The adoption of innovative cropping systems under price and production risks: a dynamic model of crop rotation choice

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Abstract

In the paper we investigate the role played by both production and market risks on farmer's decision to adopt long rotations (over 2 years), considered as innovative cropping systems. We build a multiperiod dynamic farm model (run under GAMS) that arbitrates each year between traditional and innovative rotations. With discrete stochastic programming, the production risk is accounted as an intra-year risk; yearly farming operations are declined according to a decision tree where probabilities are assigned. Subjective yield and cost distributions linked to this decision tree are elicited among a sample of 13 farmers that are experiencing this innovation in South-western France. The price risk is randomly distributed with a given market trend. The crop acreage can be revised according to the market situation. The simulations show that substantive sunk costs are incentive to remain in the long rotation when the farmer is already engaged and when he is supported for this engagement. They also show that both a high risk aversion and a highly positive market trend tend to slow down the conversion towards innovative systems.

Keywords: innovative cropping systems, dynamic model, crop rotation decision, risk, subjective probabilities

JEL classification: C61,D0, Q12, Q55

1. INTRODUCTION

French agronomic research teams, jointly with farm extension services and groups of farmers, seek to build up and spread among crop farmers new cropping systems enabling to decrease the polluting pressure at farm level (diminish water, nitrogen and pesticide consumption). In many areas, farmers feel ready to change their practices, because they face more and more soil decreasing fertility or disease-resistance problems due to intensive use of chemical inputs. Innovative Cropping Systems (ICSs) consisting in long rotations (up to seven years) enable to introduce intermediary crops with low level of inputs (legumes or nitrogen-catching crops), while farming practices are slightly rearranged (replacing chemical treatments by mechanical operations or delaying the sowing date for instance). Different cropping systems of that sort have been built up inside two research and development projects in the Midi-Pyrénées region, south-western France. They aim at diminishing the average input usage over the coming years thanks to long rotations strategies. These ICSs are tested "in the field" by several volunteer farmers participating in those projects.

The adoption of ICSs inside the existing crop acreage is perceived by farmers as risk increasing because of the uncertainty about the expected yield of the new practices "in the field" in the presence of climatic risk. This perceived yield risk is also due to the lack of knowledge and experience on the new crop systems. Also, the current instability characterizing the grain market trends could have a negative impact on the adoption of innovations and on investment in general[1].

In this paper, we propose to study the adoption of a long rotation as an alternative to the traditional wheat / sunflower short rotation (without irrigation in both cases), in a context of production and market risk. Agronomists have used an integrated method of prototyping in order to install such cropping systems in interaction with real farms, following in this way the approach suggested by Vereijken (1997) and implemented in other extension networks in France[2].

In this communication, we propose to analyze the innovation adoption under the expected utility framework. We propose to model the adjustment behaviour of the farmer facing both production and market risk during the multiyear rotation, accounting for both intra-year and inter-year risks.

[1] Even if the crop diversification can mitigate market risk when price distributions are negatively correlated, the current trend of increasing and unstable prices seems favorable to the keeping of non rotational crop mix.

[2] Network called "systèmes de culture innovants » http://www.systemesdecultureinnovants.org/.

The modelling of farm rotation choices is still subject to intensive research (see for instance Hennessy, 2007 or Carpentier et al., 2011).The issue of farm acreage decision and farm rotation revisions under risk is also connected with the literature on adoption of innovations. Some approaches of farm innovation are based on historical experimental data that enable to assess the level of risk linked to different cropping systems and to compare them according to the risk distributions (Stanger et al., 2008, Chavas et al., 2009, Acs et al. 2009). These static approaches require an access to historical data about the innovative systems. This is not possible in our case-study since we situate at the very starting point of the innovation experience with no real past data.

Bio-economic modelling approaches can overcome the absence of historical data. In the approach proposed by Blazy et al. (2010) a banana farm model is built that simulates both the biophysical and technico-economic process of resource management under different scenarios of adoption of innovations concerning pest reduction. The model combines a cropping system and a farming system which calculates the performances at farm level from the outputs of the cropping system. This mechanistic farm model enables to test the impact of different technical innovations but it does not raise the issue of adoption in an economic or risk-management perspective. Doole and Pannell (2008) propose to test the value of incorporating pasture inside land-use rotations using an integrated bio-economic model combining a deterministic simulation model of plants and seeds growth with an economic optimization tool (compressed annealing).

Other dynamic approaches enable to account for decision revisions during the innovation process and focus on the role of information in the revision decisions using Bayesian learning rules (Abadi Ghadim and Pannell, 1999) or option values approaches (Isik et al., 2001).

In order to conduct an ex-ante study of the adoption of ICSs, with few historical data, we propose to build a Discrete Stochastic Programming (DSP) model (Trebeck and Hardaker 72, Apland and Hauer 93) that maximizes Expected Utility. We assume that, in order to adopt the ICSs in an uncertain context the farmer needs technical flexibility. Technical flexibility means, for the farmer, the possibility to revise his technical decisions when the economic or climatic context is changing. In order to assess this flexibility, we build a sequential model of decision. The decision variable is the annual acreage, considering the precedent crop. The sequence of intra-year technical operations is entirely depicted, each year, through a decision tree. A level of risk is associated to the different branches corresponding to different sequences of technical operations. Also, a list of possible rotations over several years is determined, considering the innovative rotation as the initial goal, and identifying the different possible revisions along the years. Giving up a rotation-aim, *i.e.* revising the initial rotation implies sunk costs for the farmer since investments have been made to enter the innovation process (Marra et al., 2003, Chavas, 1994).

The decision to revise the acreage decision is influenced by both perceived production risks and anticipated price risk. Subjective probability judgments are directly assessed with a sample of farmers using a visual impact method to evaluate the level of perceived riskiness (Hardaker et al., 94, O'Mara, 80). Risk preferences are obtained through a direct elicitation method.

In the first section of the paper, we expose the dynamic model we built and the main assumptions on farmers' beliefs and preferences. In the second section, we briefly explain the way we obtained the farm data and the farmers' behavioural parameters used to test the model. These data come from three kinds of sources: regional reference data on production costs, experts' interviews to detail the intra-annual farm operations and their possible revisions and field experiments to assess farmers' perceptions and preferences[3]. In the third section, we present the results of several simulations testing the adoption of ICSs under a set of incentives, and analyzing the role played by the degree of risk aversion and different market trends.

2. THE MODEL OF CROP ROTATION CHOICE

The decision variable is the crop sown in year *n* considering the precedent crop chosen in year *n-1*. The crop chosen in year *n* is characterized by a technical pattern *i.e.* a set of technical operations processed all along the year. Different sets are possible, depending on the frequency and intensity of pest treatments and nitrogen applications. Different rotations and rotation lengths are also possible for farmers. The model is maximizing the expected utility of farm gross margin on the planning horizon.

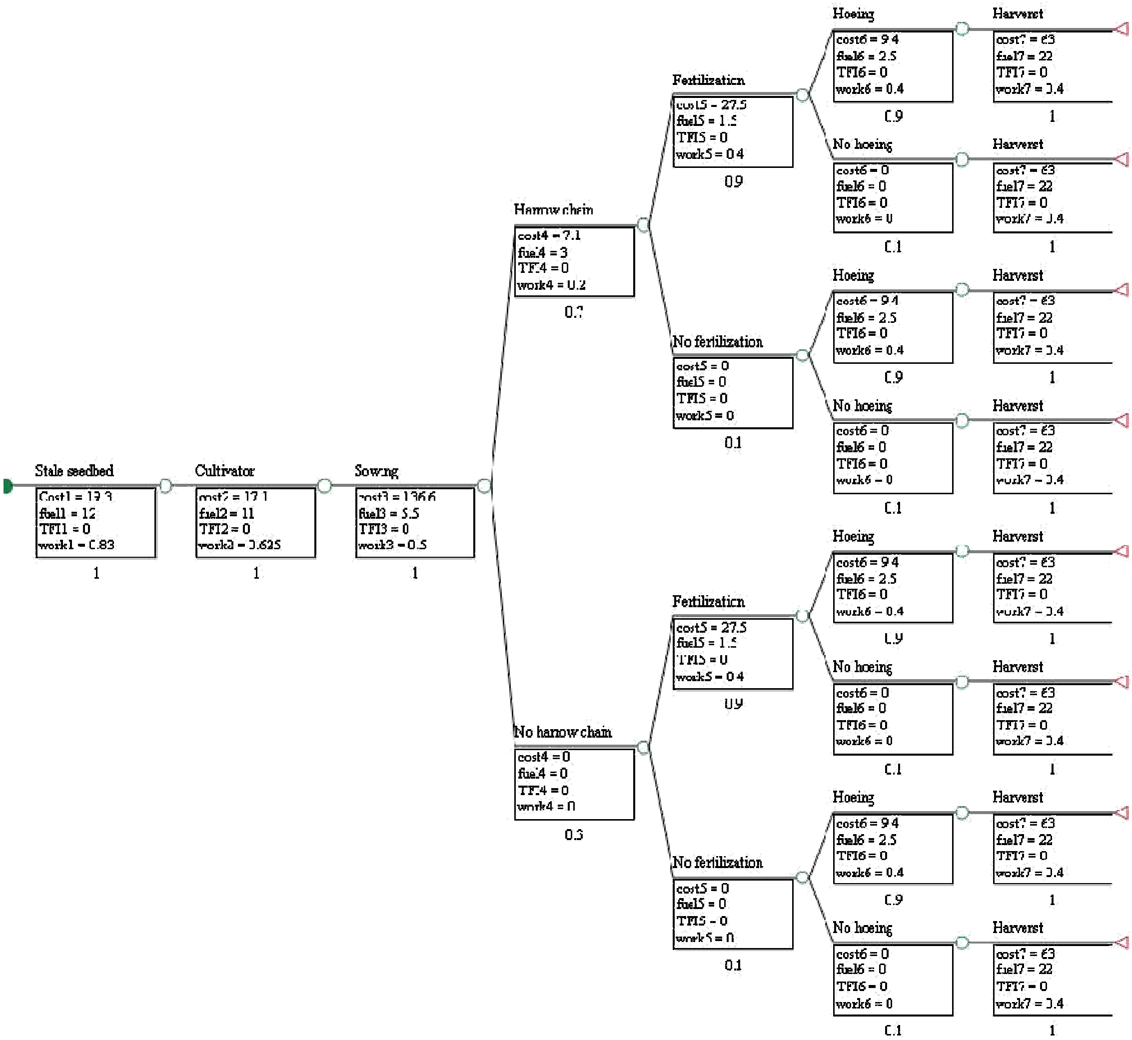
2.1. Decision variables

The innovative crop system studied here is a seven-year crop rotation. A multiperiod model of intertemporal choice is built up. Each year, land use decisions are revisable inside a set of possible rotations, considering the precedent crop and its possible impact on crop yield and the crop price situation anticipated for the coming seven years. Each year, the farmer accounts for both anticipations on yields and prices to take his decision of crop acreage for the coming seven year planning horizon and each year his decisions are revisable: the model is recursive and thus dynamic. Only a succession of seven crops belonging to the initial "innovative" rotation is considered as really innovative. If the rotation is modified meanwhile it is not considered as innovative since the "rotation-effect" is skipped. This several degrees of innovation will be considered: a succession of 2 to 6 crops belonging to the initial rotation will be considered as not totally innovative but as "partially" innovative.

[3] The detailed experimental protocol is not in the scope of this paper

Each year, a set of technical operations is also chosen[4]. The different series of intra-annual technical operations are detailed through a decision tree, each branch corresponds to a set of decisions or a state of nature with a probability associated to each branch. This probability is the combination of the probabilities associated to the different operations. Also, different indicators can be calculated; production cost, labour consumption and an index of frequency of treatments[5]. The decision tree gives a distribution for those variables (fig. 1).

Figure 1: Example of decision tree (traditional soft wheat)



[4] It is possible to vary the frequency and dose of pest and nitrogen applications at different steps of the year. These technical operations will take place according to a decision rule based on observations and agronomics criteria (climactic forecasts, plant health…)

[5] The model returns several outputs: the expected utility of the present value of the cumulated gross margin of the rotation chosen, the level of pest consumption and the level of labor consumption per hectare.

In the model t is the period of the planning horizon. Each period is divided into sub-periods corresponding to the different technical operations. As mentioned before, the decision variable is the crop acreage and it depends only on t.

Among the set of possible crops some are "conventional", and other belong to "innovative" cropping systems (long rotations). Crop succession is controlled by the model: a set of possible precedent is associated to each crop K[6].

The optimization model is choosing a seven-year rotation considering the (K, K') set. This choice depends on the distribution of costs of the intra-year operations, on the distribution of the resulting yields and on price anticipations. The choice is revised each year inside this recursive dynamic model.

2.2. The objective function

The objective function of the recursive multiperiod model is the maximization of the utility of the net present value of total farm wealth (W_t) over the planning horizon; W_t is the actual sum from t to $t+6$ of annual incomes Z_s with ρ being the actual rate of the project (eq. 1).

The Arrow-Pratt utility function is of CARA type[7], r_a being the constant absolute risk aversion (eq. 2).

$$W_t = \sum_{s=t}^{t+6} \frac{Z_{s,t}}{\rho^{s-t}} \qquad \text{(eq. 1)}$$

$$U(W_t) = 1 - e^{-r_a \cdot W_t} \qquad \text{(eq. 2)}$$

2.3. The stochastic parameters of the model

In this discrete stochastic programming (DSP) model, stochastic parameters are the cost, yield and price distributions from which the gross margin distribution per crop is calculated (equation 3).

$$Z_s = \sum_{k \in K, k' \in K} \left[X_{t,s}(k,k') \left(\widetilde{Ya}_t(k,k') \widetilde{Pa}_t(k) - \widetilde{Ca}_t(k,k') \right) \right] \qquad \text{(eq. 3)}$$

$X_{t,s}(k,k')$ is the area per crop k considering the precedent crop k' at the precedent period. $\widetilde{Ya}_t(k,k')$ is the crop yield anticipated in year t : it is the same for all the periods s of the planning horizon and depends only on the preceding crop. $\tilde{P}a_t$ is the price per crop anticipated

[6] This set has been determined by experts (extension services, researchers). Rotations that are impossible in agronomical terms, such as sunflower after sunflower, are prohibited.

[7] Constant Absolute Risk Aversion

in year t. As for yield anticipations, it is the same for all the *s* periods of the planning horizon. $\widetilde{Ca}_t$ is the cost per crop anticipated in year *t*.

The perceived yield $\widetilde{Ya}_t(k,k')$ of crop *k* with precedent *k'* is stochastic. The yield distribution is elicited in the field with farmers already involved in innovative rotations. The Visual Impact method developed in Hardaker et a. 2004 is used. Direct interviews enable to measure the probability judgments of the different crop yields involved in "traditional" versus "innovative" rotations. We checked that each farmer was taking the impact of the precedent crop in the rotation into account when building his yield estimations. This survey enabled to take, ex ante, the perceived riskiness of innovative rotations into account.

Price anticipation: we assume that the farmer anticipates prices at the beginning of each year and for the coming seven years. These anticipations are made according to a normal law in which the mean price is the price observed the year before and the standard deviation is calculated from empirical data observed quarterly between 2008 and 2010 (eq. 4).

$$\widetilde{Pa}_t(k) \sim Normal(\overline{p_t}(k); \sigma(k)) \qquad \text{(eq. 4)}$$

In the model, we simulate stochastic prices with given trend. We will test the sensibility of results to this price trend (eq. 5).

$$\overline{p_t}(k) = (1 + trend)^t p_0(k) \qquad \text{(eq. 5)}$$

The cost per crop $\widetilde{Ca}_t$ is stochastic. The first component is $\widetilde{Ca}_{op}$, it is the distribution of cost calculated for the succession of technical operations corresponding to the decision tree. It is independent of the time period but implicitly depends on *t* because it takes account of the preceding crop.

Since innovative practices involve substantial effort in terms of technical skills, learning and equipment, the second and the third components take account of an extra cost for the investment when an "innovative" crop is chosen (noted *Invest*) and a sunk cost (noted *SunkCost*) in case of return from innovative to traditional cropping system. This sunk cost is both a barrier to entry and to leave innovative cropping systems.

To compensate for these costs, an incentive premium (noted *PR*) is given to each hectare of "innovative" crop following an "innovative" crop (eq. 6). In our case study of experimenting farmers, the support given by the expert network and the knowledge brought by extension services can be considered as an implicit support, symbolised by the premium.

$$\widetilde{Ca}_t(k,k') = \widetilde{Ca}_{op}(k) - PR_{|k\in K_i \cap k'\in K_i} + Invest_{|k\in K_i} + SunkCost_{|k\notin K_i \cap k'\in K_i} \qquad \text{(eq. 6)}$$

3. DATA

The model is applied to cash crop farms of South-western France. These farms have just begun to experience innovative cropping systems, on about 10% of their total agricultural area. A sample of 13 farmers has been surveyed. Data concerning production costs per operation have been collected. An evaluation of individual risk perception (perceived yield variability) and risk aversion has been carried out. We won't give details on this methodology but we present the main outputs of these experiments which will then be introduced as model parameters.

3.1. The decision tree

A decision tree was built for each crop. The different branches describe the different possible management operations for each crop during a production cycle (= a year). Each node corresponds to a revisable operation for which several options have been reported by both experts and farmers when they conceived the new cropping system all together. For each crop, a sequence of management operations has been described; some are certain, others are risky with different states of nature for the risky operations (fig. 1). Interviews of farmers enabled to measure on a frequency-scale farmers' probability judgment on the risk linked to the different operations. Also, several indicators of: costs, labour needs, frequency of pest treatments[8] have been calculated for each operation. Finally the decision tree is detailing, for each crop, the distribution of costs and other indicators. This distribution is individual and depends on the perceptions of each farmer.

3.2. The production costs

The cost is composed of; machinery costs (integrating fuel consumption, mending and depreciation costs) and input costs. Input costs are extracted from the French technological Network on innovative cropping systems[9]. Machinery costs and labor needs per operation depend of the type of equipment. According to the type of equipment, costs are calculated thanks to the database of the French Office for Coordination of Agricultural Machinery (BCMA) and to the reference costs documented in the national inventory of farming practices (© France Agricole 2009 and 2010[10]). The remaining data are collected in local extension services and in specialized technical institutes[11]. The Treatment Frequency Index (TFI) is also calculated for each crop. It accounts for the number of homologated dose of pest treatment per hectare, over a year[12] (tab. 1)

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8 Those indicators are calculated on the basis of existing regional references according to several types of soils and climates.

[9] http://www.systemesdecultureinnovants.org/

[10] http://www.lafranceagricole.fr/gestion-et-droit/chiffres-cles-et-reperes/prix-et-baremes/facons-culturales-le-bareme-des-couts-indicatifs-pour-l-annee-2009-22700.html

[11] CETIOM : technical institute for oilseed crops

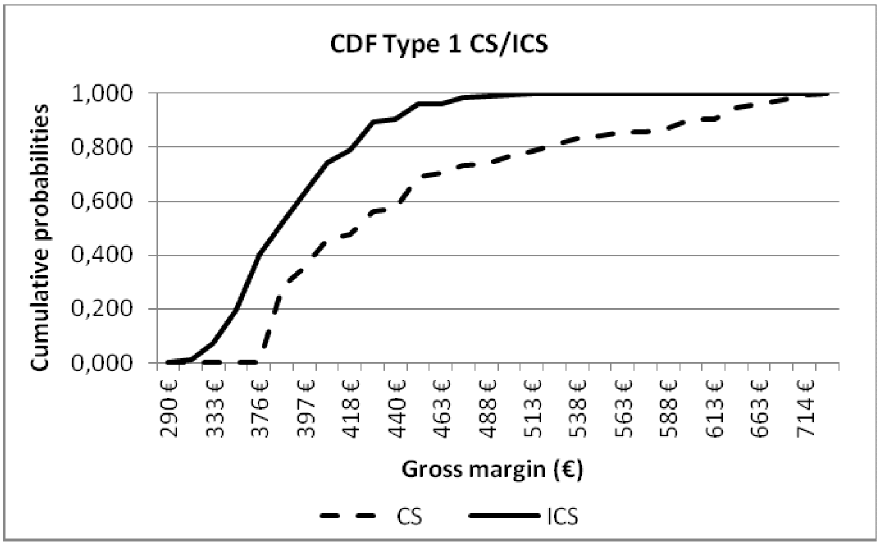
[12] TFI = ((Dose given ×area treated in hectare))/(homologated Dose ×area in hectare))

3.3. Evaluation of the yield risk perceived

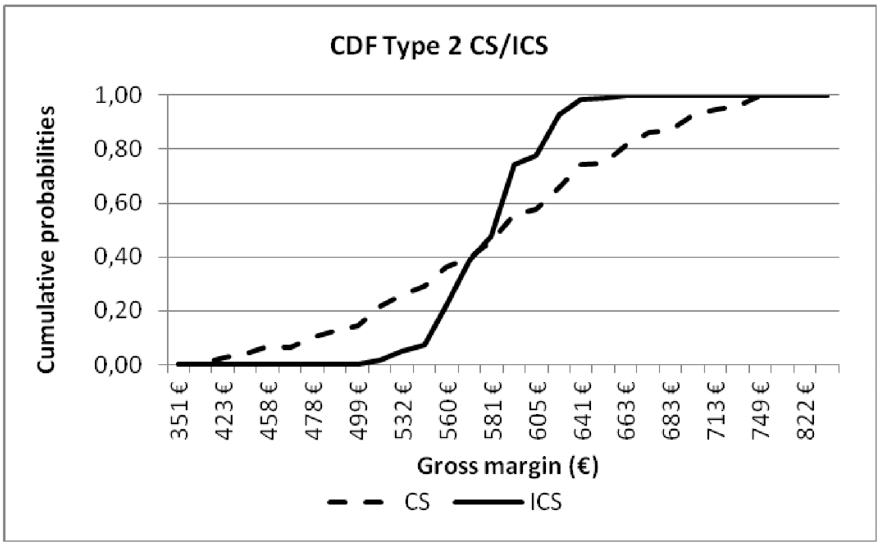
For each crop farmers' probability judgments concerning crop yields variability in the "traditional" and in the "innovative" technology are assessed following the visual-impact method proposed in Hardaker et al., 2004. This subjective elicitation of yield distribution processes as follows: several intervals of yield variability are proposed to the probability assessor between a minimum and a maximum and he is asked to allocate counters to each yield interval. In total, he uses 25 counters. The assessor is not obliged to use all the counters and he can ask for more. The probability of each interval is the ratio of the number of counters allocated to this interval on the total number of counters used. In addition to this, the assessor is asked to evaluate his own degree of confidence in his prediction.

Two distributions are elicited during the field survey on risk perceptions: the production cost distribution and the yield distribution per crop for both "traditional" and "innovative" pathways. Those distributions can be aggregated to calculate the distribution of the total gross margin cumulated during the whole crop rotation. The distribution of the total gross margins obtained, according to both technologies can be compared using first stochastic dominance criteria. This comparison enables to classify the degree of risk subjectively associated by the different farmers to both cropping systems (graphics 1- 3).

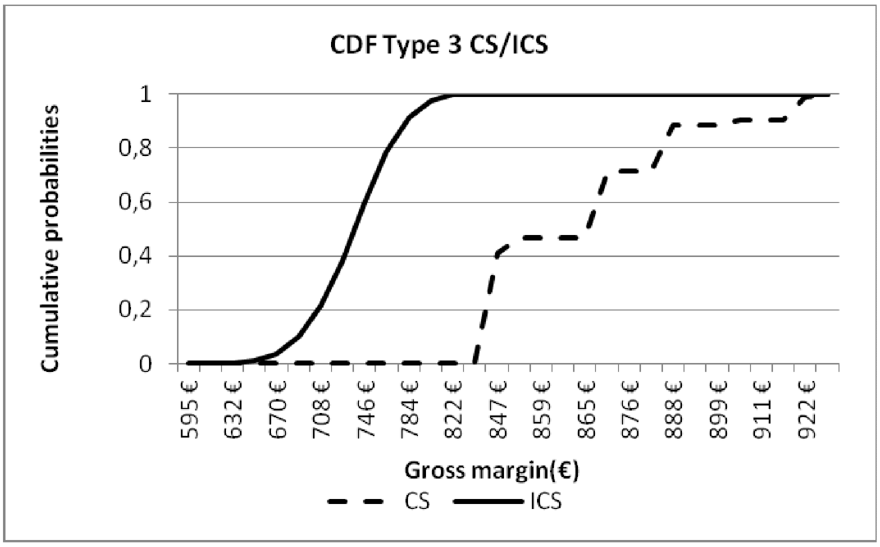
Graphic 1 – Comparison of the Cumulative Distribution Functions (CDFs) of traditional (CS) versus innovative cropping systems (ICS), perceptions of "type 1": high yields expected



Graphic 2 – Comparison of the Cumulative Distribution Functions (CDFs) of traditional (CS) versus innovative cropping systems (ICS), perceptions of "type 2: medium yields expected



Graphic 3 – Comparison of the Cumulative Distribution Functions (CDFs) of traditional (CS) versus innovative cropping systems (ICS), perceptions of "type 3": low yields expected



According to the first stochastic dominance criteria, the traditional cropping system almost always dominates the innovative one. But this classification can be changed according to farmers' preferences. Also, by introducing in the model the possibility to revise the rotation each year, some partially innovative systems could however be preferred.

As a consequence, a gap remains between the a priori gross margin calculated under certainty and the perceived risky gross margin (table 1).

Table 1: Data on certain versus perceived mean yields, costs, prices and variable inputs consumption per hectare for short rotation (wheat/ sunflower) and long innovative rotation

Crops	Soft wheat	Sunflower	Sunflower	Soft wheat	Sorghum	Soft wheat	Peas	Rapeseed	Soft wheat
Year	[1,3,5,7]	[2,4,6]	1	2	3	4	5	6	7
Index of treatment frequency	4,1	2,6	1,3	3	0	3	4,9	5,5	3
Labor (h/ha)	4,1	3,1	3	3,4	3,2	3,4	7,6	8	3,4
Certain Cost (€/ha)	584	428	311	501	281	501	613	688	501
Perceived Cost (€/ha)	510	415	284	366	279	366	596	688	366
Certain yield (t /ha)	6,2	2,5	2,4	6	7,6	6	3,4	2,5	6
Perceived yield (€/ha)	7	2,9	2,4	6,6	7,5	6,6	3,5	2,9	6,6
Market price (€/t)	205	375	375	205	150	205	260	600	205
Certain Gross margin (€/ha)	687	509	589	729	859	729	271	812	729
Perceived Gross margin (€/ha)	925	673	616	987	846	987	314	1052	987
Cumulated certain gross margin (€/ha)		4275							4718
Cumulated perceived gross margin (€/ha)		5719							5789
Perceived standard deviation (€/ah)		292							468

3.4. Risk aversion

The risk aversion has been elicited through a field experiment among 13 crop farmers under CRRA structural model based on lottery games, similar to the one used by Holt and Laury (2002), Tanaka et al (2010) and Bocquého et al., (2011) [13]. The structural model assumed is an expected utility model with a CRRA. With a profit function noted π, the utility function is $U(\pi)=\pi^r$, r being the coefficient of relative risk aversion. Our estimations give a coefficient varying from 0.69 to 0.85 among the different farmers who thus exhibit a high level of relative risk aversion.

[13] The protocol is divided into two independent tests. The first one is composed of four series of lotteries. On each line (14 lines per series) the farmer has to choose between two lotteries A and B. He can switch from A to B at the first line or later. The probabilities of the two lotteries are unchanged, while the amount of gains or losses varies. The second test is built according to the same principle. Four series of lotteries are proposed to the farmer, and he has to choose at which line he switches from A to B. This time, the values of gains and losses are unchanged while probabilities are varied. In order to validate the protocol one of the lotteries can return a pecuniary gain between 3 and 135 € to the farmer.

4. SIMULATIONS, RESULTS

In this section, we propose several scenario simulations with the model exposed in the first section, incorporating the data obtained through the field surveys presented in the second section. We will test the impact of several parameters on the adoption of Innovative Cropping Systems. The first scenario concerns the impact of sunk costs on adoption, considering a given level of investment attached to innovative crops and a given level of incentive premium mitigating this investment cost. In the scenario 2, we test the impact of the level of risk aversion on adoption, and then, in scenario 3 we test the role of different market price trends (tab. 2).

Table 2: the scenarios tested

	Scenario 0	Scenario 1	Scenario 2	Scenario 3
ρ actual rate (%)	3	3	3	3
r (relat. risk aversion)	0.7	0.7	**0.2 to 1.7**	0.7
Price trend (%/year)	+5	+5	+5	**1% to 9%**
Invest (€/ha)	**0**	90	90	90
Sunk cost (% of Invest)	**0**	**0% to 90%**	50%	50%
Incentive PR (€/ha)	**0**	120	120	120

The farm type on which those simulations are performed has an average size of 100 ha it is specialized in cash crops, with no other possible farming activities.

We analyze the simulation results according to two types of indicators. First, we monitor the way the crop acreage is changing during the 7-year planning horizon. Second, we assess the share of ha entering to and exiting from innovative techniques during the 7-year planning horizon. Three types of land use corresponding to 3 levels of breakdown will be reported:

- a total adoption of the 7-year rotation (noted Entire ICS).
- a longer than 3-year rotation (less than 6-year) occurring at any moment of the 7-year horizon will be considered as a partial adoption of the innovation (noted PARTIAL)
- a continuous cropping of one type of crop or of a two-year rotation (whatever crop is concerned among the seven possible crops) is considered as a conservative choice and a keeping of the "traditional" system (noted TRADI)

4.1. Baseline : results of scenario 0

In the baseline scenario, we set the value of investment, sunk costs and premium to zero. In this situation, since innovative crops are perceived as more risky by most farmers, it is not surprising to obtain a minority of the farm area under partial adoption (less than 6 years ; 4.5 hectares) almost no adoption of the entire ICS (0.3 ha) and a major part of the farm acreage (95.2 ha) under "traditional" short term rotation.

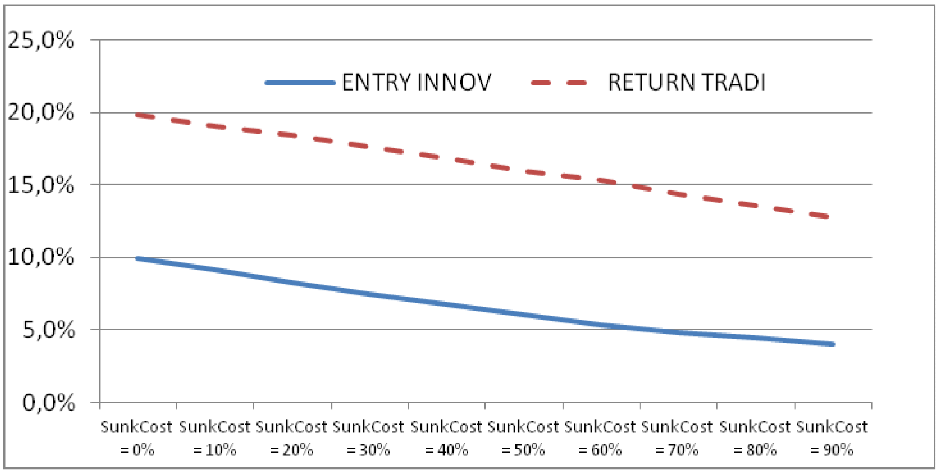
4.2. Influence of sunk costs on adoption

As written in equation 6, innovative practices involve substantial effort in terms of technical skills, learning and farm equipment. Unfortunately, this effort, composed of quantifiable and unquantifiable costs (similar to transaction costs), and which represents a barrier for adoption, has not been totally quantified in this study. However we consider that these costs are implicitly revealed in farmer's risk attitude. To compensate for this effort, we attribute a positive value to the premium *PR* given to each hectare under innovative crops succeeding another innovative crop.

After sensitivity analysis, we propose to set the value of investment to 120€/ha and the level of crop premium to 90 €/ha. In these conditions, we test the impact of sunk costs: in case of breakdown of the innovative rotation, a share of the investment costs won't be recovered. Those sunk costs are assessed in terms of percentage of the investment costs (tab. 2).

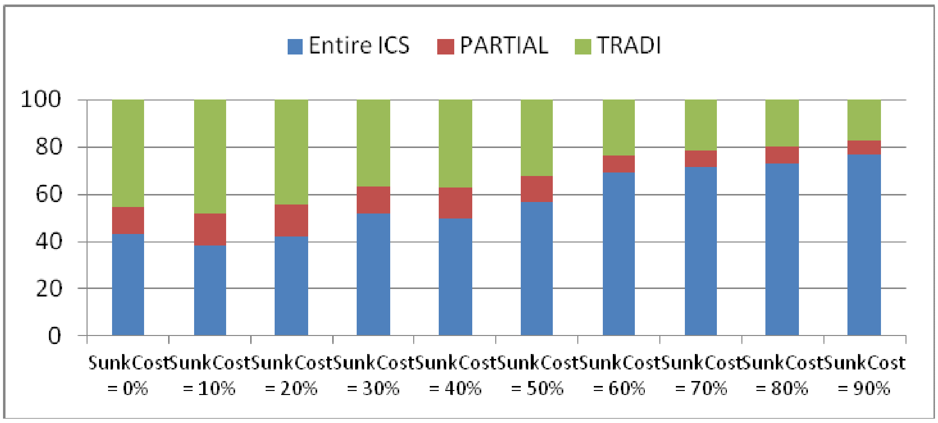
In absence of sunk costs, but with a compensatory premium *PR* for each hectare converted as "innovative", the farmer is encouraged to temporally switch to non-innovative crops that are more profitable (especially when prices are varying). This behaviour is not realistic because of the sunk costs successive to the investment in innovative systems. Thus, we are varying the sunk costs in order to test which level can prevent the farmer from switching too easily from innovative to traditional system (graph. 1).

Graphic 1: Share of farm area switching between traditional and innovative, according to the weight of sunk costs



As assumed, the graphic 1 show that the greater the sunk costs the more stable the decision to engage in innovative systems through time. In the same time, sunk costs make farmers more reluctant to engage in costly innovative practices and decrease the mean share of area engaged in longer than 3 year rotations (graph. 2)

Graphic 2: Farm average acreage on the planning horizon: share of area under partial or total adoption of innovative rotation, according to the level of sunk costs



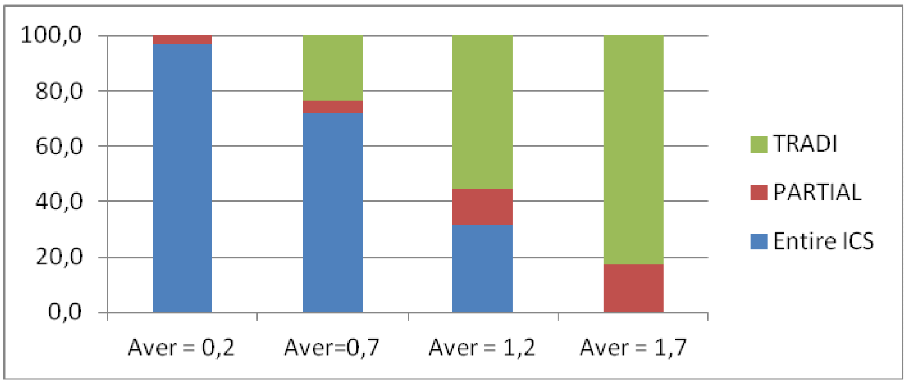
When sunk costs represent 50% of the investment, the level of adoption of the entire ICS is about 50%, which is significant. This level is achieved with a high level of both investment and sunk costs and if a compensatory premium is distributed, disconnected from investment.

4.3. Influence of risk aversion on adoption

The coefficient of relative risk aversion we revealed through the field survey among farmers is rather high, around 0.8, for all farmers. Since innovative systems are also perceived as more risky, it is clear that, with a CRRA utility function as chosen in the model, innovative systems are not favoured.

Now we propose to vary the risk aversion coefficient, between low level (0.2) and high level (1.2). It is clear in our simulations that low levels of risk aversion (below 0.7) tend to favour longer rotations that are perceived as more risky (graph. 3).

Graphic 3: Farm average acreage on the planning horizon: share of area under partial or total adoption of innovative rotation, according to the level of risk aversion

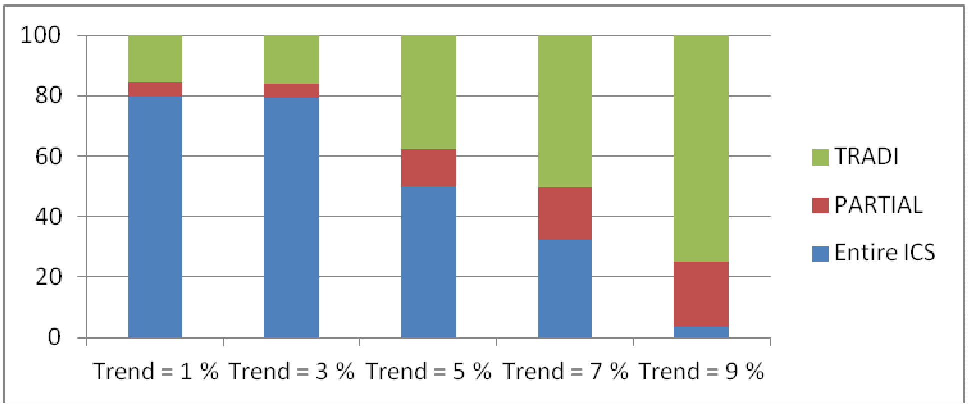


4.4. Influence of market trends on adoption

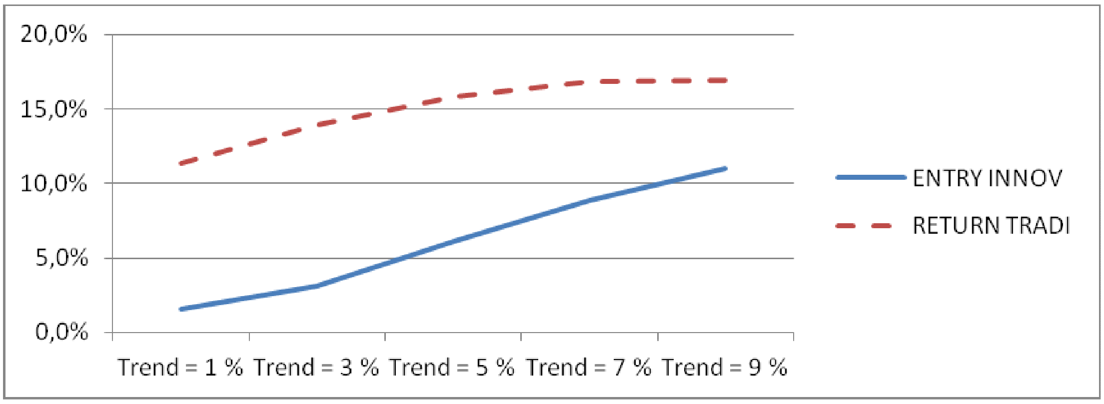
In the former scenarios, we assume that the farmer anticipates a 5% steady trend of rising prices. We now simulate other steady trends (graph. 4). The simulations show that when the price trend is positive and gets higher, the farmer chooses more lucrative crops, "innovative" or not. The results show a more frequent breakdown of the long rotation. In graphic 5, we can check that when the positive price trend gets higher, the farmer tends to switch more frequently between innovative and traditional systems.

When we simulate a negative steady price trend, the crop acreage decisions change in the opposite way: highly negative price trends tend to favour innovative crops, which benefit from compensative premium *PR*.

Graphic 4: Farm average acreage on the planning horizon: share of area under partial or total adoption of innovative rotation, according to the price trend



Graphic 5: Share of farm area switching between traditional and innovative, according to the market trend



5. CONCLUDING REMARKS

The dynamic model of crop rotation under risk enables to test the adoption of complex agronomic innovations in presence of both yield and market risk. We base our simulations on the use of data from real experimenting farmers (evaluation of perceptions of yield-risk). The results show that innovative systems (long rotations) are almost always perceived as more risky than short rotations, in terms of production risk. The engagement in long rotations brings about investment costs for farmers that are partly irrecoverable (sunk costs). By assuming the existence of positive sunk costs, our simulations show that long rotations are attractive when they are supported by an incentive premium. In the case study, some farmers have already began to experiment long rotations and this premium is symbolised by the support targeted to farmers in the form of technical advice, knowledge, information, data... This support is brought by extension networks. The results of our model simulations show that under production and market risk, both risk aversion and positive market trend tends to discourage the long term engagement of farmers in long rotations. Market forces seem to have a major influence in short term that counteracts farmers' long term efforts to improve their environmental output.

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