Combinations of productive and environmental functions in a farmland area: synergies and antagonisms: Method of analysis and application in a small area in a mixed crop-livestock farming area in France

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Summary

For some years now, in response to new social demands, agricultural policies have recognised and tended to favour the environmental and social functions of agriculture, and more generally, the multifunctional nature of farmland use. The complete evaluation of the situations and results obtained is still difficult, particularly in view of the complexity of the interactions between functions and their varied and delayed impact on the environment. This situation has prompted research and led to the development of new methods to analyse farming practices and systems. The work presented in this paper contributes to this effort and is in two parts: 1) the construction of a framework for the analysis of the relationships between environmental functions and agricultural production at area scale, and 2) the application of this framework and the proposal of a preliminary diagnosis concerning synergies and antagonisms between functions from an empirical study in a small mixed crop-livestock farming area. The first part of this work enabled us to define various concepts used in the field of multifunctionality and devise a method for characterising them: "function", "productive function", "achievement of a function", "achievement of a combination of functions", "farmland area", etc. The second part is an application of this analytical framework to a 350 ha area of continuous farmland characterised by a diversity of environment, uses and users. Two environmental functions (preservation of surface water quality and landscape diversity) and their interaction with the productive function are singled out. We show that plots of land that display synergies and antagonisms between productive and environmental functions are often located close to one another in the farms and farmlands concerned. Antagonisms are much more common on large farms and in some areas made sensitive by their geographical features (areas near watercourses or on hillsides). Synergies occur in farms that are often given little consideration in development and planning policies because of their low spatial and economic importance. Our findings argue for using different modes of intervention for different areas and for different farms. We also outline methodological perspectives for simplifying diagnosis.

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Context

The environmental expectations for areas used for agricultural production are greater than ever. Since the nineties, public policy has been taking these new social demands increasingly into account. Agricultural multifunctionality was a declared objective of the 1999 French agricultural planning act. It is also foreshadowed in the work of the European Commission on the next Common Agricultural Policy (CAP) (E.U., 2003). The different attributes that are felt to be desirable for farmland are increasing in number, with broadly diverse individual or regional variations; these attributes involve multiple items (e.g., plots, hedges, paths) that are sometimes interconnected. Despite research and methodological progress in this field (Beuret and Mouchet, 2000; Hayo and al., 2002; Hervieu, 2002; Véron, 2003), overall appraisal of multifunctionality (both quantitative and qualitative) is still difficult to carry out, especially because of the complexity of the interactions between productive and environmental functions, and the widely varied and sometimes delayed effects they exert on the environment through their aesthetic, ecological and agronomic consequences (Boiffin, 2001). For example, how do we measure and compare agricultural multifunctionality in hedged and non-hedged land environments? How do we measure and compare the efficiency of certain modes of agricultural management, while taking into consideration the state and specific interactions of landscape, ecological and productive functions in these environments?

Agricultural entities (farm areas, buildings, etc.) that can support attributes valued by society may undergo modifications due to farming practices, and interact among themselves; these interactions then generate antagonisms or synergies between productive and environmental functions within a given area. However, adjustment or changes in farming practices in an area is currently one of the ways most often advocated for improving agricultural multifunctionality, even though the relations between farming practices and multifunctionality are not yet fully known and understood.

This situation makes necessary new tools and methods of analysis of farming practices and systems. First, the agronomic approach must cover areas larger than a plot of land or a pattern of fields. The whole farmland area farmed by several operators in an area must be taken into account to assess the environmental effects of farming practices more accurately (Benoit and Papy, 1998; Boiffin, 2001; Sébilotte, 2002). Second, to promote multifunctionality of agriculture and farmlands without increasing agricultural production and support costs, it is essential to improve evaluation of and allowance for the effects of synergies and antagonisms between environmental services and agricultural production at area scale (Mahé, 2001). Thorough analysis and justification of these processes is also necessary now that the economic relevance of multifunctionality is being challenged by some countries for the renegotiation of the organisation of world markets in agriculture in 2003 (OECD, 2001; Dron, 2001).

Problem

The aim of our work is to analyse how the nature and spatial implications of farming practices facilitate synergies and antagonisms between environmental functions and agricultural production at area scale (Rapey and al., 2003).

To improve the efficacy of farmers interventions from a multifunctional point of view, different options are possible: - set out achievement of several functions on the same entity or separately on neighbouring entities? - undertake action at plot level, farm level, or over whole area. It is necessary first to have a method that defines, describes, and links characteristics of environmental and productive functions.

What are the support entities and conditions of achievement of each function? How to evaluate their level of achievement and how favourable the impact of farming practices is on each function (criteria and relevant scales of analysis)? How to characterise globally the effects of farming practices on production, water quality and landscape, for example?

Our work is accordingly in two parts:

- development of a framework for the analysis of relations between environmental functions and agricultural production at an area scale.
- application of this framework and the proposal of a preliminary diagnosis on synergies and antagonisms between functions from an empirical study in a small mixed crop-livestock farming area.

In what follows, we report methodological and analytical results from our work on the multifunctionality of farming areas.

Method

Definition of an analytical framework

Before characterising the farmland functions and their achievement, a clear meaning had to be assigned to these two concepts of "function" and "achievement of a function", as the literature showed unclear definitions varying from one author to another.

We specified a function is what must be accomplished by a farming entity to meet a user's expectation. This definition incorporates three key concepts:

- an entity that undergoes modifications as a result of interactions between farming practices and farm environments (e.g., a hedge maintained by a farmer, a plot fertilized , a co-operative delivered by a farmer).
- an explicit expectation concerning this entity, either expressed by people who share that expectation (often for some precise activity area, expressing a "local" expectation), or embodied in regulations ("global" expectations provided for in a law, a charter, etc.).
- a farmland user who uses this area not necessarily entailing farming practices with a view to claiming for himself an economic, recreational or patrimony benefit (e.g., a wet grassland orchid specialist, an soil-less livestock farmer, a livestock trader with animals out to grass over the summer, etc.).

From this definition, we consider that, for the support entity of a function, the level of achievement of the function depends on how fully the user's expectations are met. It can be evaluated either directly in retrospect by a user surveys, or indirectly beforehand by observations on the support entity, compared with known characteristics for conditions favourable to the achievement of the function. The first type of approach requires competences in sociology or psychology; the second mostly competences in ecology, agronomy or animal production. In this second case, we evaluate a capacity of achievement of the function rather than a real achievement level (because "favourable" conditions do not automatically lead to a "favourable" result that will satisfy the user, but simply indicate that this result is more probable).

Farmland, by which we mean a continuous area of land on which different operators are applying farming practices (for profit or for other purposes), is one of the supports that allows the observation of the capacity of achievement of various functions in relation with farming practices and diverse agricultural environment. Farmland is not the sole exclusive support (example of other possible supports: social or commercial networks of farmers); however, it offers a wealth of readily accessible information and variation, which enabled us to address the question of combinations of agricultural functions rapidly and significantly. We thus focused on the spatial component of the multifunctionality of agriculture, which represents only a small part of the multifunctionality of agriculture and rural areas. We could, for example, have designed and extended the approach to cover combinations of "socio-economics networks" functions, the support entities of which are not permanently locatable within the area studied, but which undergo socio-economic transformations induced by individual practices within the area (not necessarily related to agronomic practices).

The productive function of farmland for a farmer has a special status as regards the multifunctionality of agriculture. The user-farmer occupies both a supply and a demand position as regards production expectation: he both formulates an expectation and seeks to respond to it by his farming practices. His formulation of his expectation and the practices he adopts strongly incorporate the characteristics of his objectives and his economic, technical, soil and climatic constraints. He strives for the best possible fit between his expectation and the achievement of this function (Capillon and Sébillote, 1980). Consequently, there is no greater or weaker capacity of achievement of the expectation by the support entity, but rather a way in which this function can be achieved. It responds in a localised manner to the farmer's goals and constraints. It can be termed a "function for production". This concept of "function for production" we introduce here is quite similar to those of "surface function", "land use", or "plot function" defined respectively by Guerin (1990), Bellon (1992) and Fleury (1995). In complement to these authors, we also separately consider farmland areas outside the forage system that play some role in the farming system (for example: cash-crop cereals plots, family leisure parks, etc.).

These different points make it possible to differentiate the capacities for the achievement of a combination of functions concerning plots or groups of plots; it is thereby possible to define areas that are relatively homogeneous in fulfilling the expectations of farmland users. This helps to identify and understand how different areas and farms variously contribute to the multifunctionality of agriculture.

Applying this framework to the analysis of interactions between agricultural functions

The use of the above analytical framework requires some preliminary considerations to specify the forms and spatial entities of the farmland area multifunctionality . It is especially important to:

- define the boundaries of the land and farms studied, based on a prior diagnosis of multifunctionality within an agricultural region (diversity of nature and localisation of expectations);
- define common predominant functions of the land (expectations, users and support entities concerned);
- identify available information, and what remains to be collected, on targeted functions.

Definition of land and farms taken into account

To study a diversity of multifunctionality forms stemming from a variety of environments, farmers and farmland uses, we opted to study a small area that was transitional, both geographically (between granitic uplands and clay soil lowlands) and agriculturally (between stock farming and cereal-growing regions); it was an area of land located in a single local administrative area forming a vast north-facing terrace, bordered to the East and West by a watercourse and to the south by woodland. It comprised 350 ha of continuous farmland composed of 239 plots and 36 farmland users.

The farmland users had various production activities of wide-ranging nature and scale, with or without a commercial purpose: they ranged from the full-time farmer with 200 ha of crops and grasslands (in and outside the land area being studied), to the town dweller with a horse on 1 ha. Given the numerical importance of "amenity" users in the studied area (about one quarter of the total), we integrated these and met all of them for our study. All are referred to as "farmers" operating on "farmland".

Definition of predominant functions for the studied area

First of all, to restrict the field of investigation to a suitably small number of interacting functions, we made a rapid review of "local" expectations concerning agriculture (expressed in a meeting with members of the local council), and of "global" expectations (stated in regulations applicable to the area). The preservation of the quality of surface water and landscape diversity were the two environmental functions selected, accompanied by the "classical" agricultural function, i.e., the production of market food produce. Next, environmental conditions and practices that would favour the achievement of the two environmental functions to varying degrees were identified from the literature and meetings held with "experts". These conditions were then reformulated to make them applicable to the studied area on the basis of available or easily collected data for the farm plots (ground maps and farm surveys). We thus specified three degrees of capacity of achievement of each environmental function for the studied area– weak, medium, and strong - (see Table 1).

Table 1. Example of criteria used to define the achievement capacity of environmental functions for the function "water" (N.B. if environment and practices are favourable, then capacity is strong)

Conditions for the achievement of a function ("water"):	Significant characteristics of the farmland plot and practices for this function:	Capacity of achievement of this function:
Unfavourable environment / Water *(= vulnerability of the environment)*	•Proximity to watercourses(< 35 m)	⇨If practices unfavourable: weak capacity ⇨If practices favourable: medium capacity
Unfavourable practices/Water *(=aggressive nature of practices[1])*	•High[2] Surplus of N according to apparent balance figures •High[2] Surplus of P_2O_5 according to apparent balance figures •High number [2] of pesticides treatments at certified doses ➔ Unfavourable when at least one of these criteria is met	⇨If environment unfavourable : weak capacity ⇨If environment favourable: medium capacity

The various modes of achievement of the productive function of each plot (defined earlier as "functions for production"), were differentiated according to the use of vegetal product expressed by the farmer during the survey, this use being considered here as significant in defining the function of the plot in the farming system:

- standing forage(A), conserved forage (B), mixed forage -A and B- (C)
- animal confinement (D) (night, winter and control paddocks, etc.)
- cereals and forage sale (E)
- fallow land(F)
- family amenities (G) (garden, vineyard, orchard, animal leisure park, etc.)

1 For plots of land located in permanent grasslands, only exercise areas and night paddocks for animals were rated as using unfavourable practices. For temporary grasslands and crop growing, three characteristics were used and are set out in the table.

2 Relative to all values observed in each plot in the area.

- no use (H).

This nomenclature allows spatial differences of expectations and practices of farmers within farms to be taken into account, so as to provide a farming system that will locally fit the aims and constraints of each farmer.

The contribution of these eight functions to agricultural production is direct and specific to varying extents according to the case. We can define four categories:

- functions that play no part in the production system (G and H).
- functions that play a part in the system but not necessarily in production (D and F).
- functions that necessarily play a part in the production system but with no particular requirement for animals (E)
- functions that play a part in the production system with special requirement for animal production (A, B, C).

Grouping them in four categories makes it possible to characterise farms and areas globally from a production point of view; they are useful in the analysis of particularly diversified areas or farms.

<u>Information used</u>

The main part of information concerning the physical environment was extracted from ground maps (IGN, 1993) and aerial photographs (IGN, 1999). Information was précised locally by "experts" and from observations in the field. These data were digitised and integrated into a spatial database set up for the purposes of the study (Matter, 2002).

Concerning uses and users of the studied area, a preliminary localisation on a map by the mayor, himself a farmer, was necessary. All selected farmers using more than one hectare were surveyed (Fiorelli, 2002). Questions were linked to the global management of the farm and to practices localised on each plot used in the studied area. As the individuals and farming structures studied were varied and quite often outside the scope of the standard definition of farming, some “classical” technical parameters were found to be irrelevant or unimportant for many users (especially “amenity” users); during the analysis, the overall comparison of farms was not always possible and required the setting-up of sub-groups studied more individually from the point of view of certain specific characteristics. As much information as possible was entered in the spatial database to help to identify the mode, influencing factors and spatial organisation of agricultural functions and combinations of functions (Fiorelli, 2002; Klingelschmidt, 2003).

The methodological approach described here thus attaches great importance to defining the concepts necessary for the analysis of multifunctionality. Specific relations between agriculture and its functions and the area [area being a support, a factor and a product, and being subject to internal and external interactions (Lardon and al., 2001)] very strongly influence the approach and the issues developed here concerning multifunctionality: the taking into account of a continuous area of land and all its users, surveys and analyses of spatial characteristics, etc. The application and results obtained are not limited to the analysis of spatial effects; they help to define determining factors of multifunctionality at plot, farm or area scale. The key points are developed below.

Results

A part of the results obtained concerns the productive functions of the farmland: their role in the production system, their distribution, their variability, etc. It was only subsequently that the different specifications of these productive functions were linked to the characteristics of two environmental functions studied in the same area.

Diversity of farmland area functions for production in relation to the spatial structure of farms

Over both the whole land area studied, and the area used by each farm within this land area, we noted broad diversity in functions for production.

Each of these eight previously defined "functions for production" covered 2% to 30% of the area studied (out of a total of 325 ha) and 11% to 42% of users present (out of the 26 questioned). The most widely represented function was the "mixed" mode (C) (98 ha, 11 users), and the least "animal confinement" (D) (6 ha, 4 users).

Globally, for each of these four categories of contribution to agricultural production, we found: 10% of the farmland played no part in the production system (amenity use + no use = G + H), 5% played a part in the system but not necessarily in production (confinement + fallow = D + F), 20% played a part in the production system but with no particular requirement for animal production (crop sale = E), and 65% participated in the system with special requirement for animal production (standing and/or conserved forage = A + B + C). The analysis of these categories brought out similarities between certain farms[3].

A group of two farms presented only "crop sale" and "fallow" functions in the area ; their farm- stead is inside the studied area, but most of their land lay outside this area (an average of 63 ha per farm, with 64% outside the area). Farm activity did not account for most of their income (one part-time farmer, one retired). This formed a small group of "small-sized, multi-activity, local[4] cereal farmers".

Another group of four farms in the area covered a large part of the land area with requirements for animal production (standing and/or conserved forage), on a total of 159 ha, and with a small proportion of land area for cash crops. These were full-time livestock farmers working on medium-sized structures (71 to 94 ha) of which barely one half was located within the area. We called this group "medium-sized local crop-livestock farmers".

The most popular group (10 farms, 93 ha in the area) was of farms for which the land within the area was solely dedicated to production for animals. We could identify two sub-groups: (i) farms with land for cash crops outside the area of study and whose farm-stead was often located outside the local administrative area, and which had large areas (118 to 200 ha), and (ii) farms with no area for cash crops, of medium or small-sized overall area (9 to 98 ha), with their farm-stead within the local administrative area, and plots of a small size on average (less than 1 ha). We differentiated, therefore, between "outside livestock farmers operating on large structures", and "local livestock farmers operating on medium-to-small structures".

The last group represented a large group of farmers for a very small proportion of the area (9 farms, 26 ha); these belonged essentially to retired land users and those who used the land for pleasure pursuits,

3 One farm that had only fallow land within the area studied could not be integrated in the groups and was excluded from the analysis.

4 From the point of view of the farm-stead.

living within the local administrative area. In most cases, all their land was within the area, with small plots, and was not contributing to a production system. We called this group "local and amenities users".

The characteristics of these groups showed that it exists relations between functions for production in a given area and the spatial structure of the farms (size and grouping of land in an area and, in particular, close to the farm-stead). This implies that the functions for production within an area take modes that vary to different extents according to the diversity of the farms there and according to the varied localisation of their land areas. It must be noted that neighbourhood users (whose farm-stead is within the administrative area) had particularly diversified and extended uses (242 ha out of 326), while remote users had relatively similar productive uses ("feeding animals" on a total area of 84 ha); the neighbourhood users will therefore be especially important in the diversity of functions for production in a farmland area.

Continuing the analysis of the spatial structure of the farms, we also noted that the percentage of hillside land, small plots, and land close to villages over the area studied, were different in each group: "local cereal farmers" had most of their land located in the flat north-west of the area and combined the use of small and large plots. The "livestock-crop farmers" and "outside livestock farmers", had mainly large plots spread over the entire lowland area and in the valleys. The "local livestock farmers" had small plots of land on the eastern half, in small valleys, and lastly, "local and amenities users" mostly had small plots of land located close to villages.

These preliminary results indicate a wide-ranging degree of variability of functions for production over the whole farmland area, according to the farms and their spatial organisation. It is probable that the achievement of environmental functions and practices-environment relations vary according to the same criteria. We went on to deal with this point in more depth.

Diversity of environmental functions achievements in relation to functions for production

Each of these four categories of functions for production (defined earlier) presented combinations of strong and weak achievement capacities, for the two environmental functions studied. Two categories most often had combinations of strong achievement capacities (see Table 2).

Table 2: Different capacity combinations of environmental functions for each of the four categories of functions for production (NB: the percentages that differed most from average percentages measured in the studied area are in bold print)

Categories of functions for production: / Environmental functions:		Cash crop (E)	Standing and/or conserved forage (A, B, C)	Fallow+ Confinement (D, F)	Amenity+ No use (G, H)	Total
Weak capacities combinations [5]	area	17 ha	24 ha	6 ha	2 ha	49 ha
	% area	**26%**	11%	**39%**	**5%**	15%
Medium capacities combinations[6]	area	18 ha	91 ha	2 ha	15 ha	126 ha
	% area	**27%**	44%	**15%**	46%	39%
Strong capacities combinations[7]	area	31 ha	96 ha	7 ha	16 ha	150 ha
	% area	47%	45%	46%	49%	46%
Total area / % total area		66 ha / 20%	211 ha / 65%	15 ha / 5%	32 ha / 10%	324 ha

[5] = weak capacity of achievement for at least one of the two functions: "water" or "landscape", whatever the capacity of achievement of the other function.

[6] = medium capacities of achievement of the two functions: "water" or "landscape".

[7] = strong capacity of achievement of at least one of the two functions: "water" or "landscape", the other function having a strong or medium capacity.

Comparing the groups of farms, we note that they all also integrate both strong and weak capacities combinations for the two environmental functions studied. The groups of "outside livestock farmers", "local livestock farmers", and «local and amenity users» were differentiated by less often having weak capacities combinations than "local cereal farmers" and "local livestock - crop farmers" (between 1% and 5% of the area used for the first three groups, between 21% and 28% for the last two).

At this level of analysis, in spite of the differences found, it was difficult to conclude on what types of farms or functions for production would be most favourable for the achievement of the two environmental functions studied.

We therefore continued our analysis, focusing on the characteristics of land areas with a weak capacity for at least one of the two environmental functions (15% of the area studied, corresponding to 11% of "weak" areas for the "water" function and 4% for the "landscape" function); this brought out relatively well the group of farms and the categories of functions for production. We found either confinement paddocks and cash crop areas (D and E) near a watercourse ("unfavourable condition for water"), or forage areas ("standing and/or conserved forage" = A, B, C) on visible hillsides ("unfavourable condition for the landscape"). In these different plots, the function for production corresponded to what we observed on the other plots of the farm, but in an environment that was especially sensitive in terms of water quality or landscape (proximity to a watercourse, visible hillside). Nearly all these plots were larger than one hectare and were found in medium-sized to large-sized farms run with commercial aims. Given the above findings, it is probable that globally, the larger livestock farming structures and crop-livestock farming together with cereal farms occupy greater areas of land in sensitive areas, with hillside grasslands or cultivated surfaces in lowlands crossed by watercourses, owing to their localisation and surface area. The smaller structures (operated with or without a commercial aim), while presenting relatively strong capacities of achievement of environmental functions, can play a non-negligible role as they use very specific and "sensitive" plots on steep hillsides (statistically significant difference) or of small size.

Plots that support synergies and antagonisms between productive and environmental functions are, therefore, often located close together within farms and farmland; this does not favour a simplification of intervention procedures and indeed argues for their differentiation. The most difficult problems to solve due to antagonisms were more usual here in large farms and in a few sensitive zones due to geographical characteristics (areas close to a watercourse or hillsides). Situations where synergies are exercised occur in farms often given little consideration in development and planning policies because of their low economic and spatial importance.

Conclusion and discussion

The method implemented may seem relatively cumbersome, and as it is restricted to small areas of land and to spatial factors, it may, overall, appear of low operational value.

However, viewed differently, this procedure can be seen to present two "innovations" that are important for the analysis of multifunctionality and its determinants: it takes into account a continuous area of land and all its users, and it takes into account, simultaneously, various functions relating to farmland, in particular productive and environmental functions. Hence the procedure generates useful conclusions on relations and possibilities of combining these functions. It further makes it possible to differentiate the types of contribution that farms make to the multifunctionality of the agriculture in an area, and to differentiate the links between productive and environmental functions. On the area studied, for example, the large livestock structures, livestock-crop and cereal farms presented a much broader range of variation in the achievement of environmental functions, linked to the diversity of the forms of their productive functions and their environment, than did local livestock farmers and local users. The jointure between environmental and productive functions was more marked and more variable for the first three types of farming systems. We deduce from this that in order to act on this jointure and favour multifunctionality, the instruments of intervention for these three types need to be different from those used for the other two: the first three types of farms, which are the most closely market-driven, require targeted action on the area, while the last two, on the market fringe, require global action at the farm level in its whole. To progress in the transfer and application of the method to other larger farmland areas, a number of possible directions can be followed. From our exploratory approach, identification and localisation of production and environmental functions do not seem to require exhaustive surveys on farms; local panels and some surveys conducted in sampled farms, together with the study of maps and aerial photographs are probably sufficient. These simplifications still need development and specific research.

In the preliminary work reported here, we see that multifunctionality modifies the approach to farming activity, whether viewed from a political or a scientific standpoint. The acquisition of knowledge and the "efficacy" of this concept are, therefore, heavily dependent on methodological research in this field, justifying further work towards improving the applicability of our methods and analysis to other scales, more functions, and other agricultural contexts.

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