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Agriculture and Agricultural Science Procedia 8 (2016) 148 – 157

Agriculture and Agricultural Science Procedia

Florence "Sustainability of Well-Being International Forum". 2015: Food for Sustainability and Not Just Food, FlorenceSWIF2015

The Sustainability of Wildlife in Agroforestry Land

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Abstract

Wildlife management in agroforestry territory has become particularly complex in recent years because of the increase of animal density. This study proposes a review of the literature on the impact of wildlife in many areas of the world. In particular, it examines the negative effects due to the strong growth of wildlife populations and consequently the loss of the balance of agricultural and forest ecosystems. A second portion of the study shows the results of an investigation related to the rural area of the Region of Tuscany: Recreation-Opportunity-Spectrum - ROS (North American Methodology) implemented in Geographical Information System - GIS, is used with the aim of determining suitable areas for damages by wild animals. The final goal of the paper is to highlight some possible choices to be adopted by Stakeholders in order to bring the phenomenon within the limits of sustainability.

Peer-review under responsibility of Fondazione Simone Cesaretti

Keywords: wildlife damage; territorial planning; agroforestry resources; GIS.

1. Introduction

Relationships between wild animals and agricultural resources can be considered as a particular case of the relationship between agriculture and environment (Genghini, 2005). The sustainable coexistence, without notable conflicts, on the same area of agricultural activities and wild animals is determined mainly by the numerical

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Peer-review under responsibility of Fondazione Simone Cesaretti
doi:10.1016/j.aaspro.2016.02.020

dimension of game populations that should not exceed the territory's carrying capacity (Côté et al., 2004). Animal density should not be considered as a static figure, as animal species are able to adapt to differing ecological conditions and to change their behavior in response to external pressures (Jensen et al., 2014). In the last decades, changes in the utilization of rural and marginal areas have significantly altered many European countries' agro-forest-pastoral land use (Argenti et al., 2012). This situation, in turn, has resulted in a rapid increase of some populations, such as deer (Côté et al., 2004) or in a reduction of the number of individual species deeply linked to certain farmland characteristics or some cultivated crops, such as hares (Zaccaroni et al., 2013). Of course, this point of view is mainly anthropocentric, as the concept of "damage" is highly correlated to economic interest conducted by landowners. The main objective of the study is to evaluate, through the opinion of experts (stakeholders), the possible solutions for reducing wildlife impact in an examined area.

2. Impact of wildlife on agriculture and on forest

Damages to resources present a very different extent if we consider the crops that are damaged by animals, the kind of animals and the vegetative phase in which the damage occurs. We can say that some animals do no damage to some agricultural crops or natural resources or their effect is so limited that we cannot talk about damage at all. In other cases, just a little impact of a small number of animals in a particular stage of crop growth, even if it consists in a reduced utilization of vegetative biomass, can produce remarkable negative effect from the economical point of view; for example, in many annual crops, such as maize damaged by wild boars, or vineyards at early vegetative development or at grape maturation by roe deer and wild boar as well. In the forests, an overabundance of animals (mainly different kinds of deer) represents a threat for the impact on regeneration, growth of trees and survival of many herb, shrub and tree species, (Côté et al., 2004). The result is highly affected by forest structure, animals responsible for damages and utilization time, for instance after a coppice cutting (Gill and Beardall, 2001). In addition, pasture and grassland production can be impacted by wild animal presence, even if these resources are more able to face herbivore utilization (Trdan and Vidrih, 2008).

Finally, yet of great importance, the abundance of wildlife in agroforestry areas has greatly favored the return of the wolf, whose acts of predation on livestock are recently causing further and important damages for the farmers (Mattioli et al., 2014).

Many solutions have been proposed to limit animal density. For example, hunting and defensive interventions, such as fences and animal displacement are all common interventions to reduce wildlife damage to crops. Although protective measures are common, hunting has the greatest impact. In fact, a national law (157/92) has been passed to regulate the activity of wildlife hunting; this has been transposed into Tuscan regional law 3/94. The agro-forestry land hosting the fauna is intended for a variable portion (20-30%) of agro-forestry-pastoral territory (AFPT) to wildlife protection (article 10, paragraph 3) with a prohibition and abatement for hunting purposes, and up to a maximum of 15% of the regional AFPT (art. 10, para 6) for private management of hunting. On the remaining land, the Regions promote forms of management programmed for hunting in accordance with article 14. Particular attention in the regional law of Tuscany regulatory changes is given to limiting the damage to agricultural crops, through a series of measures encouraging management of wild ungulate populations, starting with the possibility of hunting at touristic farms, up to the adoption of special programs of control of populations in the areas where hunting is permitted and in those where it is prohibited.

In many forest areas, damage by wildlife occurs, particularly from browsing of forest regeneration, removal of bark, mechanical stresses on the stems of the trees. In North America the beaver and other large mammals such as bear, deer, elk, are often among the major wildlife species that damage the forest.

In economic evaluations, complex models are used that consider fluctuating timber prices and calamities such as bark beetle infestation or wind damage. It should be noted, however, that the impact of site conditions is often ignored, and therefore, any regional variations in site class are generally not considered. The change in terms of forestry production, expressed as a stumpage value less costs, can take place by comparing stands with obvious damage to other undamaged ones. The comparison in terms of net present value (NPV) is converted by means of discounting; all future financial information flows into present values, and thus provides a current value figure that takes into consideration potential revenues during the entire investment period (Klemperer, 1976; Clasen et al., 2013).

For coppices of Tuscany, income losses due to browsing ungulates are expected. In particular, for deciduous oak and chestnut based on simulations, production losses exceeding 50% have been calculated. According to Fratini et al. 2009), there is not a unique relationship between the density of wildlife, physical entity of the damage and its economic value. It should be noted that in case of permanent damage to the forest, hence permanent reduction of income, its future value will coincide with fund devaluation (lower value of the forestland). The determination of negative income also leads to substantial loss of forestland rent. In fact, many variables can affect the loss of value of the funds. It is possible, however, to estimate the economic damage starting from observations made directly in the forest.

The impact of wildlife on rural area is well documented in the specialist literature (e.g., Gill, 1992; Horsley et al., 2003; Apollonio et al., 2011). In the Basilicata region in the 6-year period from 2007 to 2012, the damaged area doubled, shifting from about 2,800 to 5,850 hectares; as a result of this increase, the estimated compensations have more than doubled, shifting from over € 550,000 up to € 1,134 million (Cozzi et al., 2015). In North America, as reported by the US Department of Agriculture's Wild Life Service (USDA, 2012), during this century there has been countless damage involving different animal species. In particular, as we shall see even for Italy, wild boar and deer are as the species that causes high damage to agriculture and forests, especially in the North East of the United States. In 2009, the damage to agriculture was estimated at about $ 71 million, mostly for lost revenue; during the same year damage from road accidents involving around 29,000 people with a loss of about $ 1 billion. It is estimated that birds cause more than $ 100 million a year for major losses to agricultural crops: the most affected are the cultivation of sunflowers, wheat, sorghum, rice and fruit. Many of the damages are brought about by species of birds that do not originate in the area, such as starlings and sparrows that are installed in many areas especially where there are fruit trees. From this point of view, there is inadequate knowledge of damage caused by birds on farm, regional and national scales. In New South Wales (Australia), it has been found that bird control was costing on average $ 500 per hectare per year, with most techniques failing to protect crops adequately (Trace et al., 2007).

In Germany, as in Austria, where the problem of wildlife damage to forest vegetation is strongly felt, many computational models have been implemented, among them a particularly interesting one (Clasen et al., 2013), in which they have documented the impact of wildlife on vegetation, particularly for growth loss or reduction in timber quality.

On the basis of their review, for spruce forest in Scotland, Gill et al (2001) concluded that much of the cost of deer control might be offset against revenue from venison and that culling appeared to be a far more cost effective option than fencing, which could cost in the region of 10-30% of yield for Sitka spruce.

Another conflict that affects rural areas is the depredation of livestock. In many parts of the world, this phenomenon in very large proportions gives rise to conflicts between farmers and wildlife protectionists. In the USA, the annual cost of depredation to the livestock industry is $ 40 million (Conner et al., 2008). Even greater losses are reported in South Africa, where a survey in 2010 estimated the annual cost of depredation to the livestock industry is $171 million (van Niekerk, 2010), although a 2007 census estimated the cost to be $ 22 million.

3. Fact-finding investigation with representatives of wildlife hunting implemented in geographical analysis.

Wildlife's density in agricultural areas of Tuscany has increased considerably during the 2000s and at the present, the conditions of equilibrium and ecological sustainability are strongly altered. To have an idea of the extension of the problem, the most recent data from Region of Tuscany (2012) indicates a total indemnity of € 1,596,360 for dealing with damage caused by wildlife animals in 2010, and this figure is increasing (+16% since 2005). A survey conducted with personnel of agriculture and hunting activities allowed us to know what remedies to apply for solving a complex problem that at least until now has remained unresolved.

The survey was conducted by means of questionnaires consisting of eight questions (table 1), which permit assessment of the complexity of the problem and verification of potential solutions. The structure of the questionnaire and responses accorded by those interviewed are summarized in Tables 1 and 2. The questionnaire was administered with the cooperation of the students of the Agriculture School, University of Florence.

Stakeholders interviewed belong to the public administration and private professional sector. In particular, we interviewed two technicians of the hunting district, experts in hunting and fishing, two selection hunters, two farmers (growers), two environmentalists, one agronomist who works on a farm, one breeder of livestock and one

rural member.

We carried out a brief examination of questionnaires performed for each single point.

Damage to agricultural crops. According to two thirds of the respondents, damages must be kept below a safety level, through the creation of a "Prevention Plan" implemented involving teams of hunters. The collaboration is important in this phase for the accomplishment of prevention works, for natural habitat restoration and for environmental improvement works for natural wildlife reproduction.

Almost all respondents (excluding ecologists) believe wildlife impact on agricultural activities is not sustainable with the current density of ungulates (three times higher than those considered optimal), and effective methods of prevention do not even exist.

Sustainability. There is a general perception that the current national, regional and EU rules (Common Agricultural Policy) have not yet addressed the problem in an efficient way by providing appropriate solutions to the current situation, and then expecting measures to improve governance from various stakeholders, perhaps with different purposes.

Prevention plan.

There is considerable variability in the perception of the costs necessary to protect crops from wild animal damage; it can be assumed that economic resources will come from the marketing of products (ungulate meat), because we are facing a market that still has high margins of expansion. The creation of a prevention plan is estimated at between € 1,000 and € 4,000 per hectare; among the expenditures expected are for electric fences for agricultural crops combined with various types of deterrents, including ultrasonic sensors.

Selection Hunting.

To resolve the issue of the conflict between wildlife and agriculture, this kind of hunting is not a solution uniquely accepted by all respondents. For two thirds of the respondents the solution should therefore be found in other forms of land management. Selective boar hunting, (approved by one-half of the respondents), can be implemented but it cannot be considered an alternative to chase hunting, normally organized in teams, and always considered more effective.

Table 1. Survey questions

a) Do you think the impact of wildlife is sustainable for agricultural and forest crops in our territory?
b) Do the existing prevention tools guarantee the safety of the crop?
c) Can selective hunting solve the problem of excessive animal density?
d) Does the current Common Agricultural Policy provide the right support to agro-forestry crops of our Territory?
e) What is the cost of an adequate prevention plan to reduce wildlife damage?
f) Do you think national and regional legislation on hunting is appropriate to the needs of the moment?
g) Can there develop a market for the meat from ungulate meat processing centres?
h) What do you propose for reducing the impact of wildlife in the territory?

Table 2. Responses to the questionnaire by interviewed stakeholders

Question	a	b	c	d	e	f	g
Hunter 1	1	0	2	1	€ 2,000	1	3
Hunter 2	1	0	1	1	€ 1,800	1	2
Ecologist 1	2	2	0	1	€ 1,000	1	1
Ecologist 2	2	2	0	2	€ 1,500	1	2
Technical staff 1	1	2	2	1	€ 1,200	2	1
Technical staff 2	1	3	1	1	€ 1,500	3	1
Farmer 1	0	1	1	0	€ 3,000	1	2
Farmer 2	0	1	1	0	€ 2,000	0	3
Breeder of livestock	0	1	0	0	€ 2,000	1	2
Professional agronomist	1	2	2	1	€ 4,000	1	1
Rural union member	0	1	1	1	€ 2,000	1	2

Table 3. Measuring of responses

Negative	0
Low	1
Medium	2
High	3

The proposals formulated (question h) can be summarized in three clear points, given below

1) Better land management is suggested. To improve wildlife management, it is appropriate to practice selective hunting based on the density of ungulates (census indicating the real consistency, reference to 100 hectares, for fallow deer, roe deer, wild boar and deer). There is also a need to make an economic assessment of these interventions.
2) Another proposal is about the enhancement of faunal productions. Farmers could promote awareness of the economic marketable value of game directly through a "publicity campaign" that informs about organoleptic and nutritional meat characteristics.
3) A third proposal is for the development of education activities and sensitizing the population on risks due to the strong increase of animal populations in areas where agricultural crops are valuable (1/3 of respondents). The final proposal is the adoption of more ecological and sustainable tools for the protection of agro-forestry land.

Determination of suitable areas for wild animal damages

Starting from the interview results, the main goals of the paper are focused on a better land management and the adoption of ecological tools for protection of lands. In this phase a GIS (Geographical Information System) methodology is using with the aim of determining suitable areas for wild animal damages. In these areas, the private or public stakeholders' efforts could be concentrated. Landscape ecology measures and other multidimensional indicator have used for individuation of suitable areas. The first phase has concentrated on a territorial classification of case study area that is represented the by Province of Florence and the Region of Tuscany using a methodology called Recreation Opportunity Spectrum (ROS).

ROS is a North American methodology developed in the 1970s aiming for a classification of territory based on

human presence and related human activities (Clark and Stankey, 1978). The ROS considers some factors such as accessibility, degree of naturalness and degree of anthropocentric presence. Different variables are used to quantify these factors: the distance between roads, and the extent of the area (accessibility), the presence/absence of human beings, the presence of accessible roads (for vehicles), and the presence of human activities (degree of naturalness and the degree of anthropocentric action). It is important to modify this methodology according to territorial characteristics of our case study because it is geographically different from North America territory (Riccioli, 2009; Riccioli et al., 2011): ROS was born in a territory where the natural component assumes characteristics of vastness and continuity and where human density results to be significantly lower than in Italy.

Considering the results of questionnaires (wild animal damages are mainly concentrated in vineyards and crops located in areas far from human presence), a map of most suitable areas for wild animal damages has been identified. Vineyards and other cultivated areas (crops) have been put in relation to their distance from roads and urban centers and their proximity to ecological corridors that favor the movement of wildlife.

Maps of roads and urban settlements have been used (cartography of Tuscany Region Administration) with the purpose of calculating the Euclidean distance from artificial areas to vineyards and crops; for ecological corridors calculation of natural areas has been selected (thus excluding artificial areas) and their fragmentation degree has been analyzed using Fragmentation Index (F), as shown in Formula 1. This index measures and highlights the different land uses in a geographical neighborhoods (kernel), in our case represented by a square of 7x7 pixels (all indicators are represented by raster maps through which a territory is subdivided into square cells called pixels).

$$F = (n-1)/(c-1) \quad [1]$$

Where
n = number of different classes present in the kernel
c = number of pixel considered (49)

A fuzzy approach has been used in order to provide a standardization of all values: high values indicate more suitable areas for wild animal impact (close to 255): this is especially for vineyards and crops that are more distant from artificial sites and next to areas with less land use, heterogeneity (fragmentation). The Fuzzy approach is also called to “infinite values” where the logical variable can take any value in the range of truth continuous [0-1] (Zadeh, 1965; Chen and Hwang, 1992; Romano et al., 2013). Table 4 shows the parameters of normalization process.

Table 4. Normalization of the indices

Criterion Maps	Type of standardization	Control points	
		a	b
Distance from artificial areas	Linear increasing	0	5.6 Km
Fragmentation index	Linear decreasing	0	0.13

Considering distance from artificial areas criteria, the maximum value represents the most favourable conditions for wild animal damages (control point *b*), in other words, areas far from human presence. The reverse is true for control point a, which represents the worst conditions for wild animal damages.

Instead, the control point *a* of the fragmentation index is related to best conditions for wild animal damages: it highlights the maximum presence of ecological corridors (minimum fragmentation of land use); vice versa for control point b that represents worst conditions for wild animal damages.

After literature review (Comber et al., 2010, Riccioli, 2010; Carver et al., 2013; Cozzi et al. 2015), to highlight the degree of susceptibility to damage to wildlife crops and vineyards, a spatial aggregation of the two maps was implemented using Weighted Linear Combination, applying the same importance weight for both maps. Using this method, the value of each alternative defined by pixels is determined by the average of the values of each criterion

multiplied by the relevant constraint (formula 2).

$$V_j = \sum_{j=1}^{n} c_{ij} \cdot p_i \qquad [2]$$

Where:
V_j = value of susceptibility of the j-th pixel
c_{ij} = value of the i-th criterion belonging to the j-th pixel
p_i = weight of the i-th criterion ($\Sigma pi = 1$)

The result is shown in Figure 1.

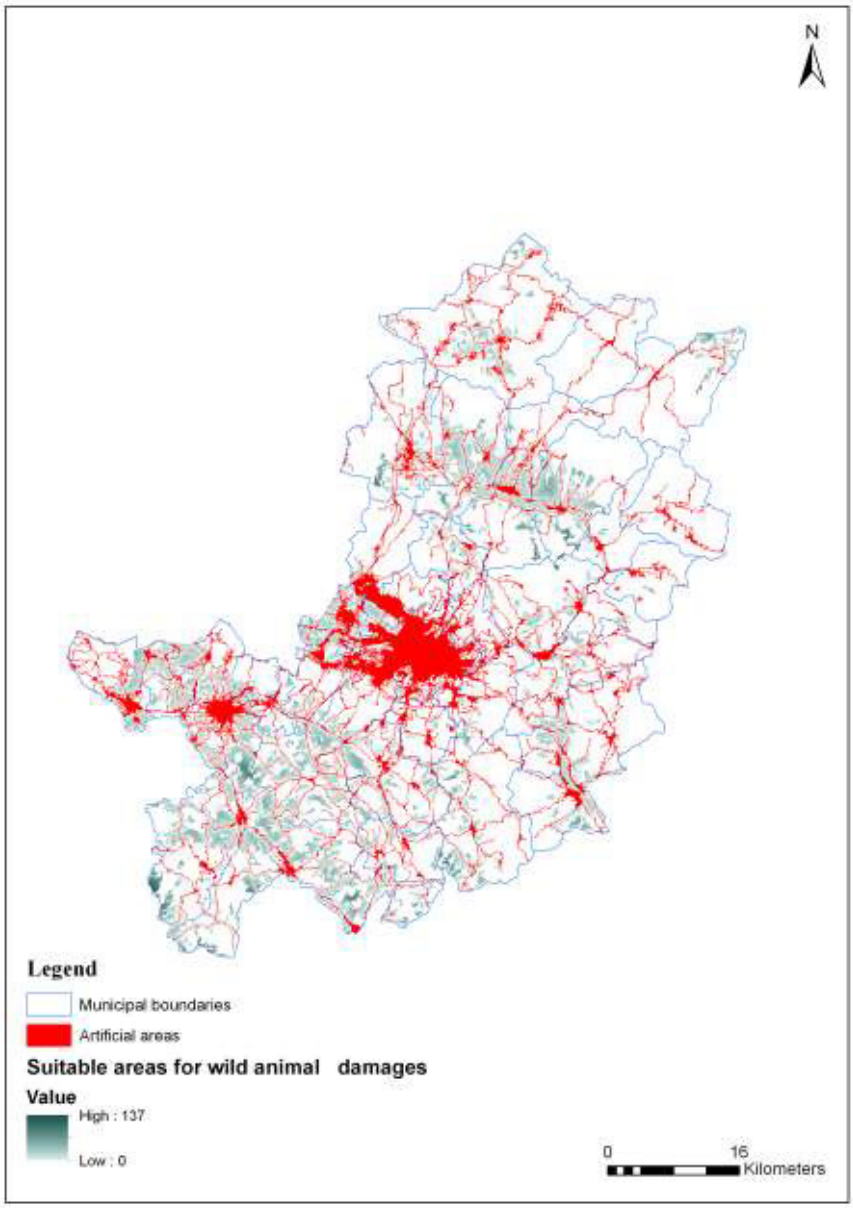

Fig. 1. Map of vulnerable areas in the province of Florence

4. Results

The deep green areas in figure 1 represent the most suitable areas for wild animal damages (normalized values equal to 137). About 53,000 hectares of vineyards and crops were examined (Figure 2). Almost half of them are characterized by a low degree of susceptibility to damage (values below 22): about 33% of the total has a normalized value equal to 7 (17,750 hectares); 25% has normalized value equal to 14 (13,340 hectares) and 15% of the total areas examined have a normalized value equal to 22 (they cover about 8.000 hectares). It is important to underline that more suitable areas for wild animal damages (areas with normalized value over 70), cover about

1,260 hectares: this small territory is 3% of the total areas. The average normalized value of susceptibility is equal to 20.45 and its standard deviation is 16.7.

5. Conclusions

The ethics and compliance of considering wild animals to be components of a complex ecosystem are undisputable values (Sandøe et al., 2008), but at the same time, it is important to safeguard human activities, in this case those linked to agriculture and forestry, the most fragile in economic terms. Reduction of wildlife density can be obtained in various ways:

a) Implementing a specific prevention plan: in rural land areas where the pressure of wildlife is more evident, preventive action should be allowed, and therefore the main cost is represented by the forms of the prevention adopted, but at the same time, the forestland and the restoration of damaged young plants must be provided for. In both cases, however, the economic damage is represented by the cost of these interventions.

b) With transparently moving of the animals to other places where the problem does not exist, and finally by the removal (extermination) of animal populations that are excessive in respect to predetermined target density.

The latter choice is certainly not a painless solution, surely the most difficult to be accepted by public opinion. At the same time, we should not forget that Tuscany has a great abundance of wild ungulates, which, if managed properly, can provide large potential income for farm owners and for hunters. It should be noted though that in Tuscany meat from chain industry of wild ungulates is currently undeveloped, and there are too many connected health problems to permit free marketing.

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