MIXED CROP LIVESTOCK FARMING INCORPORATING AGROFORESTRY ORCHARDS FACING THE NEW CAP

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ABSTRACT

In the context of the new CAP, decoupling subsidies from production should incite farmers to reorganize their production systems, particularly through diversification opportunities. In this paper we focus our analysis on the conditions that could permit the development of extensive orchards by modelling mixed crop livestock farms, which incorporate orchards. A mathematical programming model is built to simulate various intensification levels characterizing different technical pathways within the different farm activities (cattle breeding, forage fields, arboriculture). This model also enables us to take into account some environmental indicators related to these pathways. Moreover, the method illustrates technical complementarities existing within the diversified systems, thanks to the joint production phenomena introduced into our analysis. We show how these complementarities can be integrated into the farmer's decision criteria.

KEY WORDS: decoupling - diversification – agroforesty orchards - joint production – mathematical programming

JEL classification : C61-D24-Q12-Q21

Introduction

The new CAP reform introduced in June 2003 establishes the decoupling of first pillar support, the modulation of supports beyond a certain threshold, and conditionality measures to receive the totality of these supports This exposes farmers to greater dependence on market conditions. The reform must nevertheless offer the possibility, within the 2nd pillar disposals, of upgrading multi-functional production commodities more than in the past. In this context, the subject of this paper is to question the possible evolution of diversified crop-livestock farms incorporating agroforestry orchards. These farms have a certain advantage to comply with the legal obligations of the first pillar conditionality and could engage their production practices beyond those standards in order to receive 2nd pillar subsidies. These production systems, also called "eco-orchards" involve fruit trees planted in grasslands of dairy farms or in areas located near farm buildings.

With the intensification of agricultural methods over the last 50 years, such systems have to a large extent disappeared, and been replaced by intensive, specialized orchards, incompatible with afforestation and hedgerow intercropping (Codron and al., 2003). Moving from HS varieties to SS management facilitates harvesting. Added to this is the impossibility of receiving direct payments from the Common Market Organisations for arable crops on partially wooded parcels (According to the National Area Survey called "TERUTI", in 2000, the orchard agroforestery area in France is as high as 151 000 hectares).

Our hypothesis is that the biological complexity of production systems integrating agroforestry orchards is profitable, both economically and environmentally, and thus contributes to agricultural sustainability. The source of sustainability lies in the existence of joint production. The jointness may have several sources in agriculture. According to D. Zilberman, two sources of technical jointness can be distinguished: input and output jointness (Zilberman, 2002). *Output jointness* occurs when two or more commodities are produced simultaneously through the same process, but without the possibility of obtaining them separately, for example the wood and fruit harvested. In this case it is impossible to specify which part of the factors is brought into play for each commodity. Due to the type of jointness, the farmer's decisions cannot modify the number of commodities produced. However, the proportion of each commodity may be variable depending on the technical path and economic parameters (input and output prices). *Input jointness occurs in two cases*: First when two or more commodities are produced by processing at least one non-allocatable common input. For example, in agroforestry orchards, the organic fertilizer is a non-allocatable input combined in the growth process of both grass and trees. This information depends on available knowledge about the production process. The second case of input jointness, called negative jointness, is extensively depicted in the OECD analytical workshop on multifonctionnality (OECD, 2001)[1]. In the case of a limited common input, whether allocatable or not, the marginal production of a commodity decreases the production of the other commodity. For example, the amount of land is a limiting factor when producing beef and fruit trees. This last type of jointness is useful, because it enables us to determine the limits of diversification[2]. In addition we consider that inputs and outputs may be market or non-market categories since the market/non-market distinction is not rigid, because technical developments, and more generally the development of scarcity in the economy may induce factors mobility from non-market to market domain (Kasper, Streit, 1999). Here we will explore, on the one hand, the possibilities for commodity transformation (through complementarity and substitution between two sets of commodities), and therefore the diversification of the farm production system. On the other hand, we will include joint products in this transformation set through the combination of farmer's activities. These joint products come from the three sources of jointness mentioned above which may or may not exist simultaneously.

In mixed crop livestock agroforestry systems diversification means: 1st: to produce several types of commodities and more than in the past. 2nd: by increasing the number of commodities produced, the links between the activities of the farm are also increased. For example, the link between dairy and fruit production lies in the potential use of animal manure as fertilizer in agroforestry orchards. 3rd: such multi-production makes it possible to identify conventional economic commodities, as well as new material or non-material benefits (Bonnieux, Vermersch, 1999, Mollard, 2003). For example, limiting the use of chemical fertilizers can protect water resources. These new production possibilities for commodities and services either directly evaluated by the market or reflecting a collective demand as public goods, require that the farm management reference model be broadened.

The aim of this paper is to propose an input-output approach in order to assess the productivity of such systems where the role of jointness is central in the diversification process. In most economic studies dealing with productivity assessment, the debate concentrates on which functional form of production function is best suited for use in econometric studies. Generally in those models the consideration for ecological or environmental elements is marginal. The classical approach of marginal productivity assessment focuses on variation in only one or two inputs *ceteris paribus* (see Khanna and al., 2002, Peterson and Boisvert, 2001 for examples). But inputs generally interact and are fine-tuned to each other, which means that, technically, it is not realistic to study the effects of a change in only one input. The efficiency of this input would be very low if the levels of other inputs are not adapted (Koeijer and al., 1999). A model for valuing the productivity of mixed crop livestock farms with agroforestry orchards must depict those interactions between inputs and outputs and must also enable a comparison between future alternative practices, not only between "historical" practices.

[1] The OECD distinguishes strong and weak types of jointness: Strong input jointness relies on *technical interdependencies* setting relationships between products. This modifies the nature of these products and involves a reassessment of labour and farming (development of mixed crop-livestock breeding which takes advantage of economies of scale). Farmers may or may not decide to use these types of jointness, depending on the degree of modification of practices required. Weak jointness is resulting from the mobilisation of a common limited input such as labour or land, because these two commodities can be produced independently of each other and are therefore not very "dependent" on each other.

[2] See the notion of production possibilities block

One has to consider also that, in the new policy context, the driving force of technology change is evolving from a single-productive objective to a multiple-objective, including also environmental and ecological subjects.

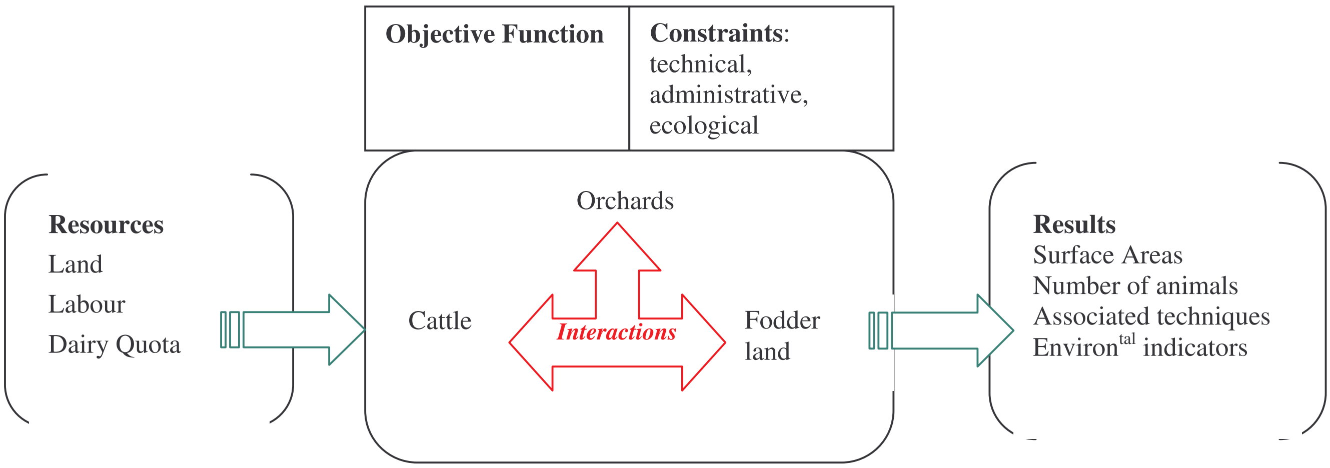
All these elements are considered in the philosophy of the *generalized joint production model* (Koeijer and al., 1999). This is a multidisciplinary approach which incorporates input-output interactions: good (desired) and bad (undesired) outputs can both be produced in variable proportions and technical adjustment can be processed to reduce bad outputs and enhance good outputs. Here is proposed a simplified shape of this model, built with mathematical programming techniques (Ducros 2003). A mathematical programming (MP) model can take into account, in the constraints, not only input interactions and the possible future combinations between inputs resulting in new outputs, but also, in the objective function, multi-objective decisions. The model represents individual typical farms, rather than on an aggregated sector (Ridier, Jacquet 2002). However this approach can be a preliminary step for a possible assessment of the sector supply since the farm modelling level is relevant to grasp the current agricultural policy incentive structure (incentives related to new environmental and regulatory constraints in general). Moreover the new CAP policies aim at modifying the technical pathways themselves. Therefore it is necessary to estimate, as accurately as possible, the feasible adaptations of the production systems (Flichman, Jacquet, 2003). This MP model explicitly depicts the links between the various product flows within agroforestry orchards and other possible activities on the farm (beef breeding, commodities processing). As far as we are concerned with the impacts on the natural environment, we consider a set, as broad as possible, of physical flows produced by some activities on the farm and beyond the farm, to include environmental elements (for example nitrogen residues). These flows can be attributed a positive or negative value through the economic or social system. We will thus integrate joint production phenomena into the multi-product model. Through this analysis of jointness, the approach to the productive transformation process in agriculture will be slightly enlarged (Grimal, Képhaliacos, 2000). We propose here to sketch out such an enlargement as a first step towards a more realistic design of the farm in its natural environment.

1- The model

The model concerns a dairy cattle farm in a steady step of its life cycle. The mathematical programming model has three main activities: breeding dairy cattle, forage (grasslands and cereals) and apples. The farm contains both small-stem (SS) and high-stem (HS) orchards planted in some grassland areas (agroforestry orchards as one can observe them in Normandy). Both activities are competing in the model, according to economic and technical data and constraints. As said before, particular attention is paid to internal exchanges and links between these activities resulting from jointness. Given a system of input prices and products, limited land resources, labour, dairy quotas, and technology, the model proposes an allocation of land areas, a choice of production techniques and an environmental assessment (Figure 1). We assume a conventional rational behaviour of the farmer. We define “environmental assessment” as a set of indicators showing the state of the pressure of the production system on the physical environment: type of technical pathway for plant systems (conventional, integrated) and associated yields, stocking density, proportion of grasslands in the total agricultural area, number of pesticide treatments in the orchards and biodiversity score.

The time factor consideration is in a forthcoming version of this model. This will lead to better consideration of risk (market risk and production risk). Moreover, at least two periods would be necessary to identify the impact on the circulation of enlarged flows on the productivity of the activities under consideration.

Figure 1: Diagram of the model



The mathematical model

$$R = \sum_i \left(XS_i y_i p_i + X_i (s_i \times BIN_i - w_i)\right) + \sum_j \left(NS_j y_j p_j + N_j (y_{mj} p_m + s_j - w_j)\right) - L_{ext} p_{ext} \quad (1)$$

$$X_{SetAside} \geq \sum_i X_i \times r - (1 - BIN) \times bigM \quad (2)$$

$$\sum_i X_i \leq \overline{X} \quad (3)$$

$$\sum_j N_j \times y_{mj} \leq QUOTA \quad (4)$$

$$\sum_j N_j \times h_j + \sum_i X_i \times h_i \leq Family\bar{W} + Lext \quad (5)$$

$$\sum_{f,j} N_j \times feed_{j,f} \leq \sum_i \left(X_i y_i - XS_i y\right)_i + F_{bought} \quad (6)$$

$$\sum_i X_i \times score_i \leq BIO \quad (7)$$

$$\sum_i X_i \times (entries_i - \text{export}_i) + \sum_j N_j \times (entries_j - \text{export}_j) \leq NITRO \quad (8)$$

$$\sum_i X_i \times pest_i \leq PEST \quad (9)$$

The farm maximises the gross annual income subject to diverse constraints: Technical constraints, environmental constraints and constraints related to CAP regimes.

The objective function representing the income is noted (R). The commodities sold are: Apples and cereals (i), meat (j), milk (m). The yields are noted ($y_{i,j,m}$), prices ($p_{i,jm}$), subsidies ($s_{i,j}$), charges per factor unit ($w_{i,j}$). A part of the labour force is purchased externally (L_{ext}) at price (p_{ext}). Certain structural charges and amortisation of annuities are not taken into account (*equation 1*). N_j is the number of heads of livestock produced, NS_j is the number of heads of livestock sold, X_i represents the hectares of land, XS_i represents the hectares which are used for commercialised cereals. The model is allocating among the area which is kept for fodder crops and the area which is used to grow commercialised cereals (*equation 6*).

The subsidies are attributed to production factors under conditionality constraints (before 2005) : for crops, obligatory set-aside of minimum crop area ratio (noted *r*). A binary variable *BIN* equals 1 when criteria for subsidies are met, i.e. equation (2) is binding and *BIN* equals 0 when criteria are not met (*equation 2*).

There are two supplementary constraints concerning fixed factors: the land constraint (*equation 3*) and the milk quota constraint (*equation 4*). The land constraint is the limitation of the sum of cultivated areas (the land total availability in short term is $\overline{X}$). The milk quota per farm is limiting the quantity of milk produced and also the number of cows (the upper limit is noted: *QUOTA* in *equation 4*).

The labour constraint is a balance between total labour needs ($h_{i,j}$ is the number of hours needed each year per hectare X_i and per animal N_j) and the family labour force (*FamilyW*) plus the possible employment of hired workers (L_{ext} is a maximum number of hours bought each year) (*equation 5*).

Technical constraints concern the possibility to feed livestock with fodder that is produced on the farm: cereals, forage maize, grass. The need for fodder resources per animal ($feed_{i,f}$) can be covered either by produced forage or by bought forage (concentrated feeds *noted* F_{bought}) (*equation 6*). Concerning pasture, the agroforestry system induces the possibility for bovine animals to pasture on grass areas which are planted with apple trees, except for big bovine animals like cows which might damage young trees.

We complete the set of classical constraints of MP models with information about the interactions between the different "traditional" activities and the environmental goods concerned. In the present case land, labour or other inputs may be allocated in one or more activities (in livestock breeding or fruit production, or in both) according to variable proportions defined by the known technical pathways. The new flows generated by joint production may cause variations in the productivity of the system, given that they may replace or complement certain conventional production factors. For example, both fruit and livestock activities use land, labour and chemical nitrate fertilizers. Supplementary inputs may enter the classical production function (manure, non-harvested apples, auxiliary insects, etc.). This results in less intensive use of market inputs, in decreasing costs and in a better protection of water resources. The absence of chemical treatment is also the basis for greater resistance of the ecosystem.

In the absence of precise quantification for the latter elements we try to take into account the underlying phenomena by introducing environmental constraints. The impact of joint production on the productivity is simulated thanks to exogenous variations of activities' returns. To do so, three environmental and ecological constraints have been introduced. The first one accounts for a biodiversity score, which is calculated by attributing +1 for each hectare of HS orchard and –1 for each hectare of SS orchard (*equation 7*). The second constraint accounts for a nitrogen balance nitrogen entries and nitrogen exports (linked to market transactions: Fertilisers use, output exports from the farm). Certain values of this indicator mean an increased risk of water pollution with nitrate (*equation 8*). This indicator presents some weaknesses but it is chosen because of its simple implementation (Girardin and al. 1999). The third constraint adds up the total number of pest treatments per year on the farm (*equation 9*). The biodiversity score, the nitrogen balance per hectare, and the number of pest treatments on the farm are considered as environmental indicators of the modelled farm. These indicators are the bases for externalities, which can be capitalized on through public policies to promote multi-functionality (second pillar) and in this way, affect profitability. The environmental conditionality of new agricultural policies aims directly at controlling these externalities through regulatory restrictions (first pillar). Thus an exogenous limit (called respectively *BIO, NITRO, PEST*) is simulated for each one of them, as an obligation to respect legal thresholds.

The data set

Data for activities

An activity may produce one or more commodities following the technical pathway employed. In parallel with the main activity of dairy cattle breeding, carried out on grasslands, the farmer can produce wheat, a part of which may be used to feed the herd. The farmer has also the possibility to allocate resources to the apple production; either using conventional SS tree management, or HS. In both cases, the destination is processing the fruit for cider, either by selling the fruit "fresh" for the cooperative, or by processing it and selling it directly on the farm.

For livestock activities, the technical pathway is that of Pie Noire dairy cattle producing 5300 litters of milk per cow and per year. The farmer may fatten the calves into 30-month beef and heifers, i.e. to slightly intensify the production per hectare by distributing more feed using purchased grain, or grain produced and transformed on the farm (Réseaux d'élevage Pays de la Loire, 1994, Coulon et al. 2002).

Each plant activity (grasslands, cereals, apple trees) has been divided into three categories of technical pathways. These categories are "conventional," "integrated," and "agroforestry." The transition from the first category to the third one supposes a limited number of input factors per hectare and gives lower yield for the intentional commodity[3] (table 1). The so-called "conventional" and "integrated" managements of wheat and grassland are characterised by a specific cost structure described the reference frameworks of the technical institutes (ITCF, 1992). Grasslands are exclusively dedicated to animal feed in the form of grass or hay.

Table 1: Yields per commodity and type of technical pathway

	Conventional	Integrated	Agroforestry
Wheat	6.5 tons/ha	5.5 tons/ha	-
Grassland	5 tons /ha	3.5 tons /ha	2 tons /ha
Orchard of cider apples	30 tons /ha	-[4]	4 tons /ha

The orchards called "conventional," are specialised here in cider apple production. The density is 300 trees per hectare. Their variable cost amounts to approximately €1250/hectare covering inputs, weed control, thinning, fertilisers, phytosanitary treatment. For all these operations, the farmer must spend about 115 hours/hectare per year. If the fruit is sold directly for processing as cider within the framework of a contract, the price may reach €150 per ton (Dubreuil, 1997). The fruit may also be processed on-site to produce added value as cider. The agroforestry orchards are much less dense; in this case, 40 trees per hectare[5]. Their management involves also less labour (limited pruning, no treatment). These orchards induce much lower costs per hectare than conventional ones (€160/ha) and require much less labour per year (16 hours/ha/yr).

Planting costs are ignored for both types of orchards. In reality, in the case of agroforestry orchards the farmer is starting this activity from existing trees which represents an advantage for this technical pathway. However, since the fruition of agroforestry orchards takes longer (5 years instead of 3), the cost of resource immobilisation is a disadvantage for agroforestry orchards but this difference is not taken into account neither.

The fruit is processed on the farm, which assumes that there are equipments suited for and sufficient labour (35 hours/ha/yr at least). Added value for the fruit on the market is very high. For example, apples sold fresh under the quality label "AOC Calvados Pays d'Auge"[6] obtain prices

[3] In comparison to the "by-product"
[4] Only two types of management, HS and SS, are considered. An "integrated" management can be envisaged for orchards in a later study as a third pathway, towards which each of the others may tend.
[5] Based on a farm surveyed by Solagro in Pays d'Auge
[6] AOC is a French quality label close to the Geographic Protected Origin (GPO) label

ranging from €185 to €220/tonne. The average price of cider is €2.50/liter. Moreover, recent studies within the framework of the ECOVERGER project[7] give estimates for on-site processing and marketing costs of the apple juice (excluding labour) of €0.61/liter (35 cents for production, 26 cents for marketing costs). The yield in fruit for pressing is 1.6 kg of apples for 1 liter of juice.
The price hypotheses for apples in the model are:

SS orchard, sold as fresh: €100 /ton
SS orchard, processed on the farm: €450 /ton
HS, sold as fresh: €130 /ton
HS, processed on the farm: €600 /ton

In reality, the fruit processed on farm gives higher margin (as high as 1100€/ton) than the margin kept in the model (450€/ton). Through this margin depreciation two elements are taken into account: firstly, the limitation of demand for these goods and secondly, the possible investment costs for processing activities. Thus, the price differential between SS and HS apples reveals a niche (for instance, in Bad Württemberg, some consumers organisations guaranty a 30% surplus on cider price when it comes from HS orchards). In relation to this point, it's important to stress the way the market is considered in this model based on an atomistic enterprise faced with given external prices (cf. objective function). However, in this context, the demand affecting the enterprise is not infinite, as in the theoretical case of an atomistic firm, since for example in the case of AOC products, this demand is limited. In order to take these limits into account, we will test several decreasing values of relative prices for apples produced in HS orchards compared to SS orchards.

Finally, the transition from HS management to SS trees creates no technical difficulties in the model. However in reality, this transition may generate costs due to the investment or disinvestments depending on the suitability of the production tools, skills, etc.

Data for constraints

- Constraints on fixed inputs are land and milk quota availability. Available family labour (calculated in hours) is limited to 3000 hours, which is the equivalent of 2 full-time workers corresponding to the mean pattern of agroforestry farms in Normandie. It is possible, within a limit of 500 hours, to hire a salaried worker, at an average hourly cost of €17/hour (which is a mean current cost in France, including social charges). This limit corresponds to the employment of an half-time worker, enabled by cash flow availabilities.
- Constraints related to production techniques require zootechnical coherence between the various herd categories. According to technical reference guides, this composition depends on the rate of renewal of dairy cows, the prolificacy and mortality of the herd. Feeding strategies are described through the coefficients of fodder input recognized in the reference works (Réseaux d'élevage Pays de la Loire, 1994[8]).
- CAP constraints concern the obligatory 10% set aside of wheat area above a certain threshold in order to receive the cereal subsidy. For cattle, the possibility is also introduced of eligibility for the male cattle subsidy, if the stocking density does not exceed 2 LU/ha. Both constraints are the legacy of the CAP before 2005.

2- Model calibration, analysis of sensitivity and simulations

[7] INTERREG SUDOE project, contribution of RENOVA producers' group.
[8] Réseaux d'élevage Pays de la Loire (1994), Chambre d'Agriculture, Institut de l'élevage

2.1- Comparison of the model farm and the survey farm (calibration)

Most of the farms including HS orchards are dairy farms. We propose a calibration of the model based on a typical farm in Normandy (more than 500 trees and 100 ha of total agriculture area) The data comes from a farm survey in "Pays d'Auge" (Coulon and al., 2002) and from the French General Agricultural farm Survey, 2000 (table 2).

Table 2: Dairy farms in Normandy with more than 500 trees of HS orchards

Number of farms	203
Mean total agriculture area	90 ha
Mean forage surface /farm	19 ha
Mean grassland area /farm	58 ha
Mean maize area /farm	16 ha
Mean number of cows /farm	47
Mean number of bovine animals /farm	133

Source : French General Agricultural Farm Survey, 2000

Through calibration we test the coherence of technical coefficients used in the model with the data from the surveyed farm. In the latter, we observe the quantities produced per period, but these data are not sufficient to define the technical coefficients. Therefore we had to use data available in the technical reference frameworks for the type of livestock operation under consideration: extensive grazing production of the Pie Noire breed in Normandy (Réseaux d'élevage Pays de la Loire 1994, ITCF, 1992[9]).

The main differences between the surveyed farm and the model farm are (table 3):

- The area of agroforestry orchard is greater in the model. This is probably linked to the quantification of the labour constraint in the model. It is therefore likely that the labour cost of a zootechnical beef unit[10] compared to the labour cost of an HS apple unit is lower in the surveyed farm than in the model.
- In the model farm, produced apples are all processed on-site, while on the surveyed farm, part of the harvest is sold as fruit, to be processed by the cooperative (40 tons out of 140). This difference may be explained by the labour availability constraint or by the risk of decrease in the price of cider, or by both simultaneous reasons.
- The quantity of feed purchased externally is higher in the model farm, probably because the feed rations in the surveyed farm are lower than those retained in the model according to the references of the technical institutes.

[9] ITCF, GNIS, Chambre Régionale d'Agriculture. (1992). Référentiel Fourrages des Pays de la Loire

[10] a "zootechnical beef unit" = 1 cow+0.45 of a 3-yr-old steer+ 0.28 of a 3-yr-old heifer+0.17 of a calf

Table 3: Comparison of the surveyed farm in Pays d'Auge with the model farm

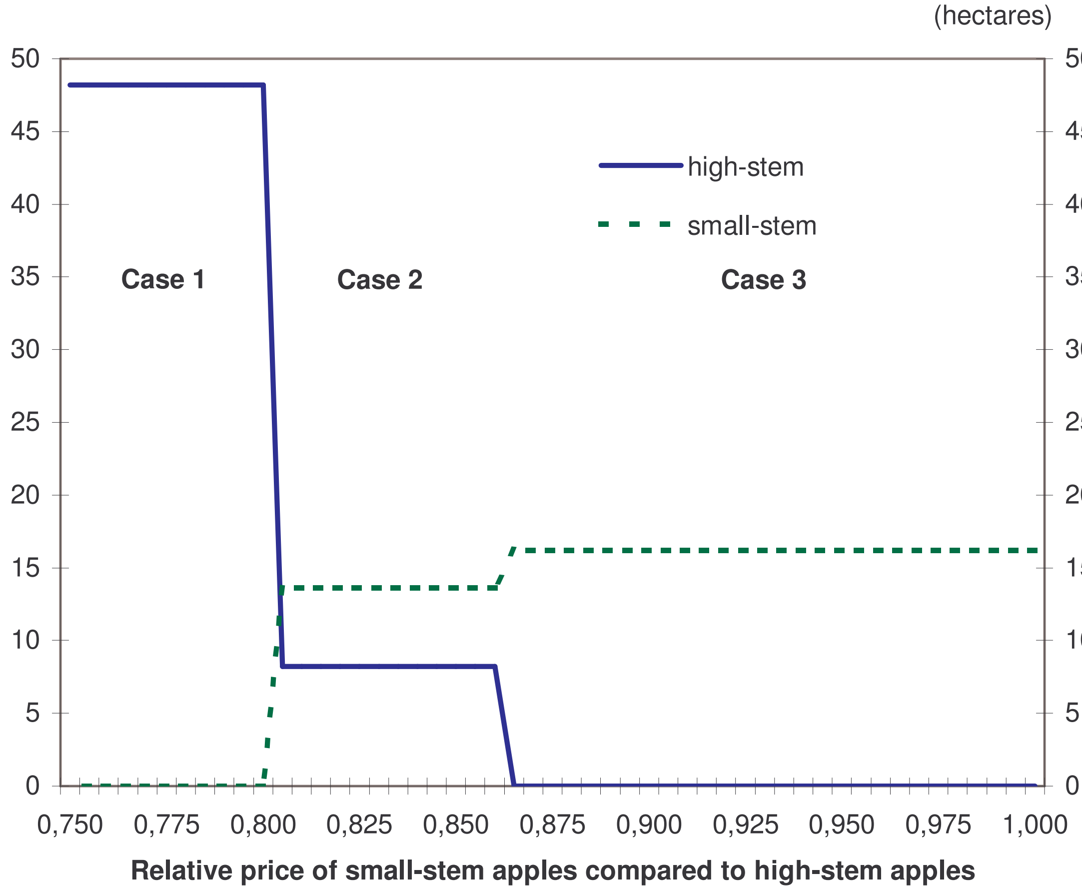
	Surveyed farm	Model farm
Total agricultural area	100 ha	91.3 ha
Milk quota	285,000 litres	285,000 litres
Number of milk cows	55	54
Sales of steers	15	0
Sales of 8-day old calves	0	34
Stocking density	-[11]	0.95 LU /ha
Area in cereals	0	
Uncultivated open space	23 ha	0
Area of grasslands	40 ha	43.1 ha
Area of agroforestry orchards	37 ha	48.2 ha
Quantity of apples produced	140 tonnes	193 tonnes
Destination:	100 t processed and sold on-site 40 t sold as fresh to the cooperative	193 t processed and sold on-site
Cereal concentrates purchased	25 tonnes	38 tonnes

2.2- Sensitivity of the model and parameters of farming activities

The sensitivity analysis is based on the following hypothesis: prices of cider processed on the farm from HS trees, as well as apples sold as fresh, can generate a higher gross margin than that obtained from SS trees. This price differential may not persist, if the HS volumes sold increase. We have therefore simulated a variation in the relative price of SS orchards apples, compared to HS orchards apples (Graph 2). The reference situation of the surveyed farm is the case 1.

[11] Not available

Graph 2: Development of HS and SS orchard areas according to the price ratio of apples



When the relative price of apples from SS orchards increases (over 0.8) the farmer transforms a part of the area in agroforestry orchards (48.2 ha) into SS orchards (13.6 ha) to end up with 8.2 ha in agroforestry orchards (cf. table 3). The rest (26.4 ha) is left fallow. Livestock operations are unchanged, with the same herd composition and the same areas in grasslands (43.1 ha). However, since the total grassland area on the farm is decreased, the stocking density increases (from 0.95 to 1.68 LU /ha). In the framework of the model, the total area effectively used decreases, because there is no better alternative. This also comes from the labour constraint, according to which the enterprise does not plan to vary from the family operation standard (the family labour force plus a maximum of one part-time worker). However this result is also due to the fixed-variable status of technical coefficients in this model[12].

[12] In another version, we could incorporate a certain variability in the technical coefficients of milk production

Table 4: Main components of the farm activities according to the relative price of apples

	Case 1	**Case 2**	**Case 3**
Price of processed apples, SS	**450**	**450**	**450**
Price of processed apples, HS (€/t)	**600**	**559**	**520**
Price of milk (€/litre)	**0.30**	**0.30**	**0.30**
Objective function (revenue in €)	300,263	284,968	282,466
Total agricultural area (ha)	91.3	64.9	66.2
Orchard area, HS (ha)	48.2	8.2	0.0
Orchard area, SS (ha)	0.0	13.6	16.2
Grassland area (ha)	43.1	43.1	50
Number of cows	54	54	54
Quantity of milk produced (liters)	285,000	285,000	285,000
Quantity of apples, HS (tonnes)	193	35	0
Quantity of apples, SS (tonnes)	0	403	486
Total biodiversity Score	48.2	-5.3	-16.2
Stocking density (LU/ha)	0.95	1.69	1.74
Nitrogen balance (N units /ha)	15.12	29.7	33.9
Number of pest treatments	43	152	180

When the relative price of SS orchards apples exceeds 0.86, apples sold are produced only with SS orchards. The grassland area is increased from 43 ha to 50 ha. The number of cattle remains the same, but as the overall grassland area decreases due to the absence of agroforestry orchards, the stocking density increases to 1.74 LU/ha. This specialisation means a deeper intensification of the production system. Moreover, as the stocking density increases, the quantity of pesticides treatments goes up sharply (from 43 to 152). This intensification is not slowed down by phytosanitary costs, which are compensated by productivity gains due to the SS technical pathway adopted (table 4).

To each one of the cases depicted in the graph 2 (case 1-only HS orchards, case 2-HS and SS orchards, case 3-only SS orchards) we can attach simplified environmental indicators:

- Biodiversity score: case 1: 48.2 points, case 2: -5.3 points, case 3: -16.2 points.
- Nitrogen balance: case 1 : 13.8 Units/ha, case 2: 23.8 Units/ha, case 3: 27.3 Units/ha.
- Number of pest treatments: case 1 : 43 treatments, case 2: 152 treatments, case 3: 180 treatments

At this step, the environmental score do not impact on the farm profitability, except the price premium that can be obtained through the AOC label.

2.3- Diversification scenarios

In order to take environmental conditionality into account, we assume that certain standards are imposed for the use of some inputs, conditioning or not financial compensation.

Table 5: Simulation scenarios

	Scenario 1	Scenario 2	Scenario 3
Price of apples from SS orchards (€/t)	450	450	450
Price of apples from HS orchards (€/t)	520	520	520
Price of milk (€/litre)	0.30	0.30	0.30
Maximum Nitrogen threshold(N/hectare)	-	25	20
Premium under N conditionality (€/ha)	-	-	158
Stocking density constraint (LU/ha FA)	≤ 1.4	-	-

The reference situation for the simulations is case 3, which is the less favourable situation for HS orchards apples (small price differential lower than 13%). In this situation, the issue is to find the incentive scheme that could lead the farm to diversify in HS orchards. Thus 3 scenarios are distinguished (table 5). Scenario 1 proposes a stocking density constraint, which is a legal limit similar to the current 1srt pillar conditionality constraints. This scenario corresponds to a situation where the stability of the milk price (associated with the permanence of a milk quota) would be conditioned by the limitation of the stocking density. The density threshold, 1.4 LU per ha, corresponds to the present density obligatory threshold to receive coupled bovine payments (eligibility to the extensification complement and the grazing bonus.). Scenarios 2 and 3 introduce maximum levels of nitrogen balance per forage area. This constraint is imposed on all the farm activities that send or receive nitrogen flows. These scenarios are built in order to show how technical complementarities between activities can decrease both mineral nitrogen purchased and nitrogen residues. This contributes to a decrease of pollution risks and therefore it can be supported by 2nd pillar subsidies. More precisely, in scenario 2, the maximum nitrogen balance constraint of 25 N units /ha is not a condition for additional premiums. In scenario 3 the level of nitrogen constraint is lower, 20 N units /ha, and this further effort may be awarded by a further premium.

Table 6: Main changes in the farm according to the three scenarios

	Reference situation (case 3)	**Scenario 1**	**Scenario 2 Without premium**	**Scenario 3 With premium**
Nitrogen threshold /ha	**-**	**-**	**25**	**20**
Premium under conditionality (€/ha)	**-**	**-**	-	**158**
Livestock density constraint	**-**	**≤ 1.4**	-	**-**
Objective function (income in €)	**282,466**	278,921	280,396	281,600
Total agricultural area (ha)	**66.2**	72.0	48.5	80.4
Orchard area, HS (ha)	**0.0**	19.0	5	31.6
Orchard area, SS (ha)	**16.2**	10.0	17.4	5.6
Grassland area (ha)	**50**	43.0	26	43.1
Number of cows	**54**	54	33	54
Total milk produced (liter)	**285,000**	285,000	172,436	285,000
Quantity of apples (tons)	**0**	150	40	169
Quantity of apples SS (tons)	**486**	300	523	253
Biodiversity score	**-16.2**	9	-12	26
Stocking density (LU/ha)	**1.74**	1.40	1.69	1.16
Nitrogen balance /hectare	**33.9**	24.7	25	20
Number of pest treatments on farm	**180**	123	165	88

Scenario 1: stocking density constraint, no price change
To meet this constraint, the farmer increases the orchard area by 12.8 ha, knowing that the area in agroforestry orchards is included in the grazing areas (see table 6). Income decreases slightly, but in reality it would have decreased more, since the cost of using extra land is not taken into account here. A more restrictive stocking density (1 LU/ha) would move the situation closer to case 1. In this scenario, all the environmental indicators are improved compared to the reference situation.

Scenario 2: Nitrogen balance constraint without additional premium
In this scenario, the number of cattle is severely decreased as well as the orchard area, a part of which serves as grasslands (5 ha). The environmental indicators are improved relatively to the reference situation. Compared to scenario 1, these indicators are less favourable, which means that a density constraint is more efficient, in an environmental sense, than a nitrogen balance constraint. This latter

constraint penalizes the bovine activity more than the density constraint. Moreover, the income decrease is lower in scenario 2 than in scenario 1. These two results are due to the possibility reduce land use (-23.5 ha) without cost.

Scenario 3: Nitrogen balance constraint with additional premium
Here is supposed that the nitrogen balance threshold is lowered to 20 N units/ha and that an additional premium is awarded. After parametrizing the level of the premium, it appears that the forage area and the dairy cattle herd are maintained only if this level is over 158 €/ha. In order to maintain these activities, the total agricultural area is increased from 66.2 to 80.4 ha. The orchard area (SS and HS orchards) is tripled while the HS orchard ratio rises to 65%. The environmental indicators are better than in the previous scenarios and the stocking density is lower than 1.4 LU /ha.
The premium simulated here is similar to a 2nd pillar premium and it is conditioned by environmental requirements going further than the 1rst pillar requirements. In addition to the improvement of environmental indicators, the farm is incited to maintain a certain degree of diversification.

All of these results certainly show that new environmental requirements are likely to be implemented and accepted by farmers, either through the use of compensations, or by the added value obtained through diversified activities (here for example, better added value for products from HS orchards). HS orchards not only produce grass and apples (joint production of marketable goods), but also environmental services through jointness.

Conclusion and limits

This paper explores the possibilities for diversification offered to farms, in a period of rising uncertainties. In this period, farmers are facing new eligibility conditions for subsidies together with a growing influence to the market hazards. We claim that the obligation to respect these conditions may, among other things, lead the farmer to benefit from what is called here the complementarities between production activities. The farmer better exploits these complementarities when he diversifies further his activities, trying to benefit from fresh market opportunities valuing new product characteristics. This paper uses an input-output approach in order to assess the productivity of diversified farms where the role of jointness phenomena is crucial. This analysis brings up two kinds of issues and forthcomings. Firstly, the social recognition of multi-functional flows in agriculture through 1st and 2nd pillar aid policies may encourage farmers to better organise their internal flows thanks to the diversification of activities and products. This requires also more active attitude of farmers, individually or in groups, towards market signals including the demand side. Secondly, some analytical elements appear in order to highlight the competition between farms within the framework of the new CAP. In this competition, some farms, as agroforestry farms, will take advantage of conditionality to the detriment of other farms that will be penalized by conditionality. New sector and/or territorial specializations will result from this competition. The analytical tool proposed here will be extended to assess these consequences, including for that other elements like risk and longer planning horizon.

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