamics, interactions, damages and risk, and the efficiency of management measures. New technologies can provide advanced information tools that could be managed in the field by the main stakeholders involved, generating a pool of direct knowledge (e.g., citizen-science based information apps, participatory mapping, zoological big-data, trackers, sensors...) for farmers and other stakeholders. Researchers can analyse and interpret these data, sharing their conclusions with stakeholders, merging them with farmers' field experience to build better knowledge. This knowledge would be instrumental to design and implement useful measures at the landscape level, sometimes also supported by new technologies (deterrents, repellents, decoys, traps, tracking devices, virtual fences...). In the third place, land-based planning tools, from urbanistic plans to protected areas plans or rural development programmes, can be updated with all this information and tools, to incorporate coexistence challenges to their own management goals. Finally, other ways to apply innovation is by networking with other areas with similar conflicts, exchanging experiences and initiatives and adopting common strategies.

Summarising, applying a territorial perspective means working with the ecosystem and people, addressing both ecological and social issues. Innovation plays an important role in territorial approach, and there have been described many innovations that could be used under this framework, included advanced technologies for monitoring, mapping and programming active measures but also social innovations, gathering people together, looking for agreements and displaying solid strategies to deal with the problem in an efficient and sustainable way.

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