Multi-peril grassland insurance, self insurance and forage stock dynamics:
a Discrete Stochastic Programming framework applied to suckler cow farms

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Abstract

The French government and private companies are currently working on a scheme to insure grassland against unfavourable weather conditions. Objectives of this study are 1) to analyse how grassland yield insurance would substitute for self insurance in suckler cow farms, 2) to assess efficiency of these insurance options and 3) to test effects of public supports on insurance demand and profit distribution**.** To meet these objectives, simulations have been performed thanks to a bio-economic model applied to French suckler cow farms. Different scenarios enables to isolate effects of risk aversion and self insurance, of market insurance, of insurance premium subsidies and additional direct payments. Self insurance is defined as the reduction of animal stocking rate compared to the stocking rate of a risk neutral farmer. Self insurance alone enables to reduce profit variability by 55 % but sensitivity to extreme yield conditions remains high. Rather risk-averse farmers will use both self insurance and market insurance to secure their farm against risk. Profit variation is divided by 70 % and the lowest value of profit increased by 400 %. Market insurance can indeed cover farmers the lowest forage yield at a lower cost than self insurance. Market insurance demand varies from one year to the next according to the availability of extra forage stocks. Both subsidies on insurance premium and a raise of direct payments induce an increase of expected profit and reduce value of the lowest profit. Premium subsidies decrease also standard deviation in spite of a slight increase of animal stocking rate.

Keywords: insurance, bio-economic model, risk, livestock production

Code JEL : Q1 14

Introduction

Suckler cow farms, also called cow-calf operations are an important feature of French agriculture. It consists in producing calves for later sale with a permanent herd of cows. The principal source of feed of those systems comes from grassland production which is sensitive to weather conditions. **Suckler cow farmers have different on-farm options for managing grassland production variability**. They encompass *ex-ante* options to mitigate risk exposure such as the creation of forage production overcapacity or forage diversification and *ex-post* options to limit impacts of unfavourable weather shocks such as adjustments of land management, animal diets and animal sales (Lemaire, et al., 2006). Until now, grassland yield has been considered as non insurable in France. Consequently, since 1964, grasslands could receive indemnities from a public fund in case of natural calamities. Different market failures could explain the absence of private insurance. First, the correlation of many natural disaster risks across widespread geographical areas requires reinsurance which could be extremely costly for insurance companies (Miranda and Glauber, 1997). Second, risk exposure and weather related damages on grassland are difficult to estimate: grass is an intermediate product which can be both grazed almost all year round and harvested at various periods. However, following other countries such as North America or Spain, **the French government plans to progressively switch from this public calamity fund toward multi-peril grassland insurance** in order to better control its budget and to offer farmers better indemnification of production losses. Both technological developments such as estimation of pasture yield by satellite and negotiations regarding public reinsurance of the companies' underwriting risk offer opportunities for the development of such an insurance. In accordance with Common Agricultural Policy rules, a subsidy up to 65 % of insurance premium paid by the farmer is planned in order to foster farmers participation. Farmers participation is indeed often well below the levels desired by policy-makers (Knight and Coble, 1997). In parallel, **CAP direct payments will certainly be augmented for suckler cow farms** with the post 2013 CAP. These payments contribute to reduce farm income risk. **Understanding the interactions between these different risk management tools is at stake** and stresses different issues. What should be the role of public support in this risk management framework? Tangermann (2011) emphasizes that "public policy should not absorb risk that farmers can manage themselves, be it on the farms or thought market instruments" (p8). Skees (1999) underlines that the general taxpaying population should not pay farmers to take on additional risk. This could happen if an increase in wealth thanks to public support (Hennessy, 1998; Finger and Calanca, 2011) reduces risk aversion. In addition, if private insurance is a substitute of self insurance, the demand for self insurance would decreases when the insurance premium price is reduced by public subsidies. Horowitz and Lichtenberg (1993) demonstrate for instance that US crop farmers use more chemicals which are supposed to be risk increasing when insured. In the same way, according to Serra, et al. (2003) and Sakurai and Reardon (1997) farms with enterprise diversification thanks to animal production are less likely to ensure their crops. Conversely, other econometric surveys found that farmers who take out a crop insurance contract are more likely to spread sales (Velandia, et al., 2009) or diversify crops (Enjolras, et al., 2012). However, one limit of these studies is that the effect of substitution between insurance options can hardly be isolated from other effects such as risk aversion that could both increases the demand for self insurance and market insurance.

Objectives of this study are 1) to analyse how grassland yield insurance would substitute to self insurance in suckler cow farms, 2) to assess efficiency of these insurance options, 3) to test effects of public supports on insurance demand and profit distribution.

This paper focuses on a typical self insurance option: the **creation of forage production overcapacity** (the average herd forage demand is below forage production potential) and **forage stock surplus** (the quantity of forage stored is higher than the current annual herd need). Models give the opportunity to provide a better understanding of complex systems such as livestock production ones. A simple **theoretical model is presented in section 1** in order to emphasize how self insurance and market insurance interacts and the main determinants of substitution between self insurance and market insurance. To better represent relations through time between animal components, forage production, economic and political context, decision making, **simulations have been performed in section 2** thanks to a discrete stochastic programming model. This model enables to take into account **the dynamics of forage stock** which impact on farm capacity to face grassland yield production.

1. Theoretical model

The objective of this simple model is to set up a theoretical framework for analyse the demand for two ex-ante risk management instruments: market grassland yield insurance and self insurance by the mean of low animal stocking rate that provides forage production surplus. The framework proposed is inspired by Ehrlich and Becker (1972).

Suppose an individual is faced only with **two states of the world** $\{0,1\}$, with probabilities $\{p,(1-p)\}$. The **grassland yields** are for those states respectively $\{Y-\alpha,Y\}$. **Incomes** are denoted $\{I_0,I_1\}$ and with insurance $\{I_0^e,I_1^e\}$. The insurance premium is the difference between income without and with insurance in state 1. This expenditure encompasses the amount of money transferred between state 1 and state 0, denoted s, multiplied by the "price of insurance", denoted π. *s* equals the difference between income with and without insurance in state 0. The price π depends on the probability *p*, on the loading cost *λ* which benefits to insurance company, and on a subsidy rate δ offered by the government. **Insurance premium** is defined as follows :

$$I_1 - I_1^e = (1-\delta)\lambda p\left(I_0^e - I_0\right) = \pi s \qquad (1)$$

Suppose the **optimal herd size** for a risk neutral farmer is LU^i. Forage need is supposed to be proportional to herd size (γLU) and to lie between Y-α and Y (outside this range, optimal herd size does not depend on on-farm grassland production). **Self insurance** is defined as the reduction of herd size $\left(LU^i - LU^e\right)$. The self insurance expenditure includes foregone expected animal profit which concerns both states. Assuming that the totality of forage surplus is harvested and stored, herd size reduction also induces additional haymaking costs in state 1.The **cost of self insurance**, denoted *c(LU^e)*,is modelled as:

$$c_1(LU^e) = I_1 - I_1^e = (\beta priA - v)(LU^i - LU^e) + priST.\gamma(LU^e - LU^i)$$

$$c_0(LU^e) = (\beta priA - v)(LU^i - LU^e) \qquad (2)$$

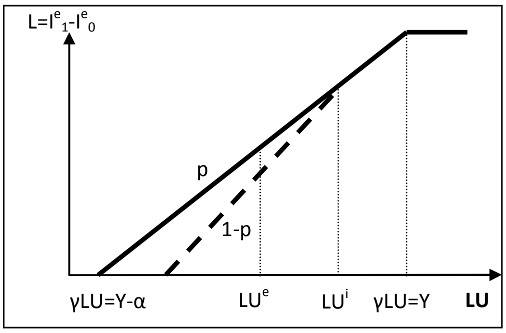
With β the quantity of beef sold per LU, 'priA' beef price,'v' : costs proportional to herd size, LUi the optimal stocking rate of a neutral farmer, priST the harvest and storage cost of forage, γ the forage requirement per LU.

The **endowed loss**, defined as $L(LU^e) = \left(I_1^e - I_0^e\right)$, is illustrated in figure 1. Within [Y-α; Y], loss is presumed to increase linearly and some forage is purchased in state 0 if $\gamma LU^i > Y-\alpha$. The expenditure is decreased thanks to forage surplus constituted in state 1 during the previous year with the probability (1-p). The loss can be written as follows:

$$L(LU^e) = I_1^e - I_0^e = priF.X_0^e - priST(\gamma(LU^e - LU^i)$$
$$L(LU^e) = priF.(\gamma LU^e - (Y-\alpha) + (1-p)(Y - \gamma LU^e)) - priST(\gamma(LU^e - LU^i) \qquad (3)$$
$$L(LU^e) = priF.(\alpha - pY + p\gamma LU^e) - priST(\gamma(LU^e - LU^i)$$

priF is the value of market substitute to on-farm forage, γ is forage need per LU,

Figure 1: Loss according to herd size in Livestock Units.



Under self insurance income in state 0 could be expressed as $I_0^e = I_0 + L(LU^e) - c_o(LU^e)$ and under market income as $I_0^e = I_0 + s$. **When both self insurance and market insurance are available and chosen simultaneously**, the expected utility can be written as:

$$U = (1-p)U(I_1) + pU(I_0) \leftrightarrow$$

$$U = (1-p)U(I_1^e + c_1(LU^e) + s\pi) + pU(I_0^e - L(LU^e) + c_0(LU^e) - s) \qquad (4)$$

Suppose Y- $\alpha \leq \gamma LU^i \leq$ Y. If the price of market insurance were independent of the amount of self-insurance, the first order optimality conditions would be:

$$\frac{\partial U}{\partial s} = \pi(1-p)U_1' - pU_0' = 0 \rightarrow \pi = \frac{pU_0'}{(1-p)U_1'} \qquad (5)$$

$$\frac{\partial U}{\partial LU^e} = (\beta priA - v + \gamma priST).(1-p)U_1' - pU_0'(p\gamma priF - \gamma priST + \beta priA - v) = 0$$

$$\rightarrow \qquad \frac{\beta priA - v + \gamma priST}{p\gamma priF - \gamma priST + \beta priA - v} = \frac{pU_0'}{(1-p)U_1'} \qquad (6)$$

Combining equations (5) and (6) and replacing π by (1-δ)λp, we get that, **in equilibrium, the shadow price of self insurance would equal the price of market insurance**:

$$\frac{\beta priA - v + \gamma priST}{p\gamma priF - \gamma priST + \beta priA - v} = (1-\delta)\lambda p \qquad (7)$$

For a given utility function, a decrease in market insurance price (lower loading cost λ or higher subsidies *δ*) would increase the demand for market insurance and reduce self insurance. Conversely, a decrease in beef price (*priA*), in level of animal production sold per LU (β), in grass quantity into animal diets (γ) or in conserved forage making cost would foster herd size reduction that is to say self insurance. A raise in price of substitute to on-farm forage (*priF*) or in proportional herd costs would also favour self insurance. The shadow price of self insurance decreases with higher probability of loss *(p)* while the shadow price of market-insurance increases. For rare losses, market insurance is likely to be more attractive.

This simple theoretical model points out three different kinds of determinants: characteristics of the animal production process (animal diets, types of animal produced), economic conditions (prices of inputs and outputs, prices of insurance, rate of subsidies) and the distribution of grassland yields. However, this model face limits. First, only two states of nature and a single year are assumed. Second, the production system is simplified a lot, ex-post adjustments are restricted and the CAP supports not represented. Eventually, impacts of risk preferences and wealth on insurance demand could not be analysed with this model.

2. Simulations thanks to a discrete stochastic programming model

This application aims at analysing how self insurance and market insurance interact in French suckler cow farms in a given economic context (average prices and cap conditions over the period 2008-2012). The demand for self insurance (decrease of herd size) and market insurance are simultaneously estimated under different public supports scenarios: subsidized insurance premium and additional direct payments. Insurance costs and distribution of profits are analyzed.

a. Model description

Our model aims at simulating a suckler cow enterprise under forage production risks. To represent farmers' decision making, we assume that they optimise their decisions regarding herd size and herd composition, animal diet, animal sales and grassland management over a two year planning horizon. The simulated year starts in April at the beginning of the grazing season and is divided into six periods. Both risk anticipation and risk adjustments within and between years are taken into account. Technically, this is modelled thanks to a discrete stochastic programming optimisation model that is resolved by the non linear programming solver CONOPT run in Gams. Compared to previous versions of this model (Mosnier, et al., 2009, Mosnier, et al., 2011), the number of states of forage yield anticipated has been raised to five to take into account extreme events but the planning horizon reduced to 2 years. It is parameterized to represent a charolais suckler cow enterprise based on grasslands located in the Northern part of the Massif Central in France.

i. Time and risk anticipations

Farmer decisions depend on their expectation regarding their future profit. The future encompass two dimensions: the possible weather conditions anticipated for each period and the length of the time horizon. Two kinds of risks can be anticipated: embedded risk which occurs when farmers plan to adjust their decisions following the realization of an uncertain event, and, non-embedded risk if risks are expected to affect profit but without real possibility for the farmer to reduce their impacts *a posteriori* (see also Hardaker, 2004). Previous works (Mosnier, et al., 2009, Mosnier, et al., 2010, Mosnier, et al., 2013) emphasized that grassland yield shocks involve many adjustments of the production systems, namely adjustments of animal diet composition, of feed product trade and haymaking. Hence**, between year grassland yield variability is introduced as embedded risks.** It involves that bimonthly decisions are differentiated after the realisation of the grassland yield event. In order to take account impacts of successive weather events while keeping the model tractable, only two years are considered which corresponds to a probability tree with two nodes. An infinite horizon or a very long planning horizon is often thought preferable since it can influence the long term equilibrium and how fast it is reached. However, in our case, the initial state of the system is optimised and corresponds already to the equilibrium state under current information.

ii. The optimization program

Barn capacity (and consequently average herd size) and initial herd composition are optimized and cannot be revised according to the realisation of weather event. Bimonthly animal sales, diet composition, purchases or sales of feed stuff and areas harvested are optimised for each branch of the probability tree. Decisions are those that maximise the objective function *Z* which is defined as the expected utility of profit (*Π)* over a finite planning horizon plus the discounted expected value of residual hay stock SV_T minus the value of initial hay stock SV_0. The utility function can be either modelled by a functional form or be summarized by its central moments. As mentioned by Coffey, et al., (2001), the esperance-variance is a strong and widely used analytical tool. However, this specification supposes that farmers have the same aversion for positive deviations from average profit as for negative ones and it overlooks the impact of production decisions on higher moments, in particular if producers may wish to reduce the variance of the likelihood of “downside” outcomes (see Antle 1983b; Groom et al. 2008). Since this application is devoted to insurance, the left-hand tail of the distribution of profit is important. The functional form used here is the **power function** as defined in Hardaker, (2004). It exhibits constant relative risk aversion (CRRA) as generally assumed. This means that the lower the level of profit, the higher the penalty applied. In order to have value on the same scales and to avoid applying a high penalty on low or negative stock variation with the power function, the inverse utility function is applied to the expected utility of profit.

$$Z = \sum_{t=1}^{T} \left(\frac{1}{1-r}\right)^{t-1} \left(\sum_{\zeta} prob(\xi).\Pi_{t,\xi}{}^{1-\gamma}\right)^{\frac{1}{1-\gamma}} + \left(\frac{1}{1-r}\right)^{T} E(SV_{T,\xi}) - SV_0$$

iii. Grassland production

In the studied area, most animals graze from April to November and are fed inside at trough in winter. The bi-monthly average yields *(y)* and forage quality characteristics (table 1) are calculated thanks to a sub model of herbage growth developed by (Jouven, et al., 2006).

Table 1: Average characteristics of Grass production within year

	April-May	June-July	Aug.-Sept.	Oct.Nov.	Dec-March
Quantity	25	16.0	11.0	6.0	0
Fill value	107	105	110	120	/
Energy content	87	85	79	63	/

Forage production varies between years in quantity, quality and in the distribution of these parameters within years. Taking into account all facets of grass production variability would require a very complex model of production anticipation. We choose here to focus on variation of total production yields as do most multi-peril crop insurance programs and suppose that the same deviation to average yield occurs at the different seasons. The distribution of grassland production between years is summarized by five states of nature [c1,..,c5]: c1 corresponds to severe loss (<-30 % of average yield), c2 to moderate one (between -30 % and -10 %), c3 to average level (between -10 % and +10 %), c4 to moderate surplus (between +10 % and +30 %), and c5 to high surplus (>30 % of average yield). Average deviations of grassland yield for the 5 states of nature and probability of occurrence of these states (table 2) are parameterized thanks to Isop[1] estimations for 9 areas within the northern part of the Massif Central over the period 1980-2010.

Table 2: Characteristics of the five state of nature for weather risks (from c1 to c5) for the studied area over the period 1980-2010

	C1	C2	C3	C4	C5
Class variation	<-30%	[-30%;-10%[	[-10%;+10%[	[+10%;+30%[	>+30%
Probability	12 %	20 %	36 %	20 %	12 %
Average yield deviation	-40 %	-19 %	0 %	19 %	40 %

iv. Feed Stock

For this study, we consider 100 ha of the grassland area. Grassland area is used either for grazing or haymaking. The share of land harvested at each period is optimized. In order to take advantage of production surplus or to face production losses, between year adjustments of this area is allowed but limited at more or less 10 % of the total grassland area. Modifying the initial harvest planning is assumed to have some drawbacks and is penalized since to be efficient, grazing or haymaking need to be anticipated. The usable grass is then less than the standing biomass. Harvested hay quantity is also decreased by 20 % to account for losses during haymaking, harvest, transport etc. Two other products are considered: grain and straw (only used as litter).

The **quantity of standing grass** available in one period corresponds to the remaining balance between previous biomass stock (cut by losses due to senescence and abscission[2]), grass produced and grass exports (grass grazed and haymaking). This quantity is set to 0 during winter.

Stock of hay is defined as the balance between inputs (production harvested or bought) and withdrawals (herd consumption and sale) plus the stock remaining from the previous period. Defining initial stock is crucial since it will limit impact of grassland yield variation. In order to have a value consistent with the production system, initial stock ("S_0") is constrained to be equal to the expected difference between hay harvested and consumed ("H") for neutral or favourable sates of nature "ξ" (c3 to c5). We hypothesise that there is no stock provision when grassland yield is unfavourable.

[1] the Isop[1] device implemented by the Inra research institute, Meteo France (French establishment for meteorology) and the SSP (Service for Statistics and Prospective of the French department of Agriculture. Grassland yields are estimated thanks to a version of the STICS model for grasslands Ruget, F., S. Novak, and S. Granger. 2006. "Du modèle STICS au système ISOP pour estimer la production fourragère. Adaptation à la prairie, application spatialisée." Fourrages 186:241-256.) http://www.agreste.agriculture.gouv.fr/IMG/pdf/syntheseprairie0904.pdf

[2] Delaying the use of grass production leads to standing biomass losses because of senescence (deterioration related to ageing process) and abscission (shedding of dead matter) processes Jouven, M., P. Carrere, and R. Baumont. 2006. "Model predicting dynamics of biomass, structure and digestibility of herbage in managed permanent pastures. 1. Model description." *Grass and Forage Science* 61:112-124..

$$S_0 = 0.5.\frac{\sum_{\xi_{t1}=c3}^{c5} prob(\xi_{t1}).H_{t1,\xi_{t1}}}{\sum_{\xi_{t1}=c3}^{c5} prob(\xi_{t1})} + 0.5.\frac{\sum_{\xi_{t1}=c1}^{c5}\sum_{\xi_{t2}=c3}^{c5} prob(\xi_{t1})prob(\xi_{t2}).H_{t2,\xi_{t1},\xi_{t2}}}{\sum_{\xi_{t2}=c3}^{c5} prob(\xi_{t1})}$$

v. Animal production

To cover the range of animal production, eight annual animal classes characterized by sex (male or female), age (from new born to mature) and production objective (culled cow fattening or lean) are introduced in the model. The initial number of animals in each class is optimised under the constraint that it would be equals to the number of animals at the end of the simulation. We assume that calvings occur on 1st February. At the beginning of each year (in April), young animal change from one class to another because of natural ageing process (for instance, the number of female calves at the end of March becomes the initial number of 1 year old heifer in April) and cows may be transferred into the fattening class. Animals can be sold every two months (except calves under five months old and their mother) but not purchased.

Live weights are allowed to vary from +/-5% of the “theoretical” live weight (*tlw)* and the weight gain from +/-20% of the “theoretical” gain. These values are calculated with a sub model which draws standard growth curves (INRA, 2007 ; Garcia and Agabriel, 2008). Diet fill values cannot exceed the intake capacity[3] of the animal but are allowed to be 20 % below. Consequently, diets energy contents and diets composition can vary.

vi. Receipts and costs

Beef margin is calculated as the difference between yearly receipts (animal sales, Common Agricultural Policy payments and insurance indemnity) and costs associated to the beef enterprise. Animal product sales take into account the number of animals sold, their live weight and their price. These prices are defined per month, which enables us to introduce price modulation according to theoretical live weight. The CAP premium specification encompasses suckler cow payments (14 k€), single farm payment (8.5 k€) and a modulation rate of CAP payment which is 10%. Variable and fixed costs can be divided into grassland crop production and animal production costs. Crop production costs include fertilizers for grassland (25 € /ha), haymaking (100 € /ha) and silage making costs (130 €/ha). Mechanisations and fuel costs are estimated at 200 €/ha. Animal production costs comprise value of purchased feeds (200 €/t of concentrate feed, 150 €/t of hay) and litter (70 €/LU), diverse costs such as veterinary or feed complementation including vitamins and minerals (92 € /LU) and housing costs. We assume housing costs are proportional to the housing capacity of the barn (52 € / LU). If herd size falls below this capacity, housing costs do not decrease because farmers still have to bear fixed costs linked to his or her barn investment.

vii. Insurance

The characteristics of insurance policies are inspired by the scheme currently in test by a French insurance company. This policies offers grassland yield risk protection through indemnity payments that are made whenever the grass yield accumulated between February and October falls below a predetermined level. This level depends on the yield coverage option chosen by the farmer. It is specified

[3] This capacity corresponds to the amount of Cattle Fill Units (CFU) an animal can eat when fed ad libitum. 1 CFU is the “standard” voluntary dry matter intake of a reference herbage by a 400 kg-heifer, set to 95 g/kg metabolic LW (INRA, 2007)

as percentages δ of the individual historic yield $\overline{Y}$. The value *P* of damages on grassland yield are estimated assuming a price of 150 €/t of dry matter. This corresponds roughly to the market price of feed substitute to on-farm forage production. The Indemnity payment function is defined as follows:

$$Indemnity = \max\left\{0, \delta\overline{Y} - Y_t\right\}.P$$

The insurance premium is calculated based on the simulated distribution of grassland yield presented in the previous section. It is equal to the expected indemnity payment times a loading factor and a subsidy rate. The loading factor accounts for administrative costs, generating profits and accumulation of reserves for the private company. Following Finger and Calanca, (2011), this parameter is set at 1.3. Similar to the multi-peril crop insurance program in the USA and in accordance with the European CAP rules, premium subsidies (up to 65 % of the insurance premium) are modulated according to coverage options (table 3).

Table 3: Characteristics of insurance policies

	Coverage option "δ"	Subsidy rate	Premium without subsidy (€/ha)
70 % coverage	70 %	65 %	5
90 % coverage	90 %	20 %	59

b. Scenarios

Five scenarios are defined to assess the effects of self insurance and market insurance on production decisions and profit distribution. The first ones corresponds to the baseline: a risk neutral famer ("Wo") under current CAP payments and without access to market insurance. Risk aversion of other scenarios is set to 2 which corresponds to a moderately averse farmer (Hardaker, 2004). The scenario "R_Wo" could only self insure in order to reduce risk exposure while in "R_Wins" both self insurance and market insurance are available. This would enable us to estimate how market insurance would modify self insurance demand and profit distribution. In the scenario "R_Wins _sub", insurance premium is subsidized. A scenario (R_Wins_DP) for which direct payments are increased by 10 % is also introduced to test the effect of wealth.

Table 4: Scenarios

	Wo	R_Wo	R_Wins	R_Wins_Sub	R_Wins_DP
Relative risk aversion	0	2	2	2	2
Market insurance	No	No	Yes	Yes	Yes
Premium subsidies	/	/	no	Yes	no
Direct payment (€/ha)	214	214	214	214	235

c. Results

i. Self insurance and market insurance

- Insurance options and cost

In section 1, cost of self insurance was defined as the difference between income without and with insurance for the favourable state of nature (state 1). In this simulation, this cost is estimated as the difference of expected profit over neutral or favourable states [c3;c5] between a risk neutral individual and a risk averse one.

When market insurance is not available (scenario “r_wo”), 50 €/ha is spent per year in self insurance (table 5). Herd size is cut by 15 Livestock Units (12 %) but the production per animal isn’t modified. This enables both to reduce feed needs and to increase the quantity of hay harvested: in average, 110 % of annual hay consumption is harvested instead of 97 % in the risk neutral scenario. Consequently, the security stock which corresponds to the residual between previous hay stock and herd consumption, is enlarged. It reaches in average 37 %, instead of 16 % for the risk neutral case. Note that even a risk neutral farmer constitutes security stock since hay surplus can’t be sold.

When market insurance is available (scenario “r_wins”), the expected amount of money spent in favourable years to reduce the impact of unfavourable grassland yield is equal to 43 €/ha. It could be divided into 21 €/ha of market insurance premium and 22 €/ha of self insurance. Compared to the risk neutral profile, herd size decreases by 7 LU (6%) and hay harvested and hay stock relative to annual consumption increase (resp. 103 % and 27 %). The production system is in between the one of a risk neutral farmer and the one of a risk averse farmer without market insurance.

Table 5: Expected profit, self insurance and market insurance over the favorable states of nature [c3;c5]

		Wo	R_Wo	R_wins
Profit	*€/ha/ year*	324	274	281
Herd size	*LU /year*	122	107	115
Initial surplus of hay Stock	% of av. consumption	16	37	27
Insurance premium	*€/ha/ year*	/	/	21

Although the expense in self insurance in year 2 remains more or less constant according to t1 grassland yield, the demand for market insurance varies greatly (table 6). Market insurance coverage is adjusted according to initial stock and varies from 0 €/ha after state “c5” to 42 €/ha following c1 or c2, after which no stock is available.

Table 6 : Expected profit over the favorable states of nature [c3;c5] and market insurance demand in year t2 according to grassland yield in t1

	Previous state of nature in year t1		c1	c2	c3	c4	c5
R_wins	Profit	*€/ha/ year*	261	261	284	294	301
	Insurance premium		42	42	17	7	0
	MI 70 % coverage	*Ha*	62	62	91	54	0
	MI 90 % coverage	*Ha*	38	38	9	0	0
	Initial surplus of hay stock	*% of av consumption*	0	0	27 %	57 %	81 %

- Distribution of economic results

The redistribution of profit from endowed states toward the others could be costly. This cost is measured by the difference of expected profit between the risk neutral scenario and the averse one. It reaches 9 €/ha with a mixed of market insurance and self insurance and 15 €/ha for self insurance only. Efficiency of these insurance options is analysed through the Coefficient of variation of profit and the extreme values of profit distribution. For the risk neutral farmer, CV equals 21 %. Thanks to self insurance only, the CV decreases by 11 points. With both market and self insurance, the CV is 7 %. Main differences of profit distribution between scenarios concern the left hand tail of the profit distribution. Minimum profit is increased by 125 % with self insurance only and by 400 % with both self and market mixed insurances.

Table 7: Distribution of profit over the two year planning horizon (*€/ha/ year)*

	mean	sd	min	max
Wo	**281**	58	39	357
R_Wo	**266**	26	88	321
R_wins	**272**	18	210	346

ii. Effects of insurance premium subsidies and direct payments

Subsidies on insurance premium and direct payments increase average profit respectively by 9 €/ha and 8 €/ha. These public policies both support income level.

The production system is slightly modified when insurance premium is subsidized. Self insurance is reduced: there are 3 more livestock units and as a consequence less extra stock of hay. Conversely, insurance demand expands by 50 %. Additional Direct Payments don't change much the demand for self insurance but decrease slightly the demand for self insurance. DP increase wealth. Since risk aversion is supposed to decrease with wealth, DP decreases insurance incentive. However, its effect on insurance is much smaller than subsidies on insurance premium. Subsidies on insurance premium decrease profit variability and increase the lowest profit. Higher direct payments make the profit slightly more variable but increase the lowest profit. Both tools help stabilizing profit but premium subsidies are more efficient. Marginal effect of market insurance clearly decreases with the amount spent. 21 €/ha increases the lowest profit value by 171 €/ha while spending 10 €/ha more brings an additional gain of 20 €/ha. Similar conclusion could be drawn from standard deviation.

Table 8: effect of insurance premium subsidies and increased direct payment on profit distribution and demand for insurance

		R_wins	R_wins_sub	R_wins_DP+
Profit	*€/ha/ year*	272	281	280
sd profit	*€/ha/ year*	18.4	15.9	18.7
Min profit	*€/ha/ year*	210	230	216
Herd size	*LU /year*	115	118	115
Initial surplus of hay Stock	% of av. consumption	27	22	27
Market Insurance premium		20.8	31.9	20.2
Subsidies on insurance	*€/ha/ year*	0	9.9	0
Direct payments after modulation	*€/ha/ year*	214	214	221

3. Conclusion

Objectives of this study were 1) to analyse how grassland yield insurance would substitute for self insurance in suckler cow farms, 2) to assess efficiency of these insurance options and 3) to test effects of public supports on insurance demand and profit distribution**.** To meet these objectives we first propose a simple theoretical model. Second, simulations have been performed thanks to a bio-economic model applied to French suckler cow farms.

The simple theoretical model points out three different kinds of determinants of the equilibrium between self insurance and market insurance. First, production system characterized by an important part of concentrate feed in animal diets and by a higher ratio of animal sales per livestock unit would have less interest in self insuring. Economic conditions (prices of inputs and outputs, prices of insurance, rate of subsidies) would affect directly the shadow prices of both insurances. Eventually the distribution of grassland yields is of prime importance. Self insurance is then more likely to be more efficient to control current loss than seldom ones. The expense in self insurance consists indeed mainly in the foregone animal receipt that affect all states of nature while market insurance cost is proportional to the probability of loss.

The simulation model take into account five states of nature and represents animal and forage stock dynamics between years. With self insurance only, animal stocking rate decreases by 12% . More forage resource is available per animal which gives the opportunity to build extra stock of hay. Profit variability is reduced by 55 % but sensitivity to extreme yield conditions remains high. Market insurance targets more specifically these states with very low profit. When possible, rather risk-averse farmers would both subscribe insurance and reduce their animal production per hectare compared to a risk neutral farmer. Market insurance demand varies greatly from states to states. It is adjusted to current extra hay stock and, as a consequence, depends on previous grassland yields. Profit variation is divided by 70 % and the lowest value of profit increased by 400 %. Both subsidies on insurance premium and additional direct payments induce an increase of expected profit and reduce value of the lowest profit. However, premium subsidies appear more efficient and avoid increasing standard deviation (even if it is a small proportion). Additional gains of these public schemes to stabilize income are relatively small compared to the one provided by the introduction of market insurance. In theory, all farmers should take advantage of this subsidized insurance. However, subjective beliefs held by the decision makers are not always accurate (Kunreuther, 1996, Sherrick, 2002, Umarov and Sherrick, 2005). If farmers underestimate the probability of severe risks as underlined by (Kunreuther, 1996), they could think that subsidized insurances are not valuable. There could be also a defiance of farmers against this new scheme or a misreading. The public fund was indeed insuring them against agricultural calamities almost for free, they didn't have to anticipate and subscribe contract in advance. Brunette and Couture, (2008) demonstrate that if public compensation are expected, then the demand for private or self-insurances decreases.

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