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How farmers feel about trees: perceptions of ecosystem services and disservices associated with rural forests in southwestern France

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Abstract

Rural forests, including the wooded areas primarily managed by farmers (e.g. farm forests, hedgerows, isolated trees), are critical for the sustainability of agricultural landscapes. Yet with agricultural industrialization, rural forests have been in decline in many regions across Europe. To reverse this trend and promote the sustainable use of farmland, 'greening' measures have been introduced by the EU's Common Agricultural Policy (CAP) in recent years. However, their effectiveness depends on local farmers' values and reaction to these measures. In this study, we investigated the socio-cultural value accorded to rural forests in southwestern France by interviewing 19 farmers. The positive and negative contributions cited were categorized as ecosystem services/disservices and analyzed using qualitative and quantitative methods. The results indicate that farmers in this region have mixed views, as they cited 32 positive and 25 negative contributions (material and non-material) of rural forests. They felt trees provide services (e.g. erosion control, windbreak) and disservices to agriculture (e.g. decline in yield, damage to tractors and infrastructures). Depending on their farming practices, farmers had contrasting opinions on how to reconcile rural forests and agriculture. Our results suggest that CAP greening measures need to better target rural forest conservation and further adapt to local contexts.

Keywords

Agroforestry; trees on farm; local knowledge; landscape features; farmer studies; EU Common Agricultural Policy

1. Introduction

The industrialization of agriculture since the Second World War has had a dramatic impact on European agricultural landscapes and their ability to sustain biodiversity (Cardinale et al., 2012). Agricultural mechanization and the extension of the surface area of farmland have contributed to a decrease in the wooded areas managed by farmers in several regions in Europe, including France (Blanco et al., 2019b; Burel et Baudry, 1990), the UK (Petit et al., 2003), and Spain (Arnaiz-Schmitz et al., 2018), as well as in Canada (Schmuki et al., 2002). In contrast, less productive agricultural land has experienced a dynamic of land abandonment and bush encroachment (e.g. Pereira and Martinho, 2017).

Wooded areas located in rural landscapes and managed by farmers (termed ‘rural forests’ in this study) include woods owned by farmers and what are commonly known as trees outside forests, such as hedgerows, isolated trees and copses. As rural forests play a key role in the functioning of agricultural landscapes, their decline has had a major impact on biodiversity and the supply of ecosystem services. For instance, hedgerows have an important function in pest and weed control and pollination (Dainese et al., 2017), as well as in creating biodiversity corridors (Dondina et al., 2016). They also provide significant non-material contributions to human well-being, such as improving the scenic value of landscapes (Oreszczyń et Lane, 2000). Isolated trees are also key assets for local biodiversity conservation, as they favor the circulation of species between forested patches (Manning et al., 2006; Sebek et al., 2016), and for local use, as they often provide edible fruits.

In recent years, one of the aims of the European Union’s Common Agricultural Policy (CAP) has been to encourage rural forests to promote the sustainable use of farmland. Since 2013, a green payment scheme of Pillar I linked 30% of the payment EU farmers receive from the CAP to three greening measures, including the reserve of 5% of their arable land as Ecological Focus Areas (EFAs) (Articles 43 to 47 of EU Regulation No. 1307/2013). While these can include agroforestry areas and trees on farms (European Commission, 2017), the real contribution of these greening measures in promoting rural forests has been the subject of debate. For instance, in the case of wood pastures, the tree density mandated in the CAP is below the current tree density in several regions (Jakobsson et Lindborg, 2017). Moreover, the majority of EFA options available for European farmers encourage the implementation of productive types of EFA (i.e. nitrogen-fixing crops and catch crops) rather than unproductive ones (i.e. landscape features, including trees on farmland, Pe’er et al., 2017). This calls into question the relevance of such a global one-size-fits-all policy for local systems and for the conservation of rural forests. Furthermore, farmers are not driven solely by profit maximization and financial incentives (Home et al., 2014), and also behave on the basis of non-economic considerations, such as environmental concern (Chouinard et al., 2008) or preexisting socio-cultural norms and practices (Sourdril et al., 2012). Thus, in order to ensure effective agricultural policy that is suitable for specific contexts, it is important that studies take into account – beyond strictly economic considerations – the socio-cultural settings that influence how farmers perceive and interact with their environment, as well as how they may react to public policies.

The socio-cultural valuation of ecosystem services (ES) has proven effective in identifying the multiple values local people assign to ecosystems (Martin-Lopez et al., 2007). For example, a study on rural forests in Sweden showed that farmers value wood pastures for the provisioning ES they provide (e.g. meat and milk production), as well as their cultural ES, in particular their heritage value (Garrido et al., 2017). These perceptions may however differ between farmers. For instance, in a study in Paraguay, Da Ponte et al. (2017) reported contrasting uses and perceptions between individual farmers according to factors such as farm size and the type of farming system practiced. Moreover, some studies have highlighted that rural forests could also be perceived as a source of various ecosystem disservices (EDS) by farmers who mentioned actual or perceived negative impacts to their well-being (Shackleton et al., 2016; Teixeira et al., 2019). In Ethiopia, rural forests were perceived as a source of pests and wild mammals that affect crops and livestock (Ango et al., 2014; Dorresteyn et al., 2017). In France, some farmers blame trees for competing with crops and obstructing mechanized work (Blanco et al., 2019b). These mixed positive and negative perceptions of rural forests are more or less pronounced depending on the local technical, social and cultural context of the agricultural system (Dorresteyn et al., 2017). As

a consequence, place-based research in different regions is crucial in order to guide locally relevant policy and enhance rural forest conservation.

In this study, we focused on the region of southwestern France to investigate how farmers perceive and manage rural forests in this area, collecting the information through in-depth interviews. A common practice in ES assessments is either to invite respondents to choose and/or rank the services to be assessed (and valued) from a list (La Notte et al., 2017), or to introduce the ES concept to respondents and ask them to explain their perceptions by means of this concept (e.g. Smith and Sullivan, 2014). While these practices can be very fruitful, they do not allow an assessment of whether the ES concept adequately reflects perceptions or effectively integrates different worldviews (Tadaki et al., 2017). To at least partly address these limitations, we used a semi-directed interview procedure that consisted of asking farmers about the advantages and disadvantages they associated with rural forests, using lay language and without introducing them to the ES concept. Their answers were then categorized as ES and EDS in a second step.

In this paper, we first present the information collected in the interviews, outlining how farmers in our case study manage rural forests and perceive the associated ES and EDS. Next, we investigate the variability in these perceptions, and how this reveals farmers' contrasting views. Finally, we discuss how the concept of ES/EDS can be used to analyze farmers' perceptions and attitudes, and how this can be used to guide both future research and agricultural policies.

2. Materials and methods

2.1. STUDY SITE

The study was conducted during Nov. 2016–March 2017 in southwestern France, near the city of Toulouse (43°13'02.63"; 0°52'53.76", Figure 1), in the district of Aurignac, which is part of the 'Pyrénées-Garonne' Long-term Social-Ecological Research site. The southern part of the study area is hilly (200–400 m a.s.l.), lying in the Pyrenean piedmont. The terrain is a succession of alternating hills and valleys crossed by a dense network of watercourses, bordered to the south by the Pyrenees mountain chain. The northern area is the beginning of the Garonne valley and consists of plains and hills. The climate is temperate, with Atlantic and Mediterranean influences. The average annual temperature is 13.8°C, and annual precipitation is 638 mm (Source: 1981–2010 data from the Toulouse-Blagnac meteorological station, <https://donneespubliques.meteofrance.fr>).

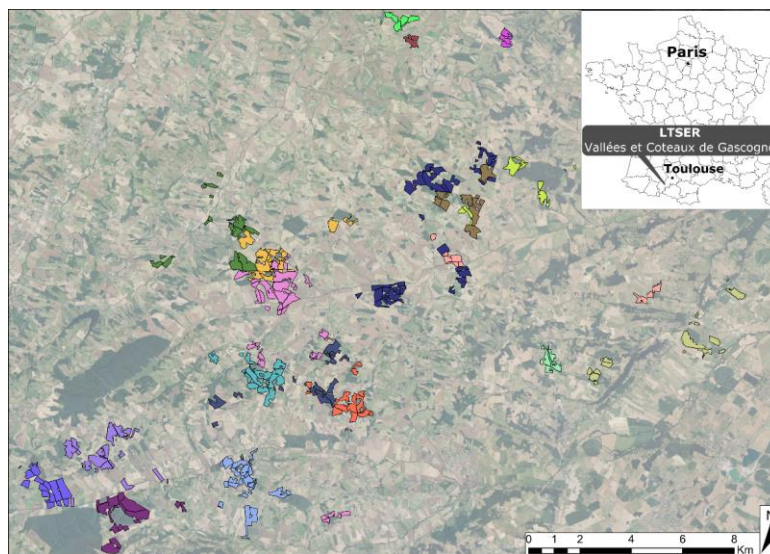


Figure 1: Location of the study site and map of the 19 farms managed by the interviewed farmers (each color represents a different farm, and each polygon is an agricultural block as defined by the Common Agricultural Policy). Background: aerial photograph (© IGN 2015).

Historically, mixed farming combining cereal cultivation (wheat, maize) and livestock rearing (for both milk and meat production) used to be the dominant system (Choisis et al., 2010). However, over recent decades, the number of farms has drastically declined, while the remaining farms have increased in size and become specialized in crop cultivation (Table S1, Suppl. material 1). More recently, society's increasing demand for organic products, as well as financial aid from the CAP to promote this type of farming, has led to the emergence of organic farms.

In this agricultural landscape, rural forests consist of small forest patches owned by farmers (i.e. farm forests) and rural trees outside forests (urban trees were not considered in the study). Most farms host a few woods that are scattered across the landscape and are mainly managed using a coppice-with-standards system. This management technique leads to woodland composed of (i) a lower story treated as coppice that provides firewood year-round, and (ii) an upper story of unevenly aged trees (the standards) that provide timber more occasionally (Du Bus de Warnaffe et al., 2006). Croplands and grasslands also contain trees that were traditionally managed for multiple purposes, especially to provide supplementary livestock forage, firewood, mushrooms, game and materials for handicrafts (Sourdril, 2008). Following our interviews with farmers, and for the sake of clarity, we organized rural forest components into five categories: forest (incl. forests and groves), isolated tree, hedgerow, riverbank, and edge tree. We use this terminology in the rest of the article and, for the sake of clarity, we use the term 'trees' in the text to refer to 'trees outside forests' that encompass isolated trees, hedgerows, riverbanks and edge trees (Table 1).

Table 1: Terminology used in this article to refer to the 5 rural forest components (including forests and trees outside forests) identified from farmers' interviews, and their associated definition within the scope of this study.

Rural forest components		Definitions established from farmers' interviews
Trees Outside Forests	Isolated tree	A single tree located in the middle, or on the border, of agricultural plots (including pastures and crop fields).
	Hedgerow	A continuous and impassable row of trees and/or shrubs located in the middle, or on the border, of agricultural plots.
	Riverbank	Row of trees associated with a water course or a ditch.
	Edge trees	Lines of trees and tree rows located at the border of agricultural plots that can be crossed by humans and livestock.
Forests	Forest (and grove)	Woody area with trees and shrubs that could be used for firewood and/or timber production.

2.2. PILOT INTERVIEWS AND INTERVIEW DESIGN

This study focused on farmers involved in crop cultivation and mixed farming, two major farming systems in the district of Aurignac along with cattle-based systems (Table S1, Suppl. material 1). To include diverse profiles, we selected both organic and conventional farmers. A total of 30 Aurignac farmers were contacted by phone and asked to participate in the study, of which 26 agreed to an initial face-to-face interview. These 26 pilot interviews of around 20 minutes in length took place between November 2016 and January 2017 and had the aim of (i) collecting data to build a more detailed interview protocol, and (ii) asking farmers' consent to participate in a second, more detailed interview. Of the 19 farmers who agreed to participate in the next phase, there were contrasting profiles in terms of farm surface area (from 13 to 250 ha), forest estate (from no forest to more than 12 ha of forest), age (from age 30 to 60+) and farming system practiced (Table S2, Suppl. material 1). However, most were male conventional farmers (there were 2 women and 3 organic farmers), which is explained by the low proportion of women farm managers and the scarcity of organic farms in this area (Choisis et al., 2010).

2.3. INTERVIEW PROCEDURE

The detailed interviews were conducted between January and March 2017, with each lasting around 2 hours. All interviews were recorded (except one due to technical issues) and consisted of four sections (Suppl. material 2). The first section collected general information about the farm (e.g. farm surface

area, farming system, etc.) and the farmer (e.g. age, gender, secondary occupation, etc.). The second section aimed to collect spontaneous information on agricultural plots and rural forests on the farm. It was conducted as an open-ended discussion facilitated by an aerial photograph of the farm and its surroundings in which all rural forest components were visible (~ 1/8000 resolution). The interviewer pointed out specific rural forest components in the photograph and asked the farmer about their associated advantages and disadvantages, as well as about management practices (section 2, Suppl. material 2). The third section of the interview was more directed, asking the farmer to list the contributions he/she associated with rural forests through two questions: (i) What advantages, or benefits, are particularly important to you regarding forested areas? (ii) What disadvantages, or constraints, are of particular concern to you? Because respondents may not spontaneously come up with everything that might be relevant during such an exercise (Diniz et al., 2015), the interviewer prompted them with suggestions (that the farmer could confirm or not) on the basis of information obtained during the second section of the interview. Finally, the fourth section of the interviews aimed at collecting data on the use of firewood and its commercialization. These interviews allowed us to collect, for each farmer, a list of advantages and disadvantages related to rural forests.

2.4. HIERARCHICAL CLASSIFICATION OF POSITIVE AND NEGATIVE CONTRIBUTIONS

The advantages and disadvantages listed by farmers were summarized and any synonyms were grouped together (Table S3 and S4, Suppl. material 1). This resulted in a final list of 32 positive contributions of rural forests (FPCs) and 25 negative contributions (FNCs). Following the hierarchical classification methods commonly used for ES (e.g. the CICES classification, Haines-Young and Potschin, 2018), we defined these contributions as specific ecosystem services or disservices (with codes) and grouped them into larger ES/EDS classes (Table 2). The FPCs that fit the ES definitions proposed in version 5.1 of the European CICES classification (Haines-Young and Potschin, 2018) were classified as ES. The FPCs that did not fit these definitions were classified as ‘Other positive contributions’. Similarly, some FNCs corresponded to ecosystem disservices (defined as ‘the ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing’; Shackleton et al., 2016). Due to the lack of a widely accepted EDS classification system, we adapted existing classifications (Gómez-Baggethun et al., 2013; Lyytimäki, 2014; Shackleton et al., 2016) to categorize these FNCs (Table 2). The FNCs that were not EDS were classified as ‘Other negative contributions’.

Table 2: List of the rural forest positive (FPC) and negative contributions (FNC) identified from interviews with farmers and classified as ecosystem services (based on CICES 5.1, see Haines-Young and Potschin, 2018), disservices, and other positive and negative contributions. The N column represents the number of farmers who evoked the FPC/FNC. The codes were used in statistical analyses.

Classes of FPC and FNC (Code)		Positive & negative contributions	N
<i>18 classes of ES (CICES 5.1 code)</i>		<i>29 ecosystem services (Code)</i>	
Provisioning	Wild plants - energy (S1.1.5.3)	Firewood (P1)	17
	Wild plants - nutrition (S1.1.5.1)	Fruits & nuts (P2)	11
		Medicinal plants (P3)	1
		Mushrooms (P4)	10
	Wild animals - nutrition (S1.1.6.1)	Habitat for game (P5)	4
	Wild plants - Fiber and other materials (S1.1.5.2)	Wood & timber (P6)	5
		Picket fence (P7)	2
	Biomass for agricultural use (S1.3.1.1)	Pastoral areas & resources (P8)	1
Regulation	Regulation of air temperature and humidity (S2.2.6.2)	Shade & fresh air for humans (R1)	5
		Oxygen production and air quality (R2)	6
		Shade for reared animals (R3)	4
	Control of erosion rates (S2.2.1.1)	Gully & erosion control (R4)	13
		Habitat for wild birds (R5)	5

	Maintaining nursery populations & habitats (S2.2.2.3)	Habitat for insects (R6)	4
	Wind protection (S2.2.1.4)	Shelter for reared animals (R7)	8
		Windbreak effect for crops (R8)	6
	Water flow regulation (S2.2.1.3)	Slow down water flows (R9)	2
	Decomposition and fixing processes and their effect on soil quality (S2.2.4.1)	Humus production (R10)	1
		Soil aeration (R11)	1
Cultural	Filtration by plants (S2.1.1.2)	Remove nitrates and other chemicals (R12)	1
	Visual screening (S2.1.2.3)	Fill gaps in the visual landscape (R13)	1
	Aesthetic experiences (S3.1.2.4)	Landscape scenic (C1)	11
		Visual aspect of wood construction (C2)	1
	Observational interactions (S3.1.1.2)	Quietness (C3)	1
		Participate in a living countryside (C4)	1
		Noble aspect (C5)	1
	Resonant in terms of culture (S3.1.2.3)	Landmark (C6)	3
	Existence value (S3.2.2.1)	Biodiversity and ecosystem conservation (C7)	7
	Option or bequest value (S3.2.2.2)	Reserve holdings & patrimony (C8)	2

10 classes of EDS (ad-hoc code)

14 ecosystem disservices (Code)

Material	Damage to equipment (D1.1)	Branches damage tractors (MD1)	7
		Risks for fences (MD2)	2
	Damage to infrastructure (D1.2)	Risks for buildings (MD3)	1
		Roots damage buildings (MD4)	1
		Roots obstruct ditches and drains (MD5)	3
	Economic costs (D1.3)	Expensive management (MD6)	2
		Low economic profitability (MD7)	1
Agriculture-related	Physical obstacle (D2.1)	Hinder work with machines (AD1)	11
		Low accessibility in wet periods (AD2)	1
	Workload (D2.2)	Additional workload (AD3)	7
	Causes of decrease in crop production (D2.3)	Habitat for pests (AD4)	2
		Overall competition causing yield loss (AD5)	4
		Local root competition (AD6)	2
		Rainfall interception (AD7)	2
		Light interception (AD8)	3
	Causes of decrease in livestock production (D2.4)	Risks for reared animals (AD9)	2
	Competition for land (D2.5)	Occupy surfaces that could be better valorized (AD10)	1
Health/ security	Animal bites (D3.1)	Habitat for the pine processionary (HD1)	1
		Habitat for hornets (HD2)	1
	Dead biomass production (D3.2)	Risks and inconvenience of leaf falls (HD3)	2
		Risks for humans of branch falls (HD4)	1

Other classes of positive contributions (code)

3 other positive contributions (code)

Economic benefits (PC1.1)	Economic valorization of least fertile lands (PC1)	1
	Low management expenses (PC2)	1
	Additional CAP subsidies (PC3)	2

Other classes of negative contributions (code)

4 other negative contributions (code)

Legislative constraints (NC1.1)	Mandatory regulation (NC1)	1
	Uncertainties on future changes in regulations (NC2)	1
	Fewer areas eligible for CAP subsidies (NC3)	1
Social pressure (NC1.2)	People do not understand farmers' need to cut down trees (NC4)	1

2.5. ANALYSES OF FARMERS' PERCEPTIONS REGARDING RURAL FORESTS

To investigate how farmers perceived and managed rural forests, we combined both quantitative and qualitative analyses. First, we tested whether our sampling effort was sufficient to allow a good appraisal of the diversity of FPCs and FNCs perceived by farmers. To this end, we examined the level of data saturation with FLAME 1.2, an Add-In running in an EXCEL® environment that analyzes free-lists (Pennec et al., 2012). Data saturation may be understood as the point in our data collection (i.e. from a given number of interviews) when no new FPC or FNC was added by a new interview. As each farmer produced two lists, two distinct tests of data saturation were performed: one for FPCs and one for FNCs.

Secondly, a comprehensive qualitative analysis of interview data was performed to understand farmers' perceptions and management choices regarding rural forests. Interviews were transcribed and encoded with NVivo 11 (QSR International Pty Ltd., 1999–2017). Four axes structured the analysis: (i) the influence of FPCs and FNCs on farmers' well-being and activities, (ii) the type of forested areas associated with FPCs and FNCs, (iii) the rural forest management strategy and how it has changed, and (iv) divergences between farmers' discourse and perceptions.

Finally, to further explore variability in farmers' perceptions, Multiple Correspondence Analyses (MCA) were performed with the package FactoMineR (Husson et al., 2017) in R (R Core Team, 2018). For these analyses, each farmer was considered as an observation and was characterized by the FPCs and FNCs he/she cited as variables. Different MCAs were performed on the basis of different analytical options. We selected the results obtained from the most relevant MCA, i.e. the analytical option that reduced bias due to its sensitivity to rare items and that limited the number of variables. This MCA was performed with 19 observations (i.e. the 19 farmers), 25 active variables (i.e. the main classes of FPC and FNC cited by farmers) and 9 supplementary variables (i.e. the socio-economic attributes of farmers). For each observation and active variable, the value was '1' if the corresponding class of FPC/FNC was cited by the farmer, and '0' otherwise. Further details on analytical options and procedures are found in Suppl. material 3.

The following results are from these quantitative and qualitative analyses. The farmers' quotes were translated from French by a professional translator.

3. Results

3.1. GENERAL RESULTS

Farmers as a whole cited more FPCs (N=32) than FNCs (N=25) (Table 2). This trend was also true at an individual level (paired Student test, t -value=10.0, $p < 0.01$) with, on average, 7.3 FPCs (SD=1.6; median=7) and 3.2 FNCs (SD=1.1; median=3) listed per farmer. According to the saturation test, the full set of 32 FPCs was obtained after interviewing 9 farmers, and the 25 FNCs after interviewing 8 farmers. Of the 32 FPCs, 5 were cited by more than 50% of the farmers (Table 2): firewood, gully and erosion control, fruits and nuts, landscape scenery and mushrooms. Only one FNC was cited by more than 50% of the farmers: the fact that trees hinder working with tractors.

Of the 32 FPCs, 29 were classified as ES, while 3 remained outside the scope of the CICES classification system. This resulted in 19 classes of FPC, including 18 classes of ES and 1 class of 'Other positive contributions' (Table 2). Of the 25 FNCs, 21 were classified as EDS, while 4 were outside the EDS definition. This resulted in 12 classes of FNC, including 10 classes of EDS and 2 classes of 'Other negative contributions' (Table 1). In total, we obtained 31 classes of rural forest contributions, including 25 cited more than once. Classes of FPC tended to be more frequently cited than classes of FNC (Figure 2).

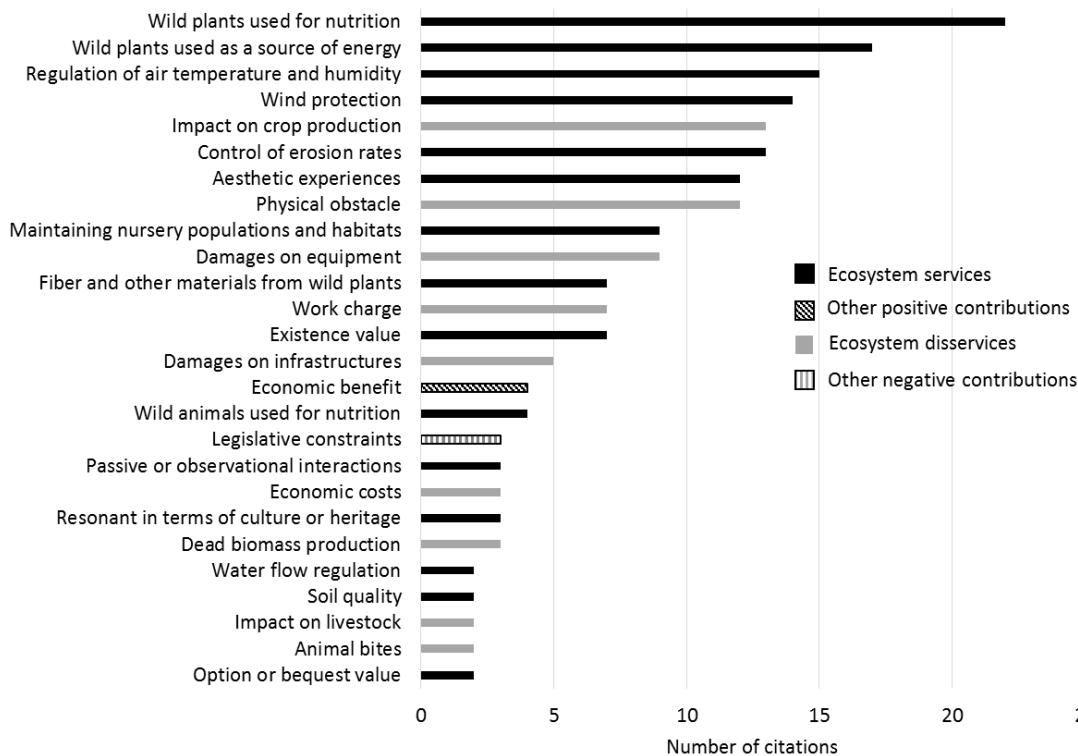


Figure 2: Number of times each class of rural forest contributions was cited by farmers. Only classes with at least two citations are represented. Black bars represent ecosystem services; black dashed-line bars represent other positive contributions; grey bars represent ecosystem disservices; grey dashed-lined bars represent other negative contributions.

3.2. A SOURCE OF FIREWOOD AND TIMBER

The most cited FPC was firewood (N=17), whereas timber was less frequently mentioned (N=5). All but one farmer was using firewood at the time of the study, and 11 farmers stated it as their main source of energy for heating, complemented by oil or electric heating systems. Firewood is mainly harvested from crop-edge trees that require regular pruning. Pruning is done in winter, when agricultural work is low intensity: “We get a lot of wood for heating from around [field] edges, wood in streams, things like that. Or we prune back the branches that reach the tractor cabins and prevent us from working” (F09). In addition, trees on farmland and fallen forest trees constitute a substantial source of firewood: “If there is an oak that’s been uprooted in the woods, I collect it to use it in my stove” (F09). Farmers therefore opportunistically make use of fallen trees that have to be removed from fields to allow agricultural work (Figure 3, left). Farmers also get firewood from preventive tree harvesting: “We just cut down a big oak by the outbuildings as it looked like it was going to fall down [...]. We did it with a friend who had a crane” (F12). They tend to prefer the option that takes the least time and technical equipment for firewood provisioning. As a consequence, most farmers no longer harvest firewood themselves by coppicing. One reason given is lack of time and the labor involved, as well as the arduous nature of the task: “I used to go [to the woods to get firewood], but now I don’t go any more. I’m too old. It’s too tiring. [...] Because you have to get it, put it in the log splitter, then collect the pieces and stack them...” (F02). Another reason is that tree harvesting demands skill (e.g. knowledge about how to cut down a tree properly and judge its fall) and special machines (e.g. a log splitter, an old tractor that can be taken into the woods) that farmers do not necessarily own. In these cases, three strategies were identified. First, farmers may ask a knowledgeable neighbor or relative for help: “If trees have to be cut down, I don’t do that because I’m not much of an expert at that. But I have a neighbor who’s a bit older than me who comes over and knows how to do it. If I tell him to cut down three or four trees, he’ll cut them down” (F06). Requests for help such as this are part of a custom of reciprocal assistance: “If I have equipment, for instance, that my neighbor doesn’t have, I’ll go and help him get rid of a tree that has

fallen down in his yard, or wherever. Then the neighbor will help me out too” (F08). Second, farmers may call upon informal loggers (especially retired farmers or unemployed relatives) who are paid in kind with half of the harvested wood. Third, farmers may rely on professional loggers who are paid on the basis of the number of cubic meters of stacked wood harvested: “A few years ago, we got some Portuguese [laborers] to come ... they cut down the trees and made it into firewood” (F06). The harvested firewood is mostly used for personal consumption, though two respondents sell part of it informally for cash.

As regards timber, in the last decade, only two farmers harvested it from trees on their land. Today, new buildings and homes are built mainly with purchased timber and non-wood materials. Yet according to the interviews, every 20 to 30 years farmers sell standing timber from their forests to local timber companies for additional income. After the timber is logged, farmers say they can “get some wood on the side” by collecting the biggest pruned branches for firewood (Figure 3, right). However, the farmers asked about this practice stated that selling timber is hardly profitable these days, which discourages some of them: “I tried one day to get an estimate for selling some wood [...] but] when I saw the selling price it would get, I gave up [...]. It’s nothing” (F04).



Figure 3: Left: Firewood resulting from edge trees pruning, and a fallen tree waiting to be harvested. Right: a farmer collecting remaining logs and branches from his forest after it has been harvested by a timber company. (Photographs from February 2017, J. Blanco).

3.3. NON-LIGNEOUS PRODUCTS AND NON-MATERIAL CONTRIBUTIONS OF RURAL FORESTS

Fruits and nuts were a frequently cited FPC. These are mostly collected from trees on farm, in particular isolated or edge trees. Walnuts (*Juglans* spp. L.), figs (*Ficus carica* L.), plums (*Prunus domestica* L.) and sloes (*Prunus spinosa* L.) were the most cited non-ligneous products. Fruits and nuts are collected, processed and used for personal consumption by families, or might be given to a neighbor in return for a service rendered. These uses encourage farmers to maintain fruit trees on their farms, notwithstanding certain associated disadvantages: “Yes, that’s a fig tree. I drive around it [with the tractor]. It’s been getting in my way for a long time now [...] though I don’t mind getting the figs!” (F02). In addition, many farmers highlighted the environmental value of fruit trees, in particular for pollinators and frugivores: “We’re really glad to see the fruit, even if we don’t eat it. And the birds are happy. And the bees! The bees (laughs)! Because if us farmers don’t do it, who’s going to?” (F07).

Mushrooms were another non-ligneous forest product particularly appreciated by farmers. When the climate is favorable, farmers go to woodland areas to harvest them, either on their own land or outside of it. Likewise, both countryside and city dwellers frequently harvest mushrooms in farmers’ woods: “Here, everyone goes to the woods to gather mushrooms, no one stops them [...] as long as they don’t take them all” (F18). This practice is tolerated as long as people do not damage property (especially fences) or harvest large quantities to sell at local markets: “Here it’s unbelievable – during mushroom season, when there are thunderstorms, [people collect them to] sell in the market. I can’t stand that. [...] But when people get them for themselves, that’s OK, it doesn’t bother me” (F12).

Finally, rural forests provide significant non-material services, in particular those related to scenic value and landscape identity: “The landscape is much prettier with a few woods and hedges than if it were bare! I’m not an ecologist, far from it, but I’m not a total destroyer either” (F18). Respondents consider rural forests to be integral to the undulating landscape, as they occupy hilly terrain that is difficult to cultivate mechanically. In this area, trees and hills are two inseparable characteristics, in contrast to the flat and deforested areas in the plain. The presence of trees testifies to the maintenance of the traditional activity of herding: “A cereal farmer [...] has big fields, with nothing in the middle to get in the way. While in the mixed crop–livestock farming we do, the livestock rearing always takes up about as much space as a wood – a parcel we can’t plough – so we keep those parts” (F05).

3.4 RURAL FOREST CONTRIBUTIONS TO AGRICULTURE

From the viewpoint of the farmers we interviewed, rural forests contribute both positively and negatively to agriculture (Figure 2). Based on their own experiences and observations, farmers were prone to cite the positive effect of erosion control (Table 2): “There was a hedge there, and a track with a hedge over there. Further on there was a bank, but all that’s been removed, and now when there’s a thunderstorm, [...] the earth] slides down to here” (F18). Aside from the role of rural forests in limiting erosion, farmers also stressed the impact of land use and tillage on erosion: “The erosion [...] also comes from the ways of working here. If you plough, there are a lot more gullies than if you just work the topsoil or use a light harrow, for instance. When you leave the organic matter on the surface, there’s less gullying” (F09).

Rural forests were perceived as being an asset for livestock, in particular for their sheltering function. Interestingly, if some patches of forest are left open to cattle, for farmers the purpose of this practice is mainly for forest clearing, not initially to provide an additional forage area: “The advantage is that [the cows] go [into the wood, where] at least they trample the brambles – what little they can trample. The fact that the wood is cleared, to start with, allows grass to regrow there. Then the cows can go and eat this fresh grass” (F05). Another positive contribution considered important for agriculture is the role of rural forests as landmarks. Isolated trees mark specific features (such as springs), and hedgerows mark out farm boundaries. They also protect crops next to a grazing pasture: “With a neighbor who raises livestock, it’s better to have a hedge than a fence, in the end. Because cattle can get through a fence, but they can’t get through a hedge,” (F08). On the other hand, farmers rarely mentioned the role of trees in sheltering useful insects, filtering pollution, or improving soil quality (Table 2): the exception was a 31-year-old woman (i.e. the youngest respondent).

As regards negative contributions to agriculture, the first cited FNCs were related to the impact on mechanized cultivation of fields, as trees constitute physical obstacles that may damage tractors. Regular pruning is practiced to mitigate these FNCs: “[The hedges] cause us problems in places where we work with tractors. In the cabin – ping ping ping – we get banged about ... I have to cut them back a bit” (F05). However, regular pruning translates to extra cost and workload: “Every year you have to go over the hedges. It’s 20 hours with the flail mower every year: 30 hours of work, the diesel fuel, the equipment [...] it costs quite a bit in the end if you really count it up” (F08). Some farmers consequently prefer to remove edge trees, which also enables them to extend their fields: “Over there, I pulled up a hedge; here there was another hedge that cut my field in two, so I pulled it up about ten years ago. This colza field was six fields to begin with – now there’s only one” (F17). The other main FNCs cited concerned the negative impact of trees on crop production. Some farmers considered that trees compete with crops for light, nutrients and water, while others emphasized one or the other of these aspects in particular: “In a field of corn, you’ll see a ring [where corn doesn’t grow] around an oak. That shows you the spread of the roots – it’s not because of the shade” (F04). In addition, farmers highlighted indirect FNCs, such as the fact that trees and woods shelter pests and wild mammals that can damage crops, especially roe deer.

3.5. CONTRASTING PERCEPTIONS AND VIEWS OF FARMERS

In addition to identifying the aspects that predominated in the farmers’ discourse, our analyses revealed contrasting views between farmers. First, the MCA revealed a gradient spanning from organic farmers to farmers of conventional crop systems, with farmers in conventional mixed systems in an

intermediate position (Figure 4A). Figure 4B and Table 3 highlight the active variables driving these patterns of variability, with the first axis tending to oppose a cluster of regulating and cultural ES from a cluster of negative contributions and lacking ES. Secondly, our qualitative analysis corroborated this trend, revealing contrasting views between farmers on how to balance FPCs and FNCs. On the one hand, some farmers promoted a ‘land sparing’ model, i.e. spatial separation of agriculture and forests: “I don’t agree with inventorying the trees at field edges so that we can’t cut them down when we want, but inventorying forests to limit cutting them down, like in the Amazon, I’m all in favor of that” (F08). These farmers were prone to criticizing CAP directives for being too constraining, and were expecting further legislative restrictions in the future: “So what’s going on these days [is] you see [mechanical] diggers pulling up hedges and trees because [farmers are] anticipating future regulations” (F09). On the other hand, some farmers tended to criticize the ‘land sparing’ vision, highlighting its roots in the post-war agricultural model: “In our minds, we’re still back in the intensive farming methods of the 1970s and 1980s. After the war, you had to produce enough to feed people, to get the economy going again, and I think this attitude is still there deep down” (F05). These farmers were particularly aware of the negative impact of tree removal and advocated for a compromise between trees and agriculture at field scale: “The old timers put in hedges, put up banks in the fields, [whereas] today we’ve got this problem with gully erosion. That’s our doing, because we got rid of the hedges and the banks” (F18). They were more favorable to recent CAP developments, although they warned about unintended effects and strategies to bypass the rules (for example, in the mandate to dedicate 5% of arable land to areas beneficial to biodiversity, farmers have the option to leave land fallow rather than keeping trees or hedges): “Some farmers influenced by the CAP are afraid that if there’s a yard of hedge that goes over into a field, they’ll be penalized. [...] The CAP and the interpretation of the CAP have had a very harmful effect on the survival of hedges. There are some farmers with Ecological Focus Areas that they choose to leave fallow. [...] A lot of farmers would rather have zero trees [...] that’s the perverse effect of the CAP on the landscape” (F03).

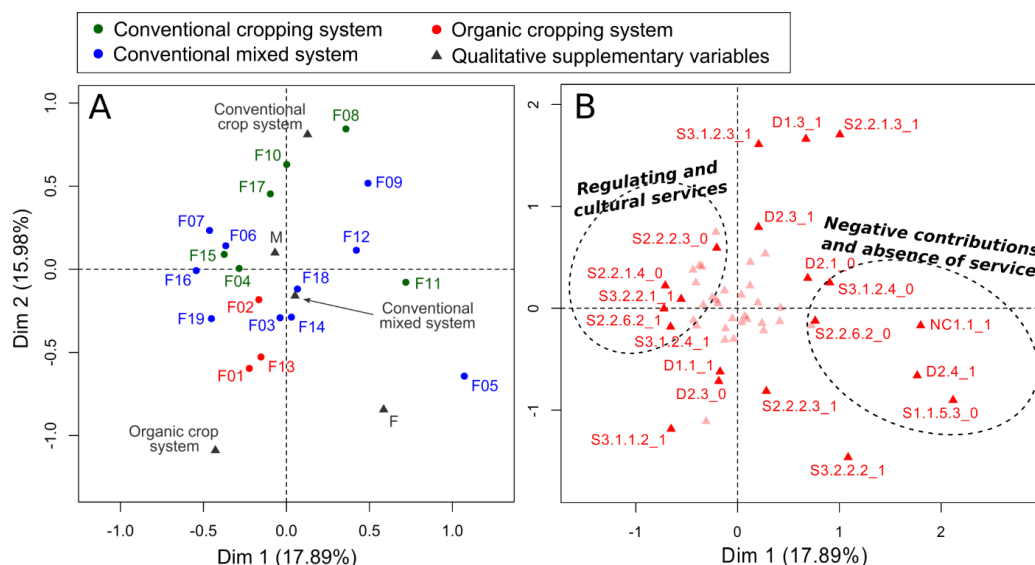


Figure 4: Multiple Correspondence Analysis outcomes: (A) Projections on the two first axes of the individuals (organic farmers in red; farmers with conventional cropping systems in green; farmers with conventional mixed systems in blue) and of the supplementary qualitative variables (i.e. gender (M/F) and farming system, grey triangles); (B) Graphs of the active categories to the first two axes of the MCA (red triangles: the 20 most contributive categories; light red triangles: the other categories). The codes used to identify the active variables are those presented in Table 2.

Table 3: Main contributors of the Multiple Correspondence Analysis for the two first axis (Dim 1 and Dim 2): only individuals and variables with a large quality of representation into the axes are reported (individuals with $\cos^2 > 0.5$, active variables with $\eta^2 > 0.5$, supplementary qualitative variables with $\eta^2 > 0.5$ and supplementary quantitative variables with $|\text{cor}| > 0.3$).

Individuals			Active variables		Suppl. qualitative variables		Suppl. quantitative variables	
	Id	Cos2	Id and name	Eta2	Name	Eta2	Name	Cor
Dim 1 (17.9%)	F05	0.61	S1.1.5.3-Wild plant for energy	0.53	-	-	Age	-0.33
			S3.1.2.4-easthetic experiences	0.60				
			NC1.1-legislative constraints	0.61				
Dim 2 (16.0%)	-	-	D2.3-decrease in crop production	0.57	Farming system	0.41	FarmArea	0.30
			D1.3-economic costs	0.52			No of cited FNC	0.41

* represents the quality of the representation for individuals on each axis.

‡ Square of the correlation ratio between each variable and each axis.

¶ Correlation coefficient between each quantitative variable and each axis.

4. Discussion

4.1. THE MULTIPLE DIMENSIONS OF RURAL FOREST ES AND EDS TO FARMERS

Our results found that the respondents perceive trees as providers of multiple both positive and negative contributions. These findings are consistent with other research conducted in farming communities in temperate and tropical environments (Garrido et al., 2017; Genin et al., 2013; Smith et Sullivan, 2014) and emphasize the complex interdependence between agricultural and forest systems.

Unsurprisingly, the most frequently cited FPCs were provisioning services, in particular for food and fuel, which are known to be important to local stakeholders and landowners who directly depend on ecosystems for their livelihood (Garrido et al., 2017). In line with other studies (Da Ponte et al., 2017; Dorresteijn et al., 2017; Garrido et al., 2017), we found that firewood is an important FPC to farmers, who mainly use it for personal consumption. Firewood effectively generates savings on energy expenses and allows the exploitation of byproducts from tree pruning, a necessary management practice for trees around the edges of agricultural plots. Thus, harvesting firewood has an undeniably rational economic basis, which may be linked to the willingness of farmers to maintain some traditional forestry uses (Andrieu et al., 2011).

Aside from provisioning services, several regulating ES were acknowledged by farmers, in particular those related to air temperature regulation, protection from wind, and erosion control. These services were generally seen as profitable to agriculture as they enhance some provisioning ES, especially food production.

At the same time, rural forests were also seen as a source of EDS by farmers, a reality that has been recognized in an increasing number of studies (Dorresteijn et al., 2017; Lugnot et Martin, 2013; Mackenzie et Ahabyona, 2012). The most frequently cited FNC – trees represent physical obstacles to mechanization – illustrates the difficulty of reconciling mechanized agriculture with trees (see also Ango et al., 2014) and confirms the link between the mechanization of agriculture and the decline of trees outside forests (Blanco et al., 2019b; Petit et al., 2003). The loss of agricultural production – caused by tree competition with crops or crop raiding by wildlife – was the second most frequent category of FNC cited by informants; this represents a major source of concern for farmers worldwide (Ango et al., 2016; Mackenzie et Ahabyona, 2012). Finally, two other frequently evoked FNCs were the additional work

involved in rural forest management, as well as the additional costs associated with the damage caused by trees.

Another noteworthy result concerned the importance of non-material ES for farmers. As has been found elsewhere, farmers in the study region attach great importance to the landscape's scenic value and identity, as well as to traditional land-use practices, and rural forests play a part in this. Similar to other landscape components, they are a feature that farmers have inherited from previous generations and will transmit to subsequent generations. This heritage and legacy value occupies an important place in farmers' discourse, suggesting that their perceptions include a vision of the landscape's history as well as its future. This non-material contribution of rural forests was also embedded in certain provisioning ES. For instance, farmers continue to harvest firewood and collect fruits, nuts and mushrooms, not only to meet material needs, but also to maintain certain traditional practices and types of social interactions. These provisioning services could therefore be considered 'cultural subsistence services', i.e. provisioning ES that are deeply related to social traditions, beliefs and norms (Pascua et al., 2017). In our case study, we found that some provisioning ES (e.g. the harvesting of firewood from hedgerows) are partly valued by local stakeholders because of their underlying cultural value (e.g. the maintenance of mutual aid networks between farmers). As we based our categories on the CICES system, and to avoid double counting, these services were classified as provisioning ES, though they could equally have been classified as cultural subsistence services since both material and non-material aspects mattered to farmers. It is important to keep in mind that such classification choices may have a significant influence on the overall results of socio-cultural valuation studies.

4.2. VARIABILITY IN FARMERS' PERCEPTIONS OF RURAL FOREST ES/EDS

The study revealed variability in farmers' views and perceptions of rural forests, emphasizing the importance of studying individual perceptions rather than considering farmers as a homogeneous group of stakeholders (Vanclay, 2004). In the MCA (Figure 4B and Table 3), we observed a significant contribution of FNCs in explaining the variability between farmers. This result could be explained by the fact that FNCs were less frequently mentioned by farmers than FPCs, so they contributed more to the MCA's dimensions. In other words, the MCA highlighted that the consensus among farmers was lower for FNCs than FPCs. This result stresses the need to better take into account perceived EDS in socio-cultural valuation studies, so as to more accurately identify differences between people's perceptions, and ultimately to better understand the variability in their behavior.

Secondly, in accordance with other studies (e.g. Da Ponte et al., 2017), we found correlations between farmers' perceptions and the type of farming they practiced. Our qualitative analysis confirmed that farmers with a mixed crop–livestock farming system were more favorable to trees than farmers solely cultivating crops. This may be explained by the various ES that trees provide to livestock and by the low EDS associated with trees in pastures (in contrast with trees in cropland). This supports studies that have shown that the maintenance of diversified pastoral systems contributes to the conservation of farm trees (Hartel et al., 2017; Pfund et al., 2011). Furthermore, organic farmers tended to be more favorable to trees than conventional farmers. Yet, because our sample included only three organic farmers, confirming this result would require further research.

Finally, farmers differed in the options they envisioned as a way to reconcile rural forests and agriculture at landscape scale. While they all agreed on the necessity of managing trade-offs between agricultural production and tree maintenance, they advocated for either a 'land sharing' or a 'land sparing' scenario. Farmers that supported the former approach highlighted the multiple ES rural forests supply to agriculture and why this made them willing to bear the associated EDS. For instance, some farmers maintain isolated fruit trees in their fields notwithstanding the inconvenience for mechanized cultivation. Others purposely let hedgerows grow and do not manage them in order to enhance biodiversity despite an observed increase in pests and the risk of getting reduced CAP subsidies due to the loss of arable areas eligible to Pillar I direct payments. In contrast, farmers who argued for a 'land sparing' model emphasized the negative impact of rural forests on crop production and mechanized cultivation. They considered that many forested areas could be better exploited by converting them into agricultural land, leaving only the least fertile or least accessible land forested. For instance, one farmer

had recently bought a forested parcel and planned to convert it to enlarge a crop field, arguing that agricultural areas should be cleared of trees and remain separate from forest areas. These different points of view echo current uncertainties regarding how to effectively reconcile food production and biodiversity conservation in agricultural landscapes and highlight the need for further research (Fischer et al., 2014).

4.3. CHANGE AND STABILITY IN THE SUPPLY AND DEMAND OF ES

Our findings highlighted both trends – continuity and change over time – in perceptions of the supply and demand of ES provided by rural forests. For example, respondents noted a pattern of change in firewood demand, which has decreased in recent decades as houses have been progressively equipped with fossil fuel-based central heating systems. Another example is that while people in the area used to use diverse forest products to make handicrafts or homemade alcohol or for forage (Sourdril, 2008), our interviews confirmed the virtual disappearance of these traditional practices and the resulting decline in rural forest domesticity (Sourdril et al., 2012). Some of these changes are associated with changes in French laws – for example, homemade alcohol production is now strictly regulated. Others are explained by the development of alternative options, in particular for firewood, handicrafts and livestock forage. As a consequence, these factors seem to have contributed to lowering the value farmers assign to rural forest ES. Similarly, changes in agricultural practices over recent decades (e.g. mechanization) seem to have reinforced certain FNCs. The expansion of the surface area of farms, alongside a decline in the available workforce due to rural exodus, have exacerbated the difficulty for farmers to properly manage woodlands. Because of the increase in cropland and the mechanization of cultivation, tree–crop competition has become a more salient issue for farmers, with a more significant impact on perceived farm profitability. Finally, the use of ever-larger machines has the result that trees further hinder mechanized work. As demand for particular ES has changed, farmers have adapted their farms, in particular by removing trees on farmland (Blanco et al., 2019b) and abandoning certain management practices dedicated to enhancing FPCs (e.g. local silvicultural practices aimed at increasing wood production). These changes in farmers’ practices have impacted the supply of ES/EDS, highlighting the critical role of human agency relative to ecosystem function in the services/disservices provided (Spangenberg et al., 2014).

Other perceptions of ES/EDS show stability over time, sometimes despite contextual changes. In some cases this is due to a certain disconnection between scientific and farmer knowledge. For example, over the last two decades, scientific literature has generally reached a consensus on the overall positive impact of hedgerows on crop yields (Baudry et al., 2000; Van Vooren et al., 2017), soil fertility (Torralba et al., 2016), and pollutant filtration (Brauman et al., 2007). Yet farmers either disagreed with these findings or were not aware of them. One reason for this gap lies in the fact that farmers’ learning is mostly based on empirical observation and experience. For example, farmers realized the efficacy of hedgerows in controlling erosion as they observed the occurrence of landslides after their removal. But less visible effects are less likely to shift perceptions. As one farmer explained, a decrease in yields next to hedgerows (caused by local tree–crop competition) is more visible than an increase in yields in the middle of a field (due to the reduction of wind speed provided by the hedgerow). This is consistent with the findings of Salliou and Barnaud (2017) who reported poor farmer awareness regarding processes that are seemingly hard to grasp, such as landscape-scale biological control. A further factor is that farmers and scientists use different indicators to assess rural forest contributions. Farmers tend to consider the actual impacts of trees on their farms and overall activities: in terms of additional labor, required knowledge and skills, and economic returns (Salliou et Barnaud, 2017). In contrast, research focuses on woodland impact on biophysical processes, and generally overlooks the impact on farming activities. A final factor is certainly related to the loss of local knowledge associated with the modernization of agricultural systems on the one hand, and insufficient availability of scientific findings among farmers on the other. The transfer of research findings from the experimental context to real-world, local settings remains a particular challenge. While scientists have a role to play in ensuring this transmission of knowledge, it also requires the engagement of agricultural advisors and agencies that have frequent interactions with farmers and that favor changes in agricultural practices.

To conclude, the poor awareness of farmers regarding some key positive contributions of rural forests to agriculture is worrisome: “lack of information affects people’s abilities to place a value on ecosystem attributes” (Bingham et al., 1995). To tackle the challenge of conserving rural forests, research should aim to better integrate farmers’ questions and concerns in order to produce knowledge that could be better operationalized locally (Duru et al., 2015). Engaging agricultural support agencies and agricultural advisors/consultants in this co-production process could further help to promote changes in farmers’ practices.

4.5. METHODOLOGICAL CHALLENGES AND IMPLICATIONS FOR RESEARCH

Our results highlighted the complementarity of ES and EDS for understanding the perceptions and behavior of farming communities regarding rural forests. As Table 2 illustrates, the ES concept was quite effective to capture most of the FPCs cited by farmers. Only 3 FPCs were not considered as ES according to the definitions we used (Haines-Young et al., 2018); these were related to benefits that farmers directly or indirectly derive from ecosystems or ES conservation (e.g. additional CAP subsidies). In contrast, the classification of FNCs as EDS was more challenging due to the lack of a widely accepted EDS conceptual framework and classification system. Just as ES are distinct from the benefits derived from them (e.g. firewood production is distinct from the economic benefits obtained by the sale of firewood), EDS should be distinct from the costs they induce (Campagne et al., 2018; Shackleton et al., 2016). Yet we found the delineation between the two was sometimes fuzzy. For example, we classified as EDS ‘damage to tractors caused by trees’, ‘management costs’ and ‘additional workload’; however, they could be considered as a set of direct and indirect costs caused by the EDS ‘growth of tree branches in fields’. While these kinds of considerations have received a lot of attention for ES and allowed the construction of widely accepted definitions of what ES are/are not, this work remains to be done for EDS (Blanco et al., 2019a).

A second challenging aspect concerns the methodology used in this study. We conducted in-depth interviews with 19 farmers, encountering each of them twice. This approach allowed a very fine-scale description of how farmers in the local area perceive rural forests and their behavior in relation to these, as well as a thorough understanding of the complexity of their management choices. However, the choice of a semi-structured interview protocol, to enable a mixed approach combining qualitative and quantitative analyses, required some trade-offs between the length of the interview necessary to uncover complex processes and perform a relevant qualitative analysis, and the number of interviews necessary to allow robust statistical analyses and a representative sample size. An examination of the level of data saturation ensured that our sample was large enough to permit a good overview of the FNCs and FPCs perceived by farmers, which required around 10 interviews (see section 3.1). We also targeted the region’s dominant farming systems when selecting the respondents. Thus, we are quite confident that our results are illustrative of the farming community in the study area. Yet while the trends revealed by the MCA corroborated the qualitative analyses, it would be valuable in future research to increase the number of farmers in order to further test certain hypotheses, in particular regarding the influence of the type of farming system and gender on farmers’ relationships with rural forests.

4.6. IMPLICATIONS FOR AGRICULTURAL POLICIES

Our findings revealed different attitudes among farmers regarding CAP greening measures. Most felt these imposed additional constraints and additional labor. While some farmers acknowledged these measures may have an overall positive impact on rural forest conservation, others were more skeptical and highlighted the unintended consequences of the policy in practice and bypass strategies. For example, as agricultural areas eligible for CAP payments can be reduced if the spread of hedgerows is not properly managed, some farmers prefer to remove them in favor of productive Ecological Focus Areas (EFAs) such as nitrogen-fixing crops and catch crops. Interview responses suggested that farmers were encouraged to do this by agricultural advisors from public agencies, confirming the reluctance of European farmers to classify rural forests as EFA (Pe’er et al., 2017). Thus, to better promote rural forest conservation, two different thresholds could be defined: a minimum area of productive types of EFA and a minimum area of unproductive types of EFA (i.e. specific landscape features such as hedgerows

and isolated trees). Furthermore, rather than one-size-fits-all targets, these thresholds should take into account the specificity of local contexts and current realities: e.g. landscapes with a current high level of wooded areas should have higher targets than landscapes with a lower level of wooded areas. In this objective, a more bottom-up approach could be taken for deciding the most relevant thresholds for a specific region, based on the expertise of local agricultural advisors and support services.

Moreover, as illustrated by the uses of rural forests pointed out by our respondents and the many provisioning services derived from them, we argue that rural forests should not be considered unproductive areas. Better recognition of their products and services and more support in exploiting these could help farmers obtain more benefits from rural forests, which could incite them to conserve this productive asset. For example, creating supportive measures to promote regional fuel wood commodification could be one way to improve economic advantages from woodlands while meeting an increasing national demand.

Lastly, some farmers raised the issue of constant changes to CAP directives, which generates economic uncertainty. For example, they worried about the possibility of a ban on tree-felling in the future, which led them to begin removing wooded areas from their farms as a precaution. While we lack data to assess the extent of these removals, our interviews confirmed this negative result of CAP greening measures on rural forests based on farmers' perceptions of the directives and an ever-changing and unclear agenda. As other authors have argued, it seems crucial for CAP measures to be better targeted and adapted to local contexts (Jakobsson et Lindborg, 2015) and for the wider agenda to be clearer. This could be achieved, for example, by adding some flexibility regarding the expansion of hedgerows over cropland and meadows to ensure that farmers would not be afraid of reductions in direct payments if hedgerows extend into arable lands. Furthermore, if one hedgerow is registered as an EFA, it should be able to be easily substituted by another hedgerow on the farm, so that farmers can more easily adapt their farms to a changing socio-economic and environmental context. In short, the indicators used to allot CAP subsidies should better integrate two antagonistic objectives: the maintenance of rural forests and other types of EFAs that favor the ecological functioning of agricultural landscapes, and the ability of farmers to adapt their farms and practices to a changing environment.

5. Conclusion

Understanding how local landscape and ecosystem managers perceive, use and manage an environment and its natural resources is increasingly acknowledged as a critical step in better targeting environmental policies and improving their effectiveness. With this perspective in mind, this study aimed to assess through interviews how farmers from an agricultural region in southwestern France perceive and manage rural forests, which are key ecological features for the functioning and sustainability of agricultural landscapes. Combining qualitative and quantitative methods, the results showed that rural forests are perceived as a source of multiple ecosystem services and benefits. Furthermore, the material and non-material aspects of rural forests are often deeply intertwined. For instance, the harvesting of firewood from trees on farmland offers the means to acquire provisioning ES and to regulate tree encroachment in cropland, as well as to maintain certain social interactions such as mutual-aid networks. The results also illustrated the reality that for farmers, rural forests also represent a source of ecosystem disservices. These impacted farmers' well-being either directly (e.g. risk to their safety, damage to tractors) or indirectly by reducing certain ES (e.g. decline in yields caused by tree-crop competition). Some EDS were reinforced by inadequate legislative frameworks, such as the loss of CAP subsidies if forested areas expand over cropland, which illustrates that EDS, like ES, are coproduced by human and ecological factors. The findings showed that ES and EDS were perceived differently between farmers, with EDS the main source of variability in farmers' perceptions. Hence, this study illustrates how a combination of ES and EDS can help explore the complexity of local perceptions of ecosystems and contribute to achieving a more accurate, exhaustive vision of views and attitudes. Including EDS in socio-cultural valuations of the environment is a key challenge for future research on social-ecological systems. Finally, by highlighting how global policies can be differently received by local stakeholders, we advocate for the adaptation of CAP greening measures to local realities and for a more stable CAP agenda to avoid farmers reacting in anticipation of potential future

restrictions. More specifically, CAP greening measures should define indicators that target the maintenance of rural forests (i.e. a minimum area of rural forests per farm) while allowing farmers to adapt their management practices of rural forests to changing socio-economic and environmental contexts.

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Supplementary material 1

Table S1: Main characteristics of the farms located in the Canton of Aurignac in 1988 and in 2010 according to data from the French agricultural statistics and assessment service (available at <http://recensement-agricole.agriculture.gouv.fr/>)

Year	In number (and percentages of the total)		In surface area (ha) (and percentages of the total)	
	1988	2010	1988	2010
Types of farming systems				
- Crop systems	41 (11%)	79 (35%)	1,321 (11%)	2,866 (35%)
- Mixed farming systems	183 (47%)	47 (21%)	5,374 (43%)	3,332 (27%)
- Cattle-based systems	114 (29%)	59 (26%)	4,068 (33%)	3,788 (31%)
- Other	52 (13%)	40 (18%)	1,597 (13%)	753 (7%)
Total	390	225	12,360	10,739
Farmers' age				
- <40 year-old	79 (20%)	42 (19%)	3,120 (25%)	3,291 (30%)
- 40-50 year-old	73 (19%)	45 (20%)	2,760 (22%)	2,127 (20%)
- 50-60 year-old	113 (29%)	74 (33%)	3,536 (29%)	4,245 (40%)
- >60 year-old	125 (32%)	64 (28%)	2,944 (24%)	1,075 (10%)
Total	390	225	12,360	10,739

Table S2: Main characteristics of the 19 interviewed farmers, of their farm and woodland estate, and total number of rural forest positive (FPC) and negative contributions (FNC) identified from interviews.

Farmer	Age	Gender	Farming system	Farm surface area* (ha)	No of blocks [¶]	No of woodlots	Woodlot total area (ha)	No of FPCs	No of FNCs
F01	59	F	Organic crop system	13.4	2	0	0.00	8	3
F02	66	M	Organic crop system	61.3	5	1	0.82	8	2
F03	54	M	Conventional mix farming	129.0	14	10	11.00	9	3
F04	68	M	Conventional crop system	114.8	15	1	1.92	7	2
F05	39	M	Conventional mixed farming	139.5	23	5	9.85	7	4
F06	55	M	Conventional mixed farming	123.5	19	4	4.73	8	4
F07	45	M	Conventional mixed farming	110.3	17	4	4.20	7	3
F08	52	M	Conventional crop system	248.7	40	3	1.13	10	6
F09	NA	M	Conventional mixed farming	108.8	9	5	5.42	7	4
F10	NA	M	Conventional crop system	72.2	9	3	12.01	7	2
F11	31	F	Conventional crop system	38.6	8	2	0.40	6	3
F12	58	M	Conventional mixed farming	94.4	15	3	3.13	4	4
F13	43	M	Organic crop system	24.8	3	3	3.91	10	2
F14	60	M	Conventional mixed farming	121.8	31	2	1.15	7	2
F15	63	M	Conventional crop system	51.2	10	0	0.00	4	3
F16	40	M	Conventional mixed farming	165.2	12	5	6.80	9	4
F17	36	M	Conventional crop system	103.2	19	1	0.39	7	4
F18	50	M	Conventional mixed farming	250.8	42	5	5.89	6	2
F19	48	M	Conventional mixed farming	152.7	22	2	4.60	8	4
Total				2124.2	315	59	77.36	32	25

* Farm surface area was assessed from the 2014 version of the RPG, which is the French version of the European Land Parcel Identification System (LPIS).

[¶] Blocks are the geographical entities in the RPG data, defined as one or several contiguous agricultural plots managed by the same farmer.

Table S3: List of the 32 “Rural Forest Positive Contributions” (FPC) and corresponding “advantages” (in French and in English) cited by farmers during interviews.

Rural Forest Positive Contributions (FPC)	Corresponding advantage (French)	Corresponding advantage (English)	Farmers
Firewood (P1)	Bois de chauffage	Firewood	F01, F02, F03, F04, F06, F07, F08, F09, F12, F13, F14, F15, F16, F17, F18, F19
	Economies sur les dépenses d'énergie	Savings on energy expenses	F10
Fruits & nuts (P2)	Fruits (au moins les voir)	Fruits (seeing them at least)	F01, F07
	Noix	Walnuts	F02, F18
	Manger des cerises	Eat cherries	F04
	Nourriture	Food	F08
	Fruits	Fruits	F09, F12, F13, F14, F16
Medicinal plants (P3)	Plantes médicinales	Medicinal plants	F13
Mushrooms (P4)	Champignons	Mushrooms	F03, F05, F06, F08, F09, F13, F16, F18, F19
	Cèpes	Ceps	F17
Habitat for game (P5)	Abri pour le gibier	Shelter for game	F02, F03
	Refuge pour gibier	Refuge for game	F05
	Gibier	Game	F08
Wood & timber (P6)	Bois d'œuvre	Timber	F04, F06, F07
	Bois de construction	Timber	F16
	Grumes	Timber logs	F03
Picket fence (P7)	Piquets	Pickets	F09
	Piquets d'acacia	Pickets in acacia wood	F17
Pastoral areas & resources (P8)	Pacage	Grazing	F05
Shade & fresh air for humans (R1)	Ombrage	Shade	F01, F02
	Ombre quand il fait chaud	Shade when the weather is hot	F04, F08
	Ombre pour les hommes et tracteurs	Shade for humans and tractors	F15
Oxygen production and air quality (R2)	Fraîcheur	Fresh air	F04
	Rend de l'O2	Produce oxygen	F04
	Qualité de l'air	Air quality	F06, F17
	Pour l'oxygène	For oxygen	F08
	Production d'oxygène	Oxygen production	F14
	Oxygène	Oxygen	F15
Shade for reared animals (R3)	Ombre pour les vaches	Shelter for cows	F06
	Fraîcheur l'été (vaches)	Fresh air during summer (for cows)	F07
	Ombre pour les animaux	Shade for animals	F16, F19
Gully & erosion control (R4)	Evite le ravinement	Avoid gully	F01
	Tient la terre	Keep soils still	F02
	Erosion	Erosion	F03, F06, F14
	Erosion des fossés et talus	(Regulate) erosion of ditches and banks	F05

	Tient les berges	Keep banks still	F06
	Tenue des digues	Keep banks still	F08
	Limite l'érosion	Regulate erosion	F09, F10
	Tenir le talus	Holding banks	F12
	Tenir le talus des ruisseaux	Holding banks along water streams	F17
	Tient la bordure des fossés et talus	Hold ditches and banks	F18
	Contre l'érosion	Against erosion	F19
Habitat for wild birds (R5)	Abri pour les volatiles (sauvages)	Shelter for volatiles (wild)	F01
	Abri pour les oiseaux (palombes)	Shelter for birds (pigeons)	F02
	Abri pour la faune sauvage	Shelter for fauna	F03
	Vie de l'écosystème (oiseaux)	Life of ecosystems (birds)	F13
	Bénéfique pour les oiseaux	Positive to birds	F14
Habitat for insects (R6)	Equilibre pour les cultures	Maintain a balance for crops	F03
	Refuge pour la biodiversité	Refuge for biodiversity	F04
	Refuge pollinisateurs	Refuge for pollinators	F05
	Abri à insectes	Shelter for insects	F11
Shelter for reared animals (R7)	Abri pour les volatiles (domestiques)	Shelter for volatiles (domestic)	F01
	Abri pour les vaches	Shelter for cows	F05, F11
	Abri naturel pour les animaux	Natural shelter for animals	F09
	Protège les animaux du vent	Protect animals from wind	F09
	Abri pour les vaches (orage)	Shelter for cows (during storms)	F12
	Coupe le vent pour les vaches	Windbreak for cows	F14
	Abri pour les bêtes	Shelter for animals	F18
	Protection pour l'élevage	Protection for rearing	F17
Windbreak effect for crops (R8)	Couper le vent (céréales)	Windbreak (cereals)	F03
	Abri du vent	Protect from wind	F08
	Brise-vent	Windbreak	F11
	Protection naturelle des cultures	Natural protection of crops	F13
	Coupe le vent des cultures	Windbreak for crops	F14
	Effet brise-vent	Windbreak effect	F16
Slow down water flows (R9)	Ralenti l'écoulement	Slow down water flows	F08
	Ralenti l'eau	Slow down water flows	F09
Humus production (R10)	Humus des feuilles	Humus from leaves	F11
Soil aeration (R11)	Racines aèrent le sol	Roots allow soil aeration	F11
Remove nitrates and other chemicals (R12)	Collecteur de nitrates	Collect nitrates	F11
Fill gaps in the visual landscape (R13)	Coupe le vide visuel	Fill visual gaps	F19
Landscape scenic (C1)	Beauté	Beauty	F01
	Esthétique	Esthetics	F02
	Paysage (visuel)	Landscape (visual experience)	F03
	côté visuel	Visual aspect	F04
	Paysage (esthétique)	Landscape (esthetics)	F06
	Aspect visuel	Visual aspect	F07
	Maintien du paysage	Landscape maintenance	F10
	Décoration/ beau	Beautiful	F13

	Joli	Beautiful	F15
	Côté paysager	Landscape interest	F16
	Aspect dans le paysage	(Visual) aspect in the landscape	F19
Visual aspect of wood construction (C2)	plus joli que le fer	(Wood is) more beautiful than iron (for buildings)	F07
Quietness (C3)	Calme	Quietness	F01
Participate in a living countryside (C4)	Campagne plus vivante	More living countryside	F13
Noble aspect (C5)	Noble	Noble	F19
	Repère	Mark	F08
Landmark (C6)	Délimitation des parcelles	Delineation of properties	F10
	Marquage des limites	Mark (properties') boundaries	F17
	Ecologique	Ecological (advantage)	F02
	Vie de la nature	Life of nature	F06
	Faune	Faune	F07
Biodiversity and ecosystem conservation (C7)	Protection de l'écosystème	Protection of the ecosystem	F10
	Protection de l'écosystème et de l'environnement	Protect the ecosystem and the environment	F13
	Biodiversité	Biodiversity	F16
	Vie sauvage	Wildlife	F19
Reserve holdings & patrimony (C8)	Patrimoine	Patrimony	F05
	Préserve un patrimoine	Conserve a patrimony	F13
Economic valorization of least fertile lands (PC1)	Rentabiliser parcelles non cultivées	Make non-cultivated plots profitable	F10
Low management expenses (PC2)	Peu de charges d'entretien	Low management expenses	F10
Additional CAP subsidies (PC3)	Economique (aides PAC)	Economic (CAP subsidies)	F16
	Aides de la PAC	CAP subsidies	F18

Table S4: List of the 25 ‘Rural Forest Negative Contributions’ (FNC) and corresponding ‘disadvantages’ (in French and in English) cited by farmers during interviews.

Rural Forest Negative Contributions (FNC)	Corresponding disadvantage (French)	Corresponding disadvantage (English)	Farmers
Branches damage tractors (MD1)	Casse les rétroviseurs	Break side mirrors	F01
	Dommage au matériel	Damages on material	F01
	Repousses de branches (tracteur)	Branches grow (issue for tractors)	F02
	Branches abîment le matériel agricole	Branches damage agricultural equipment	F05
	Dégâts sur les machines par les branches	Damages on machines caused by branches	F06
	Abîme les machines si pas entretenu	Damage machines if not properly managed	F14
	Abîme les cabines et les rétroviseurs des tracteurs	Damage tractors' cabins and side mirrors	F18
	Abîme les cabines	Damage tractors' cabins	F19
Risks for fences (MD2)	Risque de rupture sur les clôtures	Risk to break fences	F16
	Entretien pour les clôtures	Need to be managed for fences	F19
Risks for buildings (MD3)	Danger pour les bâtiments	Danger to buildings	F12
Roots damage buildings (MD4)	Racines gênent les bâtiments	Roots may damage buildings	F12
Roots obstruct ditches and drains (MD5)	Empêche entretien des ruisseaux	Obstruct water stream management	F07
	Bouche les fossés	Obstruct ditches	F15
	Bouchage des drains dans les fossés	Obstruct drains inside ditches	F16
	Dégâts sur la digue	Damage riverbanks	F17
Expensive management (MD6)	Coût de l'entretien	Management cost	F08
	Coût	Overall cost	F09
Low economic profitability (MD7)	Faible rentabilité	Low profitability	F10
Hinder work with machines (AD1)	Gêne aux manœuvres	Hinder maneuvers	F01, F13, F16
	Gêne le passage	Hinder the way	F02
	Gêne pour la mécanisation	Hinder field mechanization	F03, F04
	Gêne par les branches	Hindering effect of branches	F07
	Contournement avec les engins	Machines have to avoid them	F09
	Obstacle pour le travail des champs	Obstacle to working in fields	F10
	Gêne si pas entretenu	Hinder if not properly managed	F14
	Salissement (empêche l'accès)	Mess the place (preventing the access)	F17
	Gêne pour le travail	Hinder working (in the field)	F18
	Gêne selon là où elles sont	May hinder work (according to their location)	F19
Low accessibility in wet periods (AD2)	Trop d'humidité à l'automne	Too moist during fall season	F15
Additional workload (AD3)	Beaucoup de travail	A lot of work	F03
	Regagne le champ	Spread to fields (if not managed)	F06
	Travail	Workload	F08, F17

	Travail en entretien	A lot of work for managing	F13, F15, F16
Habitat for pests (AD4)	Abri pour les ravageurs	Habitat for pests	F10
	Amène quelques nuisibles	Bring some pests	F11
Overall competition causing yield loss (AD5)	Moins de rendement	Reduced yields	F07
	Empêche développement des cultures	Undermine crop growth	F09, F12
	Rien ne pousse dessous	Nothing grows below	F11
Local root competition (AD6)	Nuisance possible pousse des céréales	Potential harm for crop growth	F04
	Prend de l'eau sur les cultures	Take water from crops	F08
	Perte de rendement pendant l'été	Yield loss in summer	F18
Rainfall interception (AD7)	Moins d'eau pour les cultures	Less water available for crops	F06
Light interception (AD8)	Ombre sur les cultures	Produce shade on cropped areas	F06, F08, F17
Risks for reared animals (AD9)	Gestion pour l'entretien	Required management (for mitigating risks to animals)	F05
	Problème de sécurité (tempêtes)	Security issues (in case of storms)	F08
	Danger pour les vaches	Danger to cows	F12
Occupy surfaces that could be better valorized (AD10)	Surfaces cultivables en moins	Reduce cropped areas	F05
Habitat for the pine processionary (HD1)	Chenilles processionnaires	Pine processionary	F01
Habitat for hornets (HD2)	Nids de frolons	Hornet nests	F04
Risks and inconvenience of leaf falls (HD3)	Feuilles	Dead leaves	F02
	Feuilles (Sali)	Leaves (mess the place)	F07
Mandatory regulation (NC1)	Règlementation trop contraignante	Regulation too restrictive	F05
Uncertainties on future changes in regulations (NC2)	Evolution de la réglementation	Regulation changes	F09
Fewer areas eligible for CAP subsidies (NC3)	Superficie déduite de la PAC	Areas excluded from CAP	F11
People do not understand farmers' need to cut down trees (NC4)	Les gens ne comprennent pas qu'on coupe	People do not understand we cut (trees down)	F19

Supplementary material 2: detailed interview guideline

Interviewer(s):

Date:

General individual information

Last name:

Age:

Id:

First name:

Sex: ☐ M

☐ F

Postal address:

Phone: (home) _____ (cellphone) _____

No of children (and age):

Education: _____

Additional job: ☐ No ☐ Yes, specify (job name, no of hours per week/month): _____

1. Information about the farm

Farming system: _____ Organic/conventional: _____

Legislative status: _____ No of work labor: _____

Surface area: _____

	2015-2016	2016-2017
Surface area for crops		
Surface area for temporary meadows		
Surface area for permanent meadows		
Livestock (No of head, type of production)		

2. Discussion about the farm and rural forests

On the basis of an aerial photograph of the farm and its surroundings, conduct an open-ended discussion with the farmer about the farm and rural forests.

- Point different agricultural plots and ask information about land use, ownership, slope, etc.

Focus on the information that has a link with farm trees or forests and ask further details.

Examples: if the farmer cites a problem related to erosion, ask what types of measures have been taken to mitigate this problem, ask if hedgerows or other types of forested areas are effective to mitigate it, etc.

- Point different farm trees (e.g. scattered trees, hedgerows, riverbanks) and ask information about ownership, advantages and disadvantages, management practices

Focus on the terms used by farmers to name the different types of forested areas, and fill the “Spontaneous identification” column of the following table. Keep track on the cited advantages and disadvantages. Ask about the stakeholders who intervene in the management.

- Ask about forest plots and their management: locate each woodlot owned by the farmer on the map, ask information about how it is managed.

Focus on most common forest products (firewood, timber, mushrooms) and ask for other types of advantages and disadvantages. Ask information about the stakeholders who intervenes to harvest firewood and timber.

Notes:

3. Perceptions about rural forests

1) Types of forested areas present on the farm

Notice:

- **Spontaneous identification:** from the information formerly obtained
- **Co-construct typology and definition:** from the spontaneous identification, discuss with the informant the differences between the different types of forested areas in order to reach an agreement on the different type of forested areas and how to distinguish them from one another.

Spontaneous identification	Co-construct typology	Definition / Main characteristics
1-	1-	1-
2-	2-	2-
3-	3-	3-
4-	4-	4-
5-	5-	5-

2) Identification of the main stakeholders, advantages and disadvantages associated with rural forests

Notice:

- **Stakeholders:** Ask the informant for a synthesis of the main stakeholders intervening in the management of rural forests or influencing him/her in the management of rural forests.
- **Advantages:** Ask the informant for a synthesis on the main advantages, benefits and positive outcomes that are important to them associated with rural forests.
- **Disadvantages:** Ask the informant for a synthesis of the main disadvantages, constraints and negative outcomes that are important to them associated with rural forests.

Stakeholders	Advantages	Disadvantages
1-	1-	1-
2-	2-	2-
3-	3-	3-
4-	4-	4-
5-	5-	5-

Notes:

3) Mental model about rural forest management

On stickers, report the following items:

- The different types of forested areas co-construct with the farmer
- The different advantages and disadvantages cited
- The different stakeholders

With the use of the black board, co-construct a mental model with the farmer highlighting the links between: (i) Stakeholders and forested areas; and (ii) forested areas and disadvantages and advantages

Make a final oral synthesis of the mental model and ask for potential missing information or input.

Notes:

4. Use of firewood

No of houses heated with the firewood from the farm: _____ Total no of people : _____

Houses	Heating system	Annual quantity of firewood and other energy sources	% of firewood coming from farm trees and from forests

Main tree species used for firewood:

French name	Local name	Origin (farm tree/forest tree)	Overall quality (from 0 to 10)

Do you sell firewood? ☐ Yes ☐ No

Tree species	Origin (farm tree/forest tree)	Annual quantity sold (m ³)	Price (€/m ³)	Customers (type of people, place of residence)

Supplementary material 3: Multiple Correspondences Analyses (MCA)

This document exposes the main analytical steps followed to conduct MCA on the basis of rural forest positive and negative contributions (FPC and FNC) cited by the 19 farmers of our study.

A total of four MCAs were performed to explore variability in farmers' perceptions. For each MCA, we present (i) the dataset used, (ii) the active and supplementary variables that are considered by the MCA, and (iii) the main results.

Results are presented through a short text and 4 figures:

- The "MCA factor map" is the plot of the farmers in the first two dimensions of the MCA (farmers are colored according to farming systems);
- The "graph of the variables" is the plot of the active variables in the first two dimensions of the MCA and highlights 20 most contributing variables;
- The "Supplementary variables on the MCA factor map" is the circle of correlations between supplementary quantitative variables and the MCA two first dimensions. These variables include (for each farmer) the farm surface area (FarmArea), the number of agricultural blocks (Blocks), the number of woodlots (Woods), the total area of woodlots (WoodArea), the farmers' age (Age), the number of FPCs cited during the interview (PCtot) and the number of FNCs cited during the interview (NCtot);
- The eigenvalue screeplot.

In addition, a table highlights the main contributions and correlations observed in the MCA:

- Individuals with $\text{Cos}^2 > 0.5$, which indicates a significant quality of representation of these individuals in the construction of a given MCA axis;
- Active variables with $\text{eta}^2 > 0.5$, which indicates a significant contribution of these variables in the construction of a given MCA axis; eta^2 represents the square of the correlation ratio between each variable and each axis;
- Supplementary qualitative variables with $\text{eta}^2 > 0.5$, which indicates a significant qualitative correlation between these variables and the corresponding MCA axis;
- Supplementary quantitative variables with $\text{cor} > 0.3$ or $\text{cos} < -3$, which indicates a positive or negative correlation between these variables and the corresponding MCA axis.

Finally, we explain in this document what motivated each MCA. Only the MCA N°4 was presented in the main article as it was considered as the most robust for the following reasons:

- The eigenvalue screeplot shows a net gap after the first two dimensions;
- The analysis is based on a more limited number of variables (due to a low number of observations) than for the other analyses;
- The most rarely cited FPC and FNC are not included to limit issues due to the sensitivity of MCA to rare items.

1. MCA based on all the FPC and FNC cited by farmers

Dataset 1:

A first MCA was performed on the basis of all the FPCs and FNCs cited by farmers. The dataset used was composed with 19 rows (one row for one farmer) considered as 19 observations. Each farmer was characterized by a set of 66 variables, including:

- 57 active variables: these variables corresponded to the 57 FPCs and FNCs identified in this study from the advantages and disadvantages cited by farmers (Table S2 and S3, Suppl. material N°2). For the farmer i and the variable j , the cell $[i,j]$ received the value “1” if the farmer i cited the FPC (or FNC) corresponding to the variable j , and “0” otherwise.
- 9 supplementary variables that corresponded to (i) socio-economic characteristics of the farmer and its farm (farmer’s age and gender, size of the farm, type of farming system, size of the forest estate) and (ii) two quantitative indicators associated with his/her perceptions (the number of FPCs he/she cited during interviews, and the number of FNCs).

MCA N°1 computing:

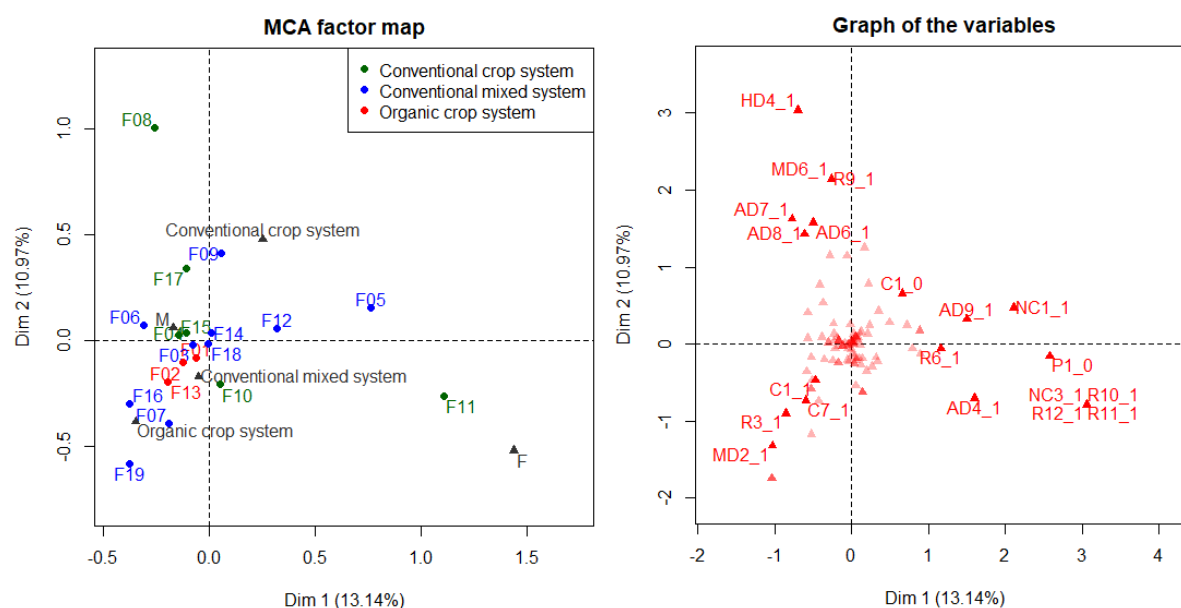
The first MCA was computed on the basis of the 57 active variables. In other words, the MCA studies differences and similarities between farmers only on the basis of the 57 cited FPCs and FNCs.

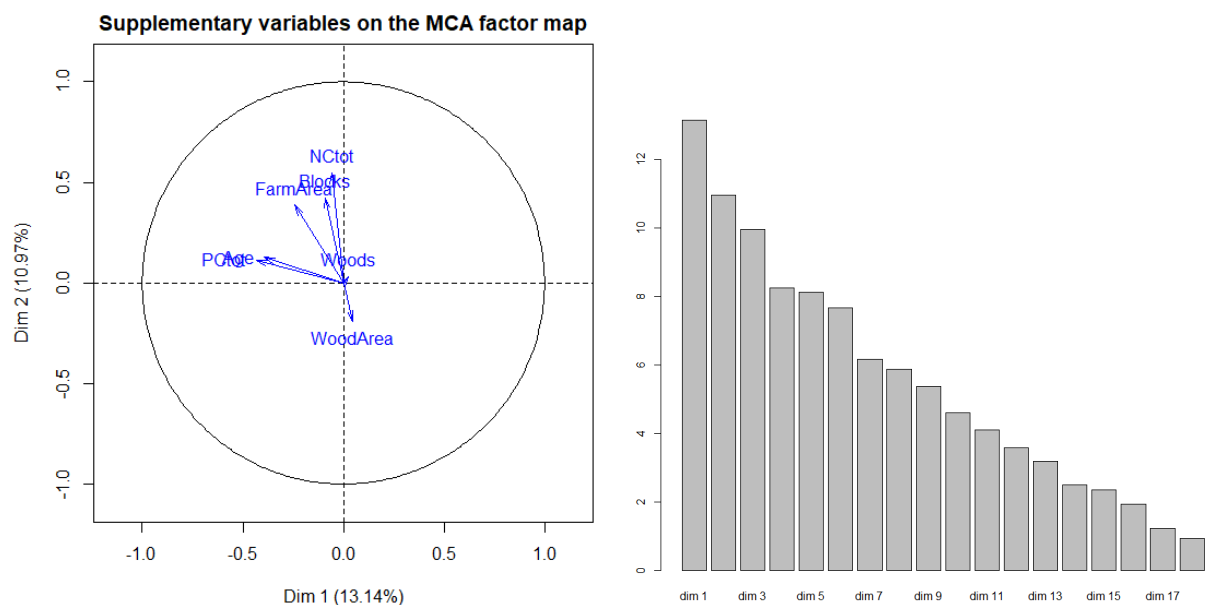
Supplementary variables are used only to study how they correlate with the dimensions of the MCA. Detailed information on the MCA statistical method is available in Husson et al. (2017).

Results of the MCA N°1:

Results are presented in the following figures and table. As expected due to the sensitivity of MCAs to rare items, variability is mostly driven by the FPCs and FNCs that were rarely cited by farmers (such as R10, R11 and NC3 that were each reported by one farmer).

In order to reduce the influence of these rarely cited items, we therefore conducted a second MCA without them.





MCA N°1	Dim 1 (13.14%)		Dim 2 (10.97%)	
Individuals (main contributors)	Id	Cos2	Id	Cos2
	F08	0.612	F08	0.671
Active variables (main contributors)	Id and name	Eta2	Id and name	Eta2
	P1-firewood	0.782	MD6-expensive management	0.541
	R2-oxygen and air quality	0.518	HD4-risk for humans	0.513
	R10-humus production	0.518	R9-slow down water flows	0.541
	R11-soil aeration	0.518		
	NC3-less area eligible to the PAC	0.518		
Supplementary qualitative variables (main correlations)	Name	Eta2	Name	Eta2
	-	-	-	-
Supplementary quantitative variables (main correlations)	Name	Cor	Name	Cor
	No of cited FPC	-0.433	No of blocks	0.424
	Farmer's age	-0.394	Farm area	0.387
			No of cited FNC	0.546

2. MCA based on the FPC and FNC cited by at least two farmers

Dataset 2:

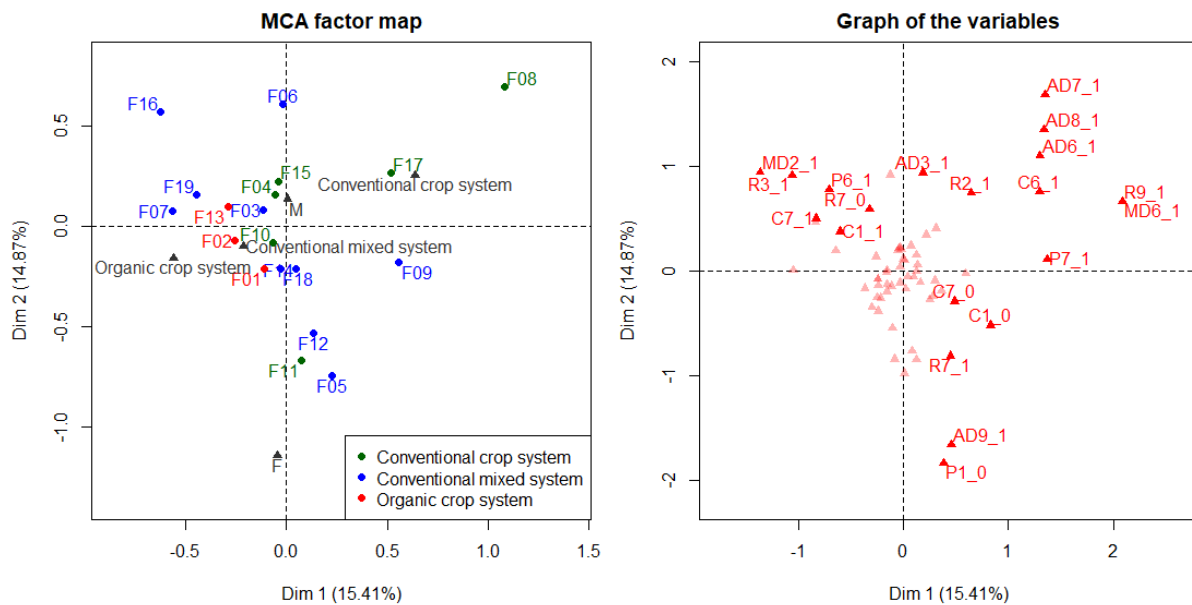
A second MCA was performed on the basis of the FPCs and FNCs cited by at least two farmers. This choice was motivated by the sensitivity of MCAs to rare items highlighted in the first MCA. We therefore chose to remove from the analysis the FPCs and FNCs cited only once, which concerned a total of 12 FPCs and 12 FNCs (see Table 2 in the article). Our new dataset was therefore composed with 19 rows (one row for one farmer) characterized by a set of 42 variables, including:

- 33 active variables: these variables corresponded to the 33 FPCs and FNCs cited by at least two farmers.
- 9 supplementary variables (the same as in Dataset 1)

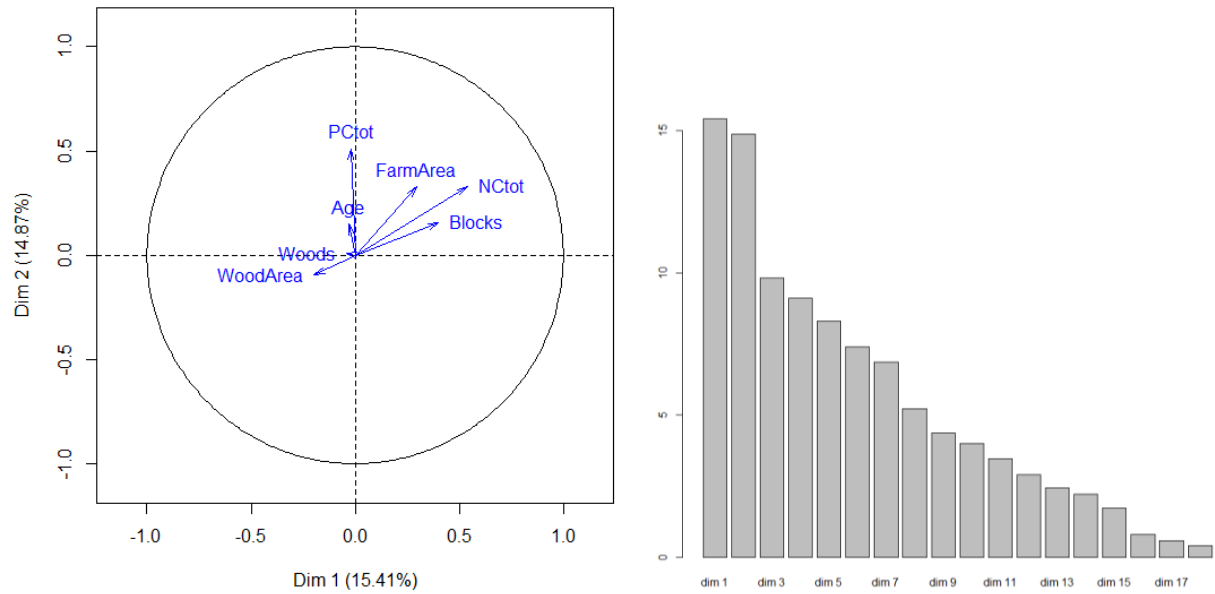
Results of the MCA N°2:

Results are presented in the following figures and table. This analysis showed the contribution of two FPCs (R9 and C1) and two FNCs (MD6 and AD3) in the construction of the two first axes. Similarly, the MCA N°1, MCA N°2 identified F08 as an outlier. Moreover, it also showed the correlation of the size of the farm (No of farm blocks and farm area) and of the total number of cited FNCs and FPCs with the first two dimensions.

These results suggest that farmers with a larger farm (or in a conventional farming system) tended to cite more FNCs than farmers with a smaller farm.



Supplementary variables on the MCA factor map



MCA N°2	Dim 1 (15.41%)		Dim 2 (14.87%)	
Individuals (main contributors)	Id	Cos2	Id	Cos2
	F08	0.579	-	-
Active variables (main contributors)	Id and name	Eta2	Id and name	Eta2
	MD6-expensive management	0.513	AD3-additional workload	0.514
	R9-slow down water flows	0.513		
	C1-landscape scenic	0.501		
Supplementary qualitative variables (main correlations)	Name	Eta2	Name	Eta2
	-	-	-	-
Supplementary quantitative variables (main correlations)	Name	Cor	Name	Cor
	No of blocks	0.400	No of cited FPC	0.511
	No of cited FNC	0.539	No of cited FNC	0.328
			Farm area	0.327

3. MCA based on the classes of FPC and FNC

Because of the low number of observations (19 farmers) compared to the high number of active variables (33 FPCs/FNCs for the MCA N°2), we performed additional MCA on the basis of the classes of FPC and FNC. Indeed, using classes of FPC and FNC instead of FPCs and FNCs themselves allowed reducing the number of variables used to describe farmers from 57 (Dataset 1) to 31 (Dataset 3).

Dataset 3:

A third MCA was performed on the basis of the classes of FPC and FNC associated with farmers' perceived FPCs and FNCs (see Table 2 in the article). The dataset 3 was therefore composed with 19 rows (one row for one farmer) characterized by a set of 40 variables, including:

- 31 active variables: these variables corresponded to the 31 classes of FPC and FNC defined in the Table 2 of the article. For the farmer i and the variable j , the cell $[i,j]$ received the value "1" if the farmer i cited at least one FPC (or FNC) belonging the class corresponding to the variable j , and "0" otherwise.
- 9 supplementary variables (the same as in Datasets 1 and 2)

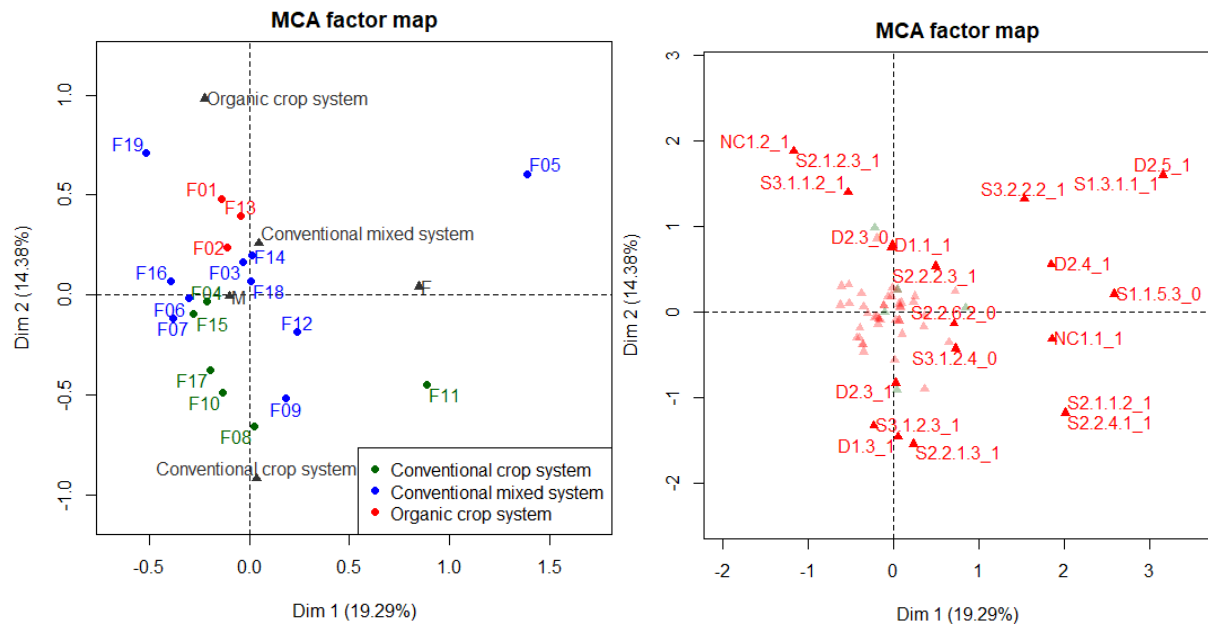
Results of the MCA N°3:

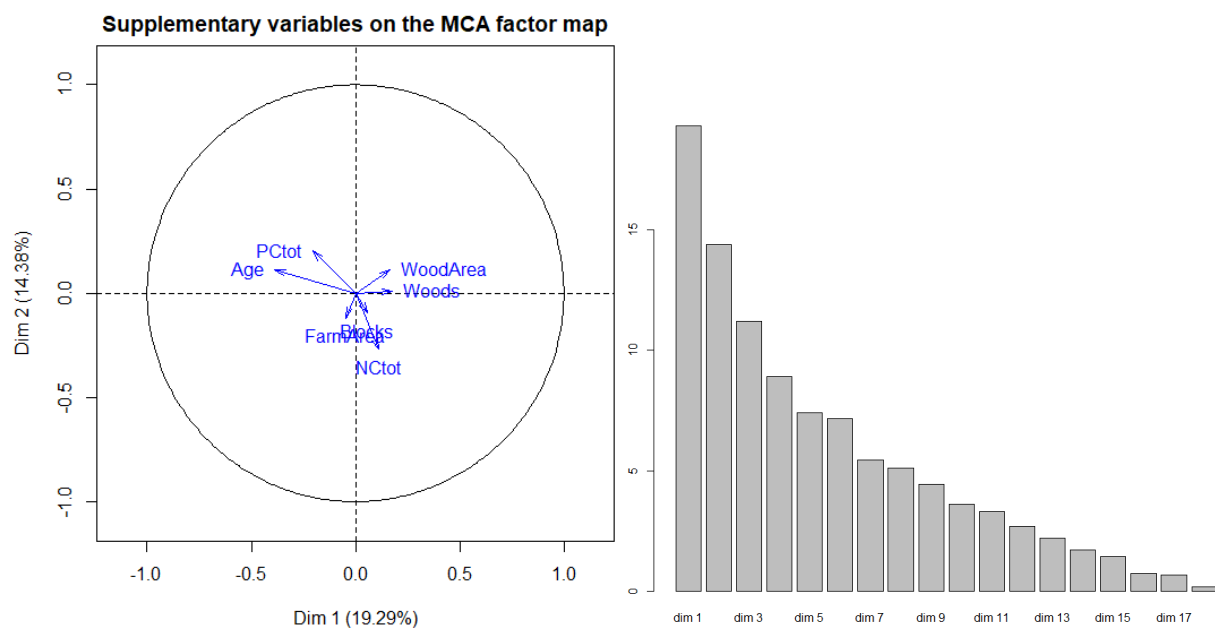
Results are presented in the following figures and table.

F05 was identified as the main contributor of the axis 1.

Main contributing variables to the two first axis were relative to 2 classes of FPC and 3 classes of FNC.

The only supplementary variable that tended to correlate with the MCA axes was the farming system.





MCA N°3	Dim 1 (19.29%)		Dim 2 (14.38%)	
Individuals (main contributors)	Id	Cos2	Id	Cos2
	F05	0.715	-	-
Active variables (main contributors)	Id and name	Eta2	Id and name	Eta2
	D2.5-competition for land	0.554	D2.3-decrease in crop production	0.514
	S1.1.5.3-wild plant for energy	0.787		
	S1.3.1.1-biomass for agriculture	0.554		
	NC1.1-legislative constraints	0.650		
Supplementary qualitative variables (main correlations)	Name	Eta2	Name	Eta2
	-	-	Farming system	0.455
Supplementary quantitative variables (main correlations)	Name	Cor	Name	Cor
	-	-	-	-

4. MCA based on the classes of FPC and FNC cited at least twice

Finally, in order to take into account the sensitivity of MCAs to rare items, we performed a fourth MCA on the basis of the classes of FPC and FNC cited by at least two farmers. This MCA is the one presented in the main article.

Dataset 4:

A fourth MCA was performed on the basis of the classes of FPC and FNC cited by at least two farmers. We removed from the dataset 3 the classes FPC and FNC cited only once, which concerned a total of 6 classes of FPC and FNC (see Table 2 in the article). The dataset 4 was therefore composed with 19 rows (one row for one farmer) characterized by a set of 34 variables, including:

- 25 active variables: these variables corresponded to the 25 classes of FPC and FNC cited by at least two farmers. 9 supplementary variables (the same as in all previous Datasets)

Results of the MCA N°4:

Results of the MCA are presented in the following figures and table, as well as in the main article.

The main observation that contributes to the first axis is F05.

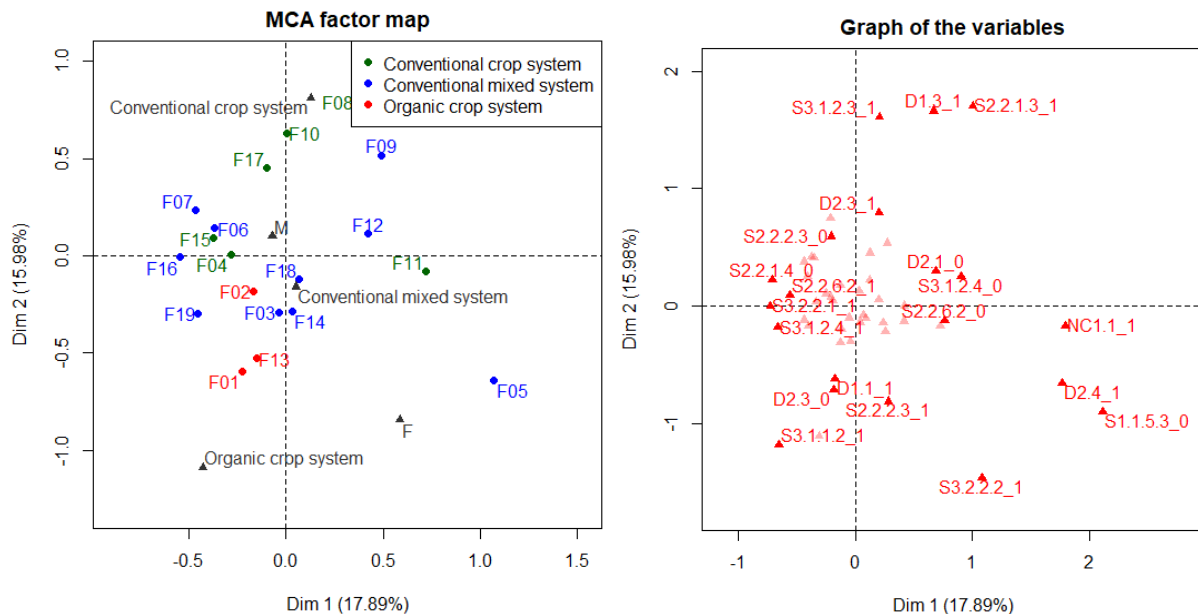
The active variables contributing to the first two dimensions of the MCA are 2 classes of FPC and 3 classes of FNC.

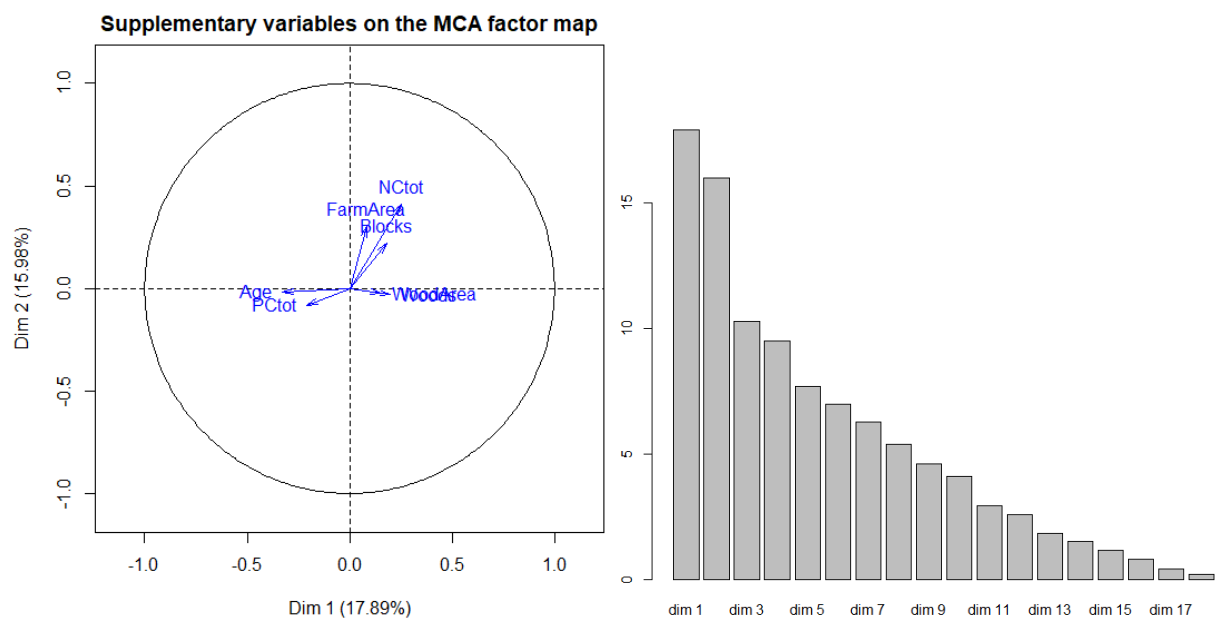
Finally, four supplementary variables tended to correlate with the axes displaying the highest variability observed in farmers' perceptions. Three of these were associated with socio-demographic characteristics (farm area, farming system and farmer's age) while one was the number of FNCs cited during interviews.

Results corroborate previous MCAs and indicate an influence of the farming system and farm area on farmers' perceptions.

References

Husson, F., Lê, S., Pages, J., 2017. FactoMineR: Multivariate Exploratory Data Analysis and Data Mining.





MCA N°4	Dim 1 (17.89%)		Dim 2 (15.98%)	
Individuals (main contributors)	Id	Cos2	Id	Cos2
	F05	0.609	-	-
Active variables (main contributors)	Id and name	Eta2	Id and name	Eta2
	S1.1.5.3-wild plant for energy	0.527	D2.3-decrease in crop production	0.570
	S3.1.2.4-aesthetic experiences	0.596	D1.3-economic costs	0.517
	NC1.1-legislative constraints	0.607		
Supplementary qualitative variables (main correlations)	Name	Eta2	Name	Eta2
	-	-	Farming system	0.408
Supplementary quantitative variables (main correlations)	Name	Cor	Name	Cor
	Farmer's age	-0.327	Farm area	0.302
			No of cited FNC	0.411