# Impact of voluntary Agri-Environmental Measures on farms' income and labour management: The case study of a "Test –Action" in a river basin of south-western France*

**BEN EL GHALI Mohamed** [a,b], elghali_ma@yahoo.fr

**RIDIER Aude** [a,b], aude.ridier-martos@educagri.fr

**KEPHALIACOS Charilaos** [a,b] , charilaos.kephaliacos@educagri.fr

**NGUYEN Geneviève** [a], nguyen@ensat.fr

a) Toulouse University, LEREPS, Manufacture des Tabacs 21 allée de Brienne 31042 Toulouse Cedex 9

b) ENFA : BP 22687 • 2 route de Narbonne • 31326 Castanet Tolosan cedex

**3èmes journées de recherches en sciences sociales**

**INRA SFER CIRAD**

09, 10 & 11 décembre 2009 –Montpellier, France

* Research financed by the European Life project "Concert' eau"

## Abstract

Since the late 1980s, many legal and voluntary measures have been initiated among farmers in European regions to change farm management practices to reduce pesticides and nitrogen pollution. However, few farmers in southwestern France have adopted these practices. This research analyses how impacts of expected income, labor requirements, and risk could be key barriers in the adoption of these practices. A Mathematical Programming Model (MPM) analysis shows that reducing pesticides and adopting long rotation and no-tillage practices have in some cases both increased expected profitability and reduced labor requirements. However, increased risk and/ or larger labor requirements are shown to be the primary barriers to adoption. Results may provide the basis to improve the adoption of agri-environmental measures.

**Keywords:** Labor, risk, adoption, agri-environmental measures, mathematical programming model.

## 1. Introduction

In Europe, marketed pesticides are efficient, relatively cheap and easy to handle. Their intensive use over years has led to serious water pollution in many agricultural areas. Alternative biological pest management methods also exist, but their adoption is limited. The adoption and diffusion of new technologies are important issues that have been addressed by specific research studies in agricultural and environmental economics (Sunding and Zilberman, 2001; Jaffee et al, 2003). The adoption of a new technology can be considered as a long term investment for which the costs and benefits need to be evaluated (Griliches, 1957). Among the determinants of adoption in agriculture (Knowler and Bradshow, 2007), are added production costs or the financial benefits/gain expected from adopting the technology.

The production cost can be estimated according to the labor factor. Fuglie and Kascak (2001) demonstrated that farmers can reduce the cost of pesticide use by increasing labor on the farm. The opportunity cost of labor indeed plays an important role. These authors showed that arable farms with a livestock breeding activity tend not to adopt alternative pest management practices because they prefer to allocate their extra labor force to the execution of standard tasks rather than to the management of new technically demanding practices. Other determinants of adoption have been identified, such as the farmer's level of education, the agrarian structure (land ownership, access to credit, etc.), the state of the infrastructure for communication and transport. These factors may increase the costs of transaction or change the level of uncertainty associated with the adoption of new technologies.

However, studies by Dupraz et al. (2003) in Belgium and by Lohr et al. (1999) in the United States showed that some altruistic farmers are willing to sacrifice part of their income to adopt more environmental-friendly practices. The diversity of the results in the economic literature on the adoption of new technologies in agriculture underscores the complexity of the farmer's decision-making process, which relies on multiple trades-offs (costs against benefits, short term versus long term) and involves different dimensions of risks.

Governments play an important role in the promotion and diffusion of new technologies (they stimulate, limit and guide the diffusion). Since the 1980s, with the growing concern regarding the impact of pesticides on health and the environment, the European Union (EU) has imposed stricter regulations aimed at reducing the use of pesticides and controlling associated risks. In France, the taxation of polluting activities was introduced in 1999. However, despite the fact that the level of taxation depends on the type of pesticide, the rate is too low to yield a positive impact (Aubertot et al, 2005). Other innovative policies based on voluntary contractual schemes - the agri-environmental measures - were developed by several European countries in the late 1980s to reduce the use of pesticides (Aubertot et al, 2005). These policies are still effective under the second pillar of CAP.

As a preliminary to the research work presented here, we identified all the agri-environmental measures funded over the 2000-2006 period, in the agricultural area of a river basin in Gers in the Adour-Garonne watershed south-west France (source : CNASEA[1]). We observed that the two most widely-adopted measures concern, first, reducing the use of pesticides and, second, matching fertilization with yield objectives. It was not surprising to note that measures that do not require much additional effort were mostly adopted by arable farmers already engaged in precision agriculture (a concept based on information that makes it possible to modulate inputs). In 2005, an experimental program was launched in the same area to reduce groundwater pollution. This program aimed at promoting alternative agricultural practices through financial incentives. It provided subsidies for investments and compensated for the costs of changes. The measures targeted specific areas and were associated with an information and training program for the targeted farmers. Policies that target specific areas and that are appropriate for the territory concerned, could be expected to give more incentives to farmers and favor the adoption of alternative practices. However, a year after the beginning of the program and despite substantial financial incentives, the rate of adoption of the proposed agri-environmental measures was very low. Out of the 700 targeted farmers, only 137 (19%) participated in the program. Of all those who participated, 80% signed a contract to use an additional crop in their cropping system, and 55% agreed to simplify_their plowing techniques. Less than half adopted both measures. Simplified or superficial plowing techniques were developed mostly for dry production systems and for soils with low clay content. In these conditions, experiments showed that these techniques substantially reduced the cost of mechanization and plowing time. The benefit could be even greater as in these conditions? The problem of weeds is not too serious. By contrast, less than 10% of the participants adopted time consuming measures or measures that imply major changes for the farming system. Those measures include the cultivation of N-labeled catch-crops during winter and the conversion of arable fields to meadows.

In the first approach, the marginal cost of some of the practices observed on the watershed, such as the superficial plowing, is equal to zero or is negative. These practices indeed allow a reduction in the use of inputs and in working time, while having no impact on the expected yield. A high adoption rate of such practices could thus be expected, even without subsidies. We observed the

[1] Centre National pour l’Aménagement des Structures des Exploitations Agricoles (National Center for Installation and Farms Structures)

opposite. The fact that the adoption rate was very low even with substantial financial incentives suggests that some costs were not taken into account in the first evaluation. We propose to interpret this apparently surprising result by the presence of yield uncertainty. Even if technical information and field experiments demonstrated that yields are not reduced, farmers may still perceive new techniques as more uncertain in terms of expected yield and variability. Are the farmers thus expecting to be adequately compensated for such uncertainty? In this case, governmental measures play the role of a risk premium.

With regard to the low rate of adoption of alternative practices that are apparently "economically efficient" and not too risky given the associated subsidies, the objective of our paper is to analyze the principal determinants of changes in practices at the farm level. Our preliminary evaluation underscored two factors: first, the impact on the farmer's expected income, and second, the availability of labor on the farm to manage the new practices and possibly to manage the associated changes in the farm system. We also take into account factors such as information and the farmer's experience, that play a role in the farmer's capacity to evaluate the consequences of adoption and thus determine the degree of uncertainty of his domain of action.

To analyze the farmer's adoption decision-making process, we developed a mathematical programming model of production systems, which includes labor and risks. In the following section, we describe the methodology including the model, the data used, the different types of farming systems in the river basin and the calibration of the model according to the typology. The simulation results of different adoption scenarios are then presented and discussed. We end our paper by evaluating the amount of subsidies - as a risk premium - that would result in the adoption of the practices by the different types of farmers.

## 2. Methodology

### 2.1. Structure of the model

We built a farm level model using mathematical programming methods. These methods enable the production function to be depicted through an optimisation choice among several products and techniques. Different existing and future techniques with different levels of inputs compete and technical change is explicitly modelled. This approach also enables complex policy tools to be accounted for that impact the production function such as the decoupled Single Farm Payments of the new CAP, the cross-compliance of these payments and also the possibility for the farmer to contract voluntary agri-environmental measures. The choice of contracting is endogenous thanks to the use of binary variables. This kind of method has been extensively applied for farm-level or sectoral studies and is well suited to combine ecological and economic analysis (Falconer and Hodge, 2001; De Koeijer et al, 2002, Havlik et al. 2005, Mosnier et al, 2009).

**Objective function**

The model incorporates the variability of yields as a function of soil types and climate conditions. The yield distribution is discrete and depicted through several states of nature *k*. It is assumed that farmers confronted with new management practices are risk averse and the expected utility model was thus retained. The expected utility of income is the arithmetic mean of the utilities obtained for the various states of nature of the observed yields. It is assumed that farmers allot the same weight to all the states of nature, good or bad. This assumption is questionable insofar as the literature considers that the farmers generally give more weight to bad seasons than to good seasons (equation 1).

$$EU(\tilde{R}) = \sum_{k} U(R_k) \times \pi_k \qquad \text{Equation 1}$$

*EU(R): expected utility of the risky income; U($R_k$): utility of income per state of nature k;*

*$\pi_k$: probability of each state of nature*

A Constant Relative Risk Aversion (CRRA) utility function is appropriate in our case because while the relative risk aversion is constant (the indifference between risky payoffs is not disturbed when all payoffs are multiplied by a positive constant), it exhibits a decrease in absolute risk aversion with an increase in wealth (Hardaker and Lien, 2007) (equation 2).

$$U(R_k) = \left(\frac{1}{1-r}\right) * \left(R_k\right)^{(1-r)} \qquad \text{Equation 2}$$

*Rk: expected income for the state of nature k; r: coefficient of relative risk aversion*

The farmer's net income is determined for each state of nature by the difference between the income and costs per hectare of the various activities *j* (equation 3).

$$R_k = \sum_{j} (\tilde{y}_{jk} p_j - c_j) X_j \qquad \text{Equation 3}$$

*X : area for activity j; p : price of activity j; cj : direct costs of activity j;* $\tilde{y}_{jk}$ *: yield of activity j per the state of nature k*

It is assumed that the matrix of yield variability $\tilde{y}_{jk}$ is normally distributed with mean ω and standard deviation σ. The normal distribution is estimated through Monte Carlo simulations on the basis of data extracted from regional references collected for four climatic years[2] (equation 4).

$$\tilde{y}_{jk} = \mathrm{N}(\omega, \sigma) \qquad \text{Equation 4}$$

**Constraints of the optimization model**

The main constraints are related to agricultural and economic resources (land, water, labor and rotation) as well as those related to policy and environmental restrictions:

- *Land Constraint*. The availability of two different soil types (clay-lemon and sandy-clay soils) is specified for each farm type.
- *Irrigated land constraint*. For each farm-type and soil-type the share of irrigated land is limited.
- *Rotation constraint*. In order to account for cropping successions in a static model reasoning based on the previous crop is used. First, for each crop, the set of possible previous crops is identified. Then constraint limits the share of area of each crop by the total area of its previous crop (equation 5)

$$X_{c,\text{"previous-crops"}} \leq \sum_{\text{previous-crops}} X_{\text{"crop"},pc} \qquad \text{Equation 5}$$

- *Set-aside constraint*. Based on the former CAP regulation, a rate of 10% set aside of land under cereals, oilseed and protein crops is imposed.
- *Buffer strip constraint*. 3% of the area allocated to cereal, oilseed and proteins crops has to be converted into buffer strips.
- *Subsidy constraints*. In the reference situation, subsidy constraints are set according to the subsidy scheme included in the 2003 CAP reform.
- *Labor constraint*. Input saving practices may be more labor intensive in "peak periods". Therefore time needs and time availability has to be detailed month by month. The labor resource is calculated on the basis of one or two family workers (depending on farm size) and additional seasonal workers. Finally, the availability in days per month depends both on

[2] *Chambre Régionale d'Agriculture Midi-Pyrénées, références technico-économiques en systèmes de grandes cultures, Résultats 2001, 2003, 2005, 2007*

family holidays and bad weather conditions (with a probability that bad weather days happen during holidays).

- *Constraints for livestock activity*. These constraints concern fodder availability (cereals, hay, grazing), animal demography, and labor constraints linked to breeding operations (food, births, care, etc.).

## 2.2. Study area and farm typology

## Farm types

The model is calibrated on three farm-types corresponding to three types of areas with different cropping systems in the Adour-Garonne watershed. These three production systems were identified according to the degree of farm specialization, which was computed based on data from French National Farm Survey (RA 2000), the regional database SICOMORE belonging to the Midi Pyrenees Regional Chamber of Commerce (*Chambre régionale d'Agriculture de Midi-Pyrénées*) and direct interviews with experts from the extension services in the study area. Indicators concerning the structural characteristics and the current acreage of each crop variety were determined proportionally to the characteristics of standard farms in the region concerned (table 1)

***Farm-type 1: specialized in "dry cereals".***

This type is located in a dry and hilly area. The mean area of this farm type is about 150 hectares (ha) with two soil types 120 ha are on clay-muddy soil and 30 ha are on sandy-clay soil. Labor availability is calculated with reference to two manpower units. Six different crops can be grown on this type of farm: durum wheat, soft wheat, maize, colza, sunflower and soya.

***Farm-type 2: predominance of irrigated maize.***

The second farm-type is located in valleys where the main rotations are Maize/Maize, Maize/Soft Wheat/ and Maize/Soya. The mean area of this farm type is about 120 ha again with two soil types: 24 ha of clay-muddy soil and 30 ha of sandy-clay soil. The irrigable land is about 40% of the total area. Labor availability is 1.5 manpower units (the farmer who works full-time and a part time worker, usually a family member)

***Farm-type 3: mixed crop-livestock***.

The third farm-type uses rotations including temporary and permanent meadows. Beef production is the major activity in this area. The mean farm size is about 70 ha divided into two soil types: 55 ha of clay-muddy and 15 ha of sandy-clay soil. The average size of the herd is of 55 head of cattle/dairy cows with 95% of rate of gestation, 8% death rate and 19% growth rate. One and half manpower units are present on the farm.

## Input-output coefficients

The prices of inputs and outputs are based on prices observed in the region for the year 2005. The input-output coefficients are estimated according to regional references *(Chambre régionale d'agriculture, Institut de l'élevage,..)*. Crop yields are estimated by taking into account the previous crop in the rotation, the soil type, and the cultivation practices. Data used for the estimation came from the regional experts' references database and from simulations performed with the CROPSYST model (Belhouchette et al, 2009)

The technical coefficients for labor requirements per crop were estimated according to the different farming operations (tillage, fertilization, harvest, fungicides, insecticides, herbicides, etc.), based on data from farm equipment cooperatives (*CUMA*).

## 2.3. Model calibration

The calibration of the model consists in the adjustment of exogenous parameters in order to fit the simulated crop patterns to the one observed for the different farm types described in paragraph 2.3 and for the baseline year of 2005. The parameter used here to improve the calibration was the risk aversion coefficient. The value retained for the three farm types is 0.7 as it gives the lowest Percentage of Absolute Deviation (PAD)[3] between the observed and the simulated results (in terms of crop pattern). The PAD was used as an indicator to evaluate quality of the model by calculating the crop pattern variability. Its value is less than 20%, which is acceptable according to the literature. Thus, we considered that our model provides reliable information on farm acreage decisions and could be used to analyze different scenarios.

The baseline scenario used for calibration was 2005 prices and CAP regulations. It includes flat rates for crop premiums as well as the adoption of modulation and Single Farm Payment.

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[3] $PAD(\%) = \frac{\sum_{i=1}^{n} \left| \hat{X}_i - X_i \right|}{\sum_{i=1}^{n} \hat{X}_i} .100$ ; $\hat{X}_i$ : observed level ; $X_i$ : simulated level

### 2.4. The scenarios

Three scenarios corresponding to the implementation of new farming practices were simulated and compared to a baseline scenario (2005):

- Scenario 1: "no tillage", minimum level of soil maintenance
- Scenario 2: use of long rotations
- Scenario 3: reduction in pesticide use

These scenarios were performed for the year 2008 and no additional extra assumption was introduced between the baseline year of 2005 and 2008.

## Scenario 1: no tillage

This practice requires the withdrawal of plowing operations usually dedicated to soil preparation. No alternatives to tilling are used. In this scenario, two types of techniques (plowing and "no tillage") were specified, and an additional premium was allocated for the "no tillage". The level of the premium is endogenous and corresponds to the minimum level of incentive necessary to change plowing practices.

## Scenario 2: long rotation

The long rotation scenario consists in setting up a rotation containing four different crops over a period of five years. Thus, a new constraint concerning the total number of crops was introduced in the model.

## Scenario 3: reducing pesticide use

The need for data to simulate a scenario of reduction of pesticide in agriculture is an important issue today. According to the agronomic literature, there is no clear relationship between the quantity of pesticides and the degree of yield variability. The estimation of "input-output" functions involving the use of pesticides is thus a difficult task. Here, we decided to interview regional experts and to base our assumptions on their knowledge. It was assumed that reducing the quantity of pesticides by 30% reduces yields by 5 to 10% (depending on the crop). However, farmers have to run extra mechanical operations to compensate for the reduction in pesticide use. Another assumption is that farmers replace pesticides by diverse mechanical operations on the soil, such as the use of a harrow. According to the agronomic literature and to experts, farmers should replace one pest treatment by three harrowing operations. In scenario 3, two techniques were added for each crop: *conventional* with current use of pesticides and *integrated* with less use of pesticides.

## 3. Results and discussion

The following section reports the results of the three scenarios performed for year 2008. The results of these scenarios are compared with the baseline scenario before setting up agri-environmental measures. The main outputs of the simulations we report here are : i) the crop patterns and the area converted under new farming practices, ii) the change in labor intensity and iii) the impact on expected income

### 3.1 Technical results: crop pattern and labor spending

The results obtained in Scenario 1 (“no tillage”) show some changes in the crop pattern of the three farms (fig1, 2, 3): the absence of plowing decreases the global time needs by 19% for dry cereals farm, by 11% for the maize farm and by 3 % for the livestock farm (table 2). Thus, the farmers can optimize their time availability and reduce the labor peak periods in order to grow other more profitable crops in their cropping systems (fig 4, 5, 6). In the case of the two cereal farms, we observed a decrease in the area of winter crops (soft and durum wheat), replaced by an increase in oilseeds and maize. For the livestock farm, the cropping pattern shows a reduction in barley and meadow and an increase in soft wheat and alfalfa, which has a better nutritive contribution, but needs more labor efforts. As a consequence, the number of animals is decreased by 4.4%.

The results obtained in **Scenario 2** show that the “long rotation” requirement impacts the most the cropping patterns of the area predominated by irrigated maize. In this area, soya and sunflower are introduced (fig2). At the difference, in the dry cereals area, changes are not so important large as compared to the baseline scenario (fig1): only soya is introduced. In this hillside part of the watershed, farmers already and traditionally cultivate a large range of crops in order to face market and production risks (yield variability). In mixed crop-livestock farms, changes are characterized by the introducing of a new crop (triticale) and by a slight reduction of alfalfa and soft wheat (fig3). These changes induce a decrease of the number of animals (-7.3%), which explains also the reduction of labor time by 5%. On the contrary, the change of cropping patterns in the two other specialized cereal farms induce an increase of spring labor peaks, which requires farmers to hire occasional labor workers(fig 4 and 5).

The results of **Scenario 3** (reducing pesticides by 30%) show a major change in crop patterns. In dryness cereals farms, only three types of crops remain. Durum wheat and colza are removed; the soft wheat area falls while the area with maize and sunflower increases considerably (fig1). In farms with irrigated maize, changes are similar: soft wheat is decreasing, while maize and sunflower are increasing (fig2). In livestock farms, the new crop pattern shows an increase in meadow areas and the remove of barley (fig3). These changes allow for an increase in the number of animals by 20% (table3).

All these results seem coherent with the modeling assumption: crops which generate the most profitable expected gross margins (with lowest yield variability), and which allow a better labor management are preferred (maize, sunflower). With uncertain yields and the increase of labor needs due to the reduction of pesticides use, farmers will try to concentrate their efforts and time availability on crops having the strongest gross margins. The analysis of the labor time spent shows a very important increase during spring (April, May) reaching 54% in dry cereals farm and 84 % in areas with predominance of irrigated maize. This is coherent with the new crop pattern and with the replacement of pesticides treatments by mechanical operations (fig 7 and 8).

In the livestock farm no variations in labor time and organization is observed. This is mainly due to the decrease in the area with winter crops and to the increase of meadow, which do not need additional mechanical operations. The time saved by this change is re-allocated to breeding activities (fig 6).

### 3.2 Sensitivity analysis to the level of incentive in different risk situations

For all farm-types, the expected income is increased by all scenarios, compared with the baseline (table 2). This increase is mainly due to both the associated compensation premium and to the decrease of labor or machinery costs in some cases.

Concerning **Scenario 1 (non tillage),** a 20 €/ha premium results in about 80% of the total area produced under no tillage practice for all farms, which is lower than the amount currently programmed in the Agri Environmental Scheme (fig. 9). The difference can be interpreted as a risk premium or an incentive for farmers to adopt even if they have a pessimistic perception of the impact of the no tillage practice on yields (they overweight the bad results).

To test this assumption the model was run with different levels of the Mean Standard Deviation of yields (higher than the one observed in reality). For a strong level of risk perception (deviation of 30%) the rate of area produced under the no tillage practice increases more slowly with higher levels of risk premium (fig. 9 and 10). Under these conditions of subjective risk perception, the rate of 80% of area converted is reached, in all farms, for a 50 €/ha premium. This emphasizes the importance of risk perception in the adoption process of new farming practices.

In the **Scenario 2 (long rotation),** the income increase is more important than in scenario 1 for all farms (table 2). This is mainly due to the amount of additional premiums received in response to the respect of the long rotation (130 € /ha) and to the additional income of the new crops (soya, durum wheat, triticale, sunflower). The level of premium given by the model for the implementation of this practice is very close to the currently premium given to farmers (137.2 € /ha). This premium allows farmers to face additional costs caused by the introduction of new crops, especially the remuneration of occasional labor (case of farms with predominance maize).

The results of **Scenario 3 (reducing pesticides use)** show a substantial increase in income, especially for the two farm-types specialized in cereals (table 2). The levels of incentive are very different in the three farm-types: 120 €/ha in dry cereals farms, 140 €/ha in maize farms, 70 €/ha in mixed livestock farms. These gaps can be explained by the labor constraint. Farmers in dry cereals area and mixed crop-livestock area prefer to reduce their pesticides use than making long rotation because of time organization. In spite of the important increase of time labor in pick periods, time needs in the other periods remains less than in scenario 2 (long rotation). Whereas farmers specialized in irrigated maize prefer long rotation practice because it needs less pick labor.

In the other hand, livestock farms exhibit a better economic and ecological performance due to the simultaneous increase in meadow areas and number of animals bred. In comparison with the reference scenario, the cattle stocking density in scenario 3 have decreased by 25%. However, it has increased by 0.5 % for the no tillage scenario 1, and by 2.7% for the long rotation scenario 2.

The sensitivity analysis to different levels of risk perception in this scenario 3 doesn’t show any impact of the level of premium on the rate of area converted, so we present here only one graphic for a low level of risk perception (Fig 11). This is probably because of the labor factor which is a more restrictive constraint in the optimization than risk.

The fig 11 shows that the relation between the rate of area with “reduced pesticide use” and premium values are depending on farm-types characteristics, especially labor availability. For a premium of 70€/ha this rate for the livestock farm is about 100%. However in the other farm-types, the rate remains near to zero. It starts to change for a premium of 80 €/ha for dry cereals farm and 90€/ha for farms with predominance of irrigated maize.

To assess the role played by labor availability in the adoption process in this scenario, we tested for the dry cereals farm-type two alternatives: with occasional labor and without occasional labor. Results show that in presence of occasional labor and for the same amount of premium, the rate of area with reduced pesticides is more important. Without access to occasional labor, the dry cereals farm-type can produce only 50% (75 ha) of its area with reduced pesticides use.

## 4. Conclusion

Our results highlight that, according to different agronomic contexts and in presence of incentives the implementation of new farming practices can be an opportunity for farmers to re-allocate their available time towards more profitable crops or projects. These results, also confirm that the quantity and the quality of labor spent in the change of practices is probably the main obstacle to the adoption of innovative farming practices. Even if the total time spent in farming operations can be decreased by some new practices, time organization can get more complex. The modeling option that is the introduction of monthly labor constraints and of risk as two major decision criteria enable to interpret the gap between the efficient incentive levels and the current levels of premium in terms of risk premium. In practice, the implementation of agri-environmental measures faces many other kinds of constraints, such as farmer's skills and human capital, transaction costs (learning costs, monitoring costs…) and the professional context, which can slow down or improve the adoption process.

***Tables and figures***

*Table 1*: Characteristics of the different farm types

| Crop pattern (ha) | Farm type 1 (dry cereals) | Farm type 2 (irrigated maize) | Farm type 3 (mixed crop livestock) |
|---|---|---|---|
| Fallow | 15.0 | 12.0 | |
| Colza | 5.7 | 4.4 | |
| Soft wheat | 43.6 | 29.5 | 6.0 |
| Durum wheat | 16.7 | | |
| Barley | | | 4.0 |
| Sunflower | 35.8 | 16.7 | |
| Soya | 8.0 | 6.2 | |
| Maize | 20.8 | 47.6 | |
| Maize /fodder | | | 5.0 |
| Alfalfa Pasture | | | 25.0 |
| Rye Pasture | | | 12.0 |
| Permanent Pasture | | | 18.0 |
| Total Agricultural Area | **150.0** | **120.0** | **70.0** |

*Table 2*: Economic results and labor spent in the different scenarios compared with ref. situation

| | | Scenario 1 (no plowing) | **Scenario 2** (long rotation) | **Scenario 3** (reducing pesticides) |
|---|---|---|---|---|
| **Farm-type 1** | Gross Margin-variation (%) | + 6 | + 17 | + 27 |
| | Labor variation (number of hours /year) | - 19 | - 4 | + 54 |
| **Farm-type 2** | Gross Margin -variation | + 12 | + 12 | + 23 |
| | Labor variation (number of hours /year) | - 11 | + 10 | + 84 |
| **Farm-type 3** | Gross Margin-variation (%) | + 4 | + 9 | + 8 |
| | Labor variation (number of hours /year) | - 3 | - 5 | 0 |

*Figure 1:* Cropping plan in farm-type 1 (dry cereals)

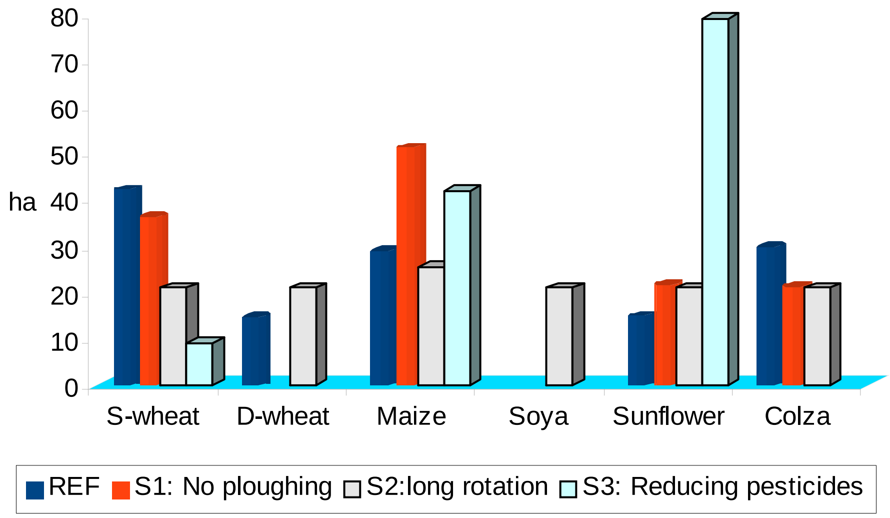


*Figure 2*: Cropping plan in farm-type 2 (predominance maize)

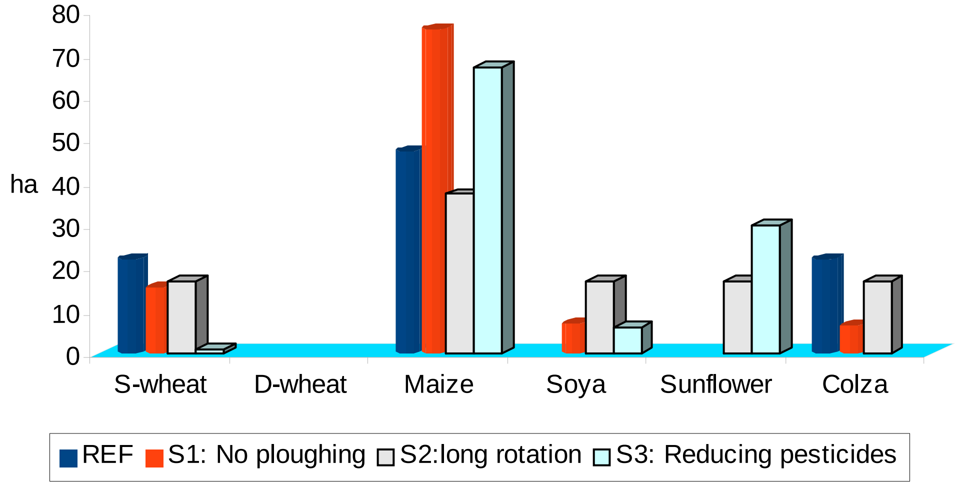



*Figure 3*: Cropping plan: in farm-type 3 (mixed crop- livestock)

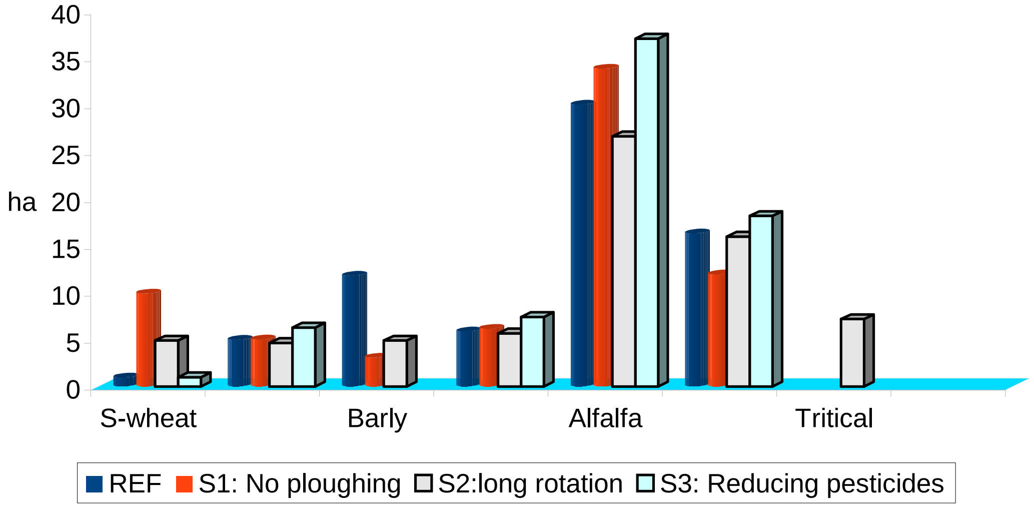



*Figure 4:* Time organisation in farm-type 1 (Dry cereals)

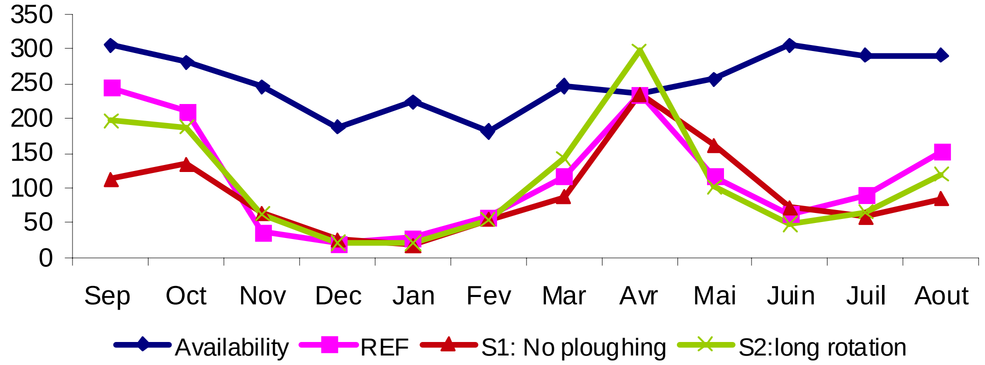


*Figure 5 :* Time organization in farm-type 2(irrigated maize)

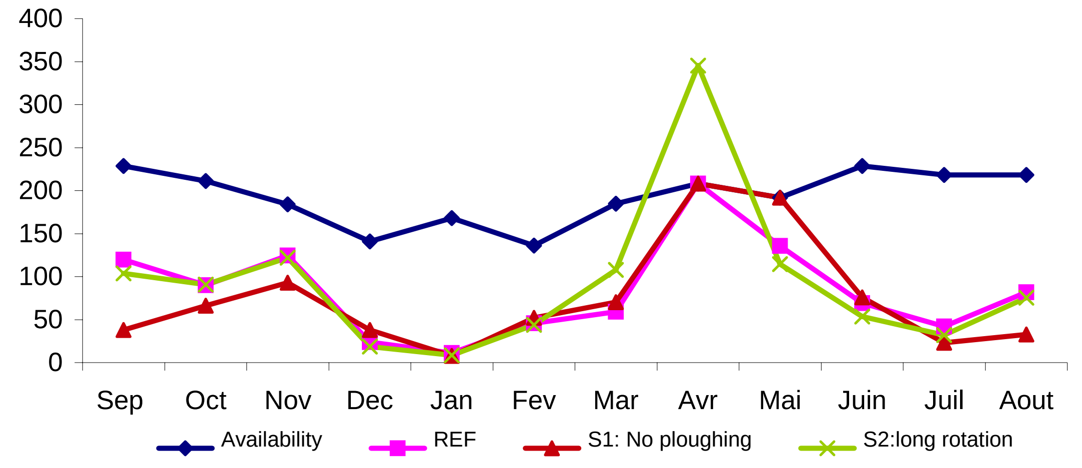



*Figure 6*. Time organization in farm-type 3(mixed crop-livestock)

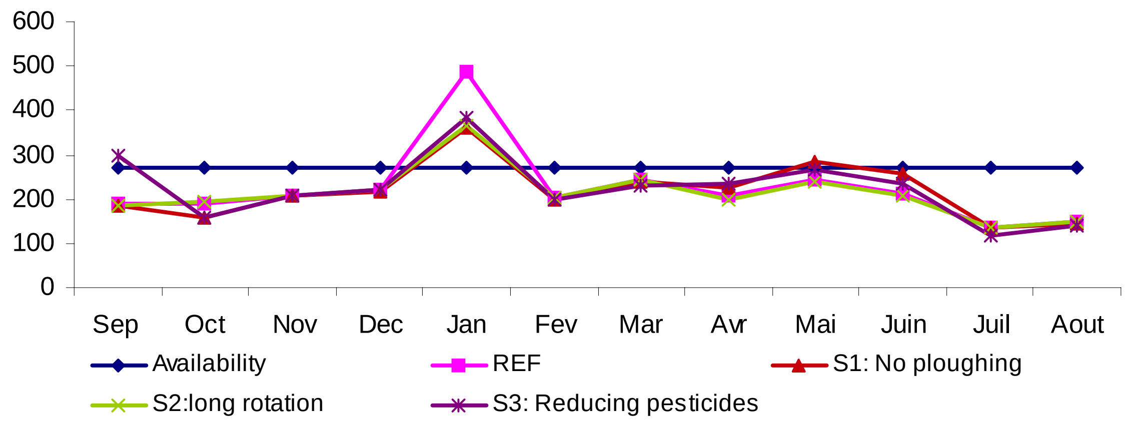



*Figure 7*: Scenario 3 (reducing pesticides), distribution of labor time in farm-type 1 (with and without occasional labor available)

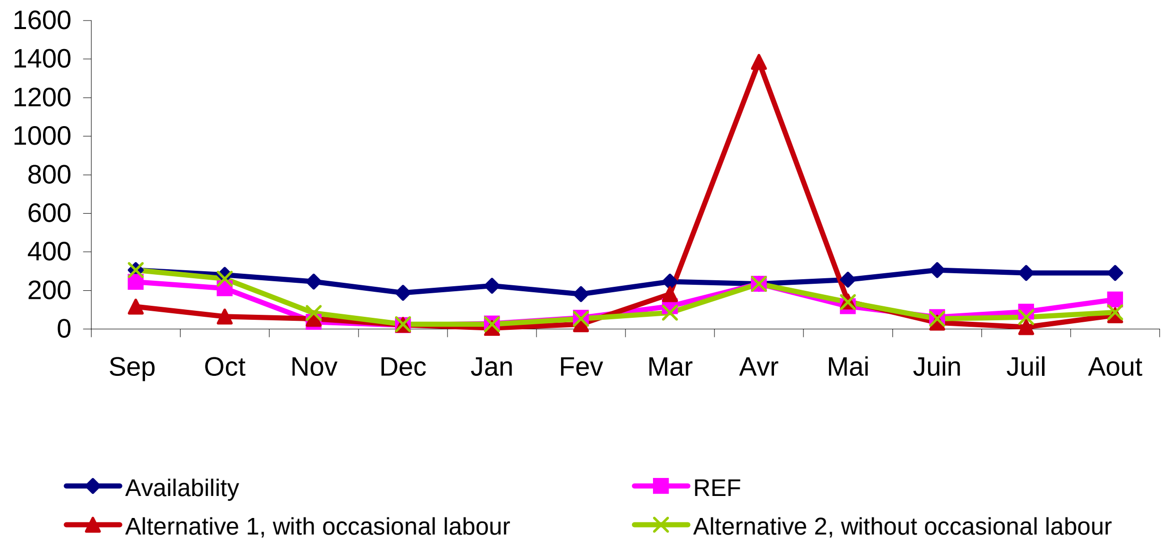


*Figure 8:* Scenario 3 (reducing pesticides), distribution of labor time in farm-type 2

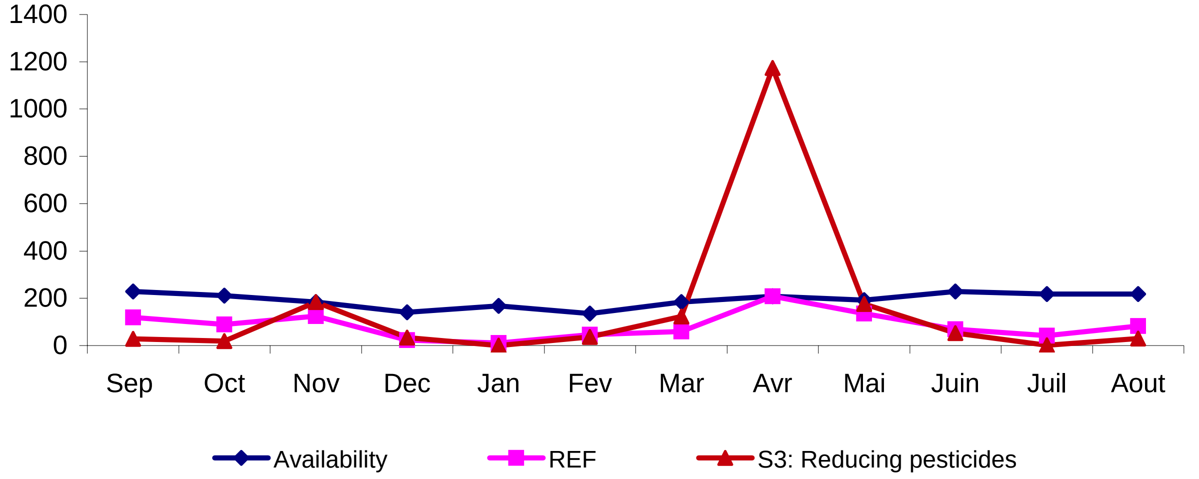



*Figure 9*: Level of incentive according to rate of area converted in no plowing techniques (low level of yield variability perceived: standard deviation = 0.1), farm – types 1 and 2

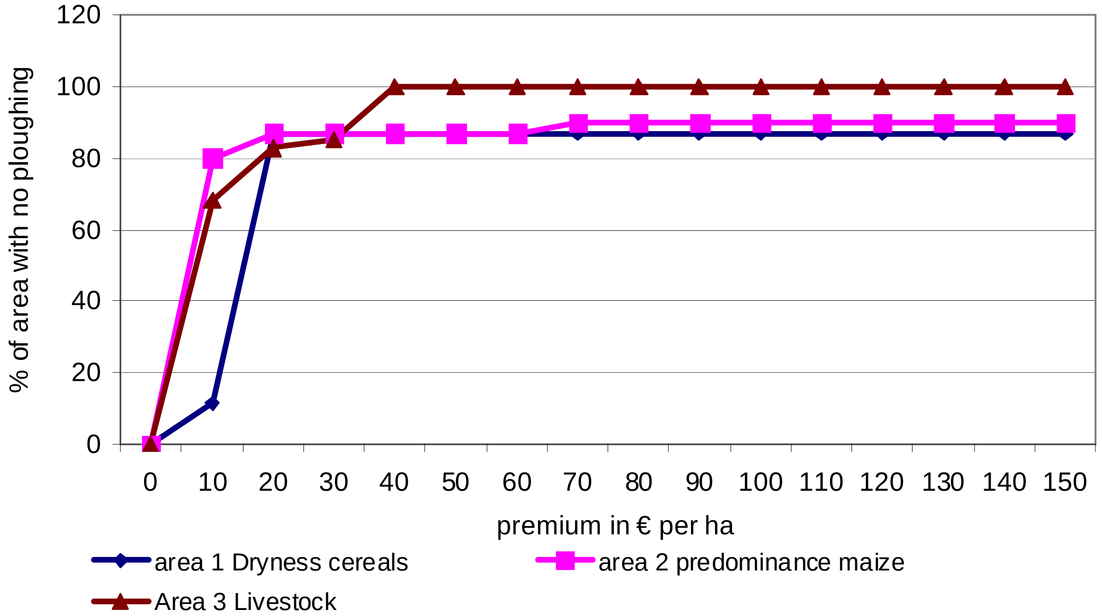


*Figure 10*: Level of incentive according to rate of area converted in no plowing techniques (high level of yield variability perceived : standard deviation = 0.3), farm – types 1 and 2

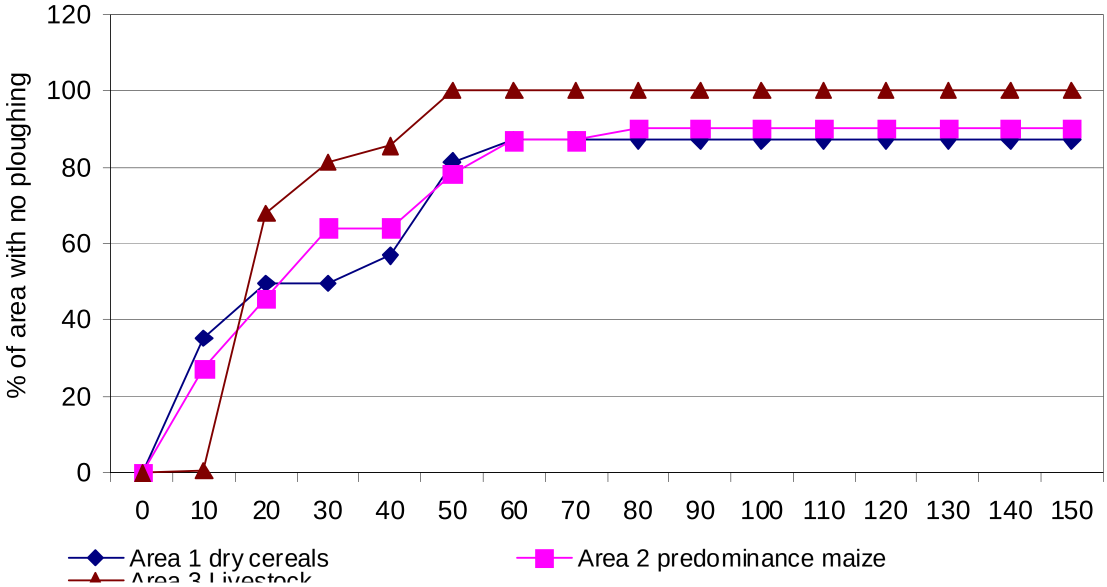
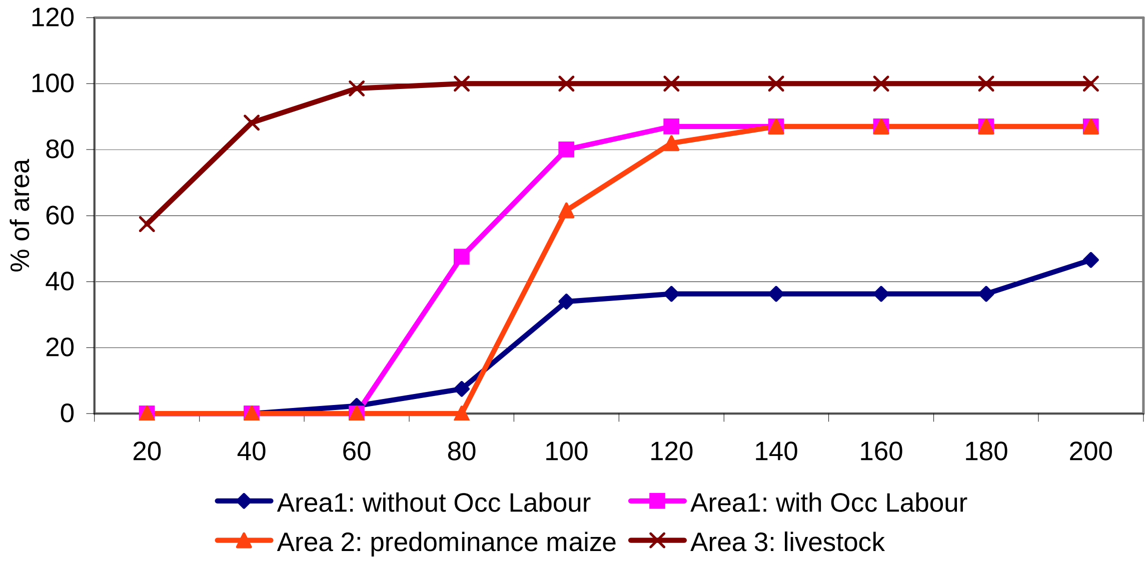



*Figure 11*: Level of incentive according to rate of area converted with reduced pesticide use farm – types 1 (with and without occasional labor available), 2 and 3



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