On-farm weather risk management in suckler cow farms: A recursive discrete stochastic programming approach

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Paper prepared for presentation at the EAAE 2011 Congress
Change and Uncertainty
Challenges for Agriculture,
Food and Natural Resources

August 30 to September 2, 2011
ETH Zurich, Zurich, Switzerland

Abstract: *Currently France wants to introduce a weather risk management framework into its agricultural policy for livestock farming. The aim of this paper is to better understand how on-farm risk reducing strategies modify the production system and profit distribution of French suckler cow enterprises. We present in this paper an original bioeconomic model that takes into account both risk anticipation and risk adjustments and that details biotechnical relationships between the different components of the beef cattle production system and their dynamics. On-farm risk management strategies are endogeneized under weather uncertainty and tested on real observed weather sequences. We simulate four scenarios characterized by different risk aversions and feed prices. Results emphasized that production adjustments, particularly the adjustments of area of grassland harvested and the possibility to purchase substitutes to on-farm forage production, improve farmers profit under weather variability. However, limiting the amplitude of these adjustments helps decreasing profit variability. All simulated long term decisions associated to risk reducing strategies encompass a reduction of long term stocking rate and the constitution of feed stocks. The impact of hay feed price on the market has similar effects on the long term strategy.*

1 Introduction

The 4.3 million French suckler cows represent more than one third of all European suckler cows and supply around 60% of the beef production in France. They also participate in rural development and help in maintaining large areas under grassland which favors biodiversity and limits pollution and erosion (Le Goffe, 2003), even if their complete environmental impact should be taken into account (FAO, 2006). However, these farms rely on grassland production which is very sensitive to weather conditions (Gateau et al., 2006). Currently the European Union (EU) and France want to introduce a risk management framework into their agricultural policy. Since farmers individual risk-management strategies can supplement or replace public compensation policies and private insurance, they have to be well understood. Farm risk management aims at securing and improving farms potential of profit over time. It encompasses two stages. The first one, prior to the realisation of a random event, deals with the mitigation of future risks of loss. The second stage, subsequent to the realisation of this uncertain event, corresponds to decision adjustments in order to take advantage or to limit damages caused by the random event. These two stages are interlinked since first stage decisions can reduce for instance farm exposure or increase adjustment capacity. In the case of French suckler cow farms, numerous production options exist to manage risks linked to weather conditions. Strategic decisions to mitigate risks encompass land allocation, average herd size and herd composition (Lemaire et al., 2006a, Mosnier et al., 2009). The definition of an appropriate level of animal stocking rate, of the source of feed supply (Lemaire et al., 2006b) and of calving date (Pottier et al., 2007) are crucial too. Adjustments are very diverse and concern for instance animal diets (Blanc et al., 2006; INRA 2007), animal sales, end use of crop production (Le Gall et al., 1998) or feed purchases and sales (Veysset et al., 2007). The aim of this paper is to better understand how on-farm risk reducing strategies encompassing both risk anticipations and risk adjustments modify the production system and profit distribution of French suckler cow enterprises.

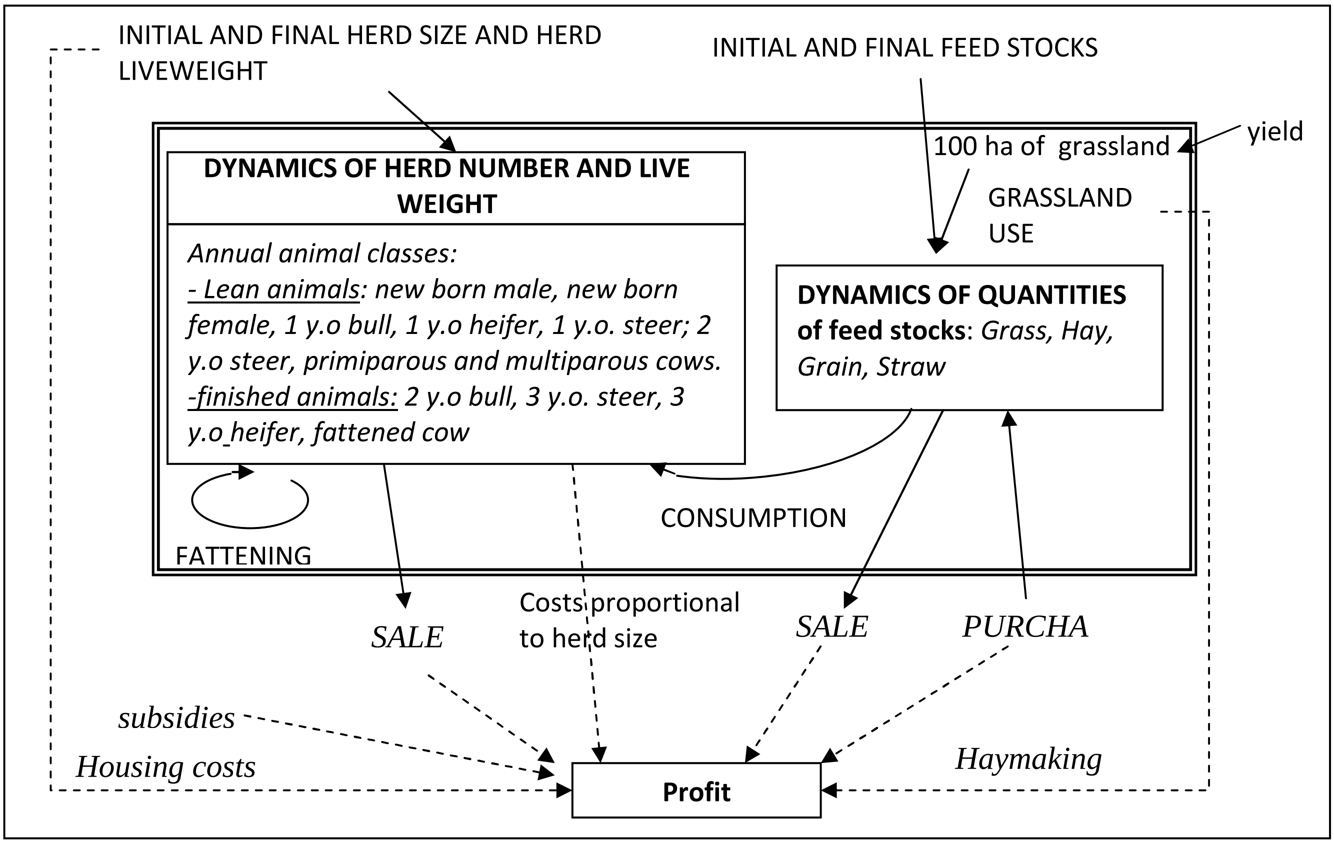
Both econometric and mathematical programming methods can be used to model risk management. Although econometric models have the advantage of being based on statistic inference, they are hardly able to represent the sequential decision making process (Antle, 1983) and to disentangle the complex relationships between the different components of the systems. In the vast literature devoted to farm modelling under uncertainty, two approaches can be distinguished: Discrete Stochastic Programming (DSP) and Stochastic Dynamic Programming (SDP). Previous bio-economic livestock farm models using DSP approach are though limited by the number of decision stages introduced and by their short time span (Lambert, 1989; Kingwell et al., 1993; Jacquet and Pluvinage, 1997; Lien and Hardaker, 2001). Livestock farm models using a SDP approach have to reduce the number of activities considered (Moxnes et al., 2003; Kobayashi et al., 2007) since the calculation requirements increase exponentially with the number of dynamic variables. To overcome limitations of the previous approaches, we propose to use a sequence of recursive DSP models in a way somewhat in the line to the proposal of Blanco and Flichman (2001) and to use this framework to simulate successive stochastic weather events over a long period.

The remainder of the paper is organized as follows. We describe first how the production system and the decision making process are modelled. We simulate then different weather risk management strategies according to farmers risk aversion and market hay price. A simulation of stochastic weather conditions observed over the period 1990-2007 is then simulated in order to analyse the differences between farmers anticipations and consequences of the realization of the whole distribution of weather events.

2 Model Description

Our model aims at simulating long-term strategies to manage weather risk in a suckler cow enterprise as well as the impacts of successive random weather conditions on annual technical and economic results. The production system modelled consists of beef cattle production based on a suckler cow herd, combined with grassland crop production (figure1).

Figure 1: representation of the modelled production system (optimised decisions are in capital letter)



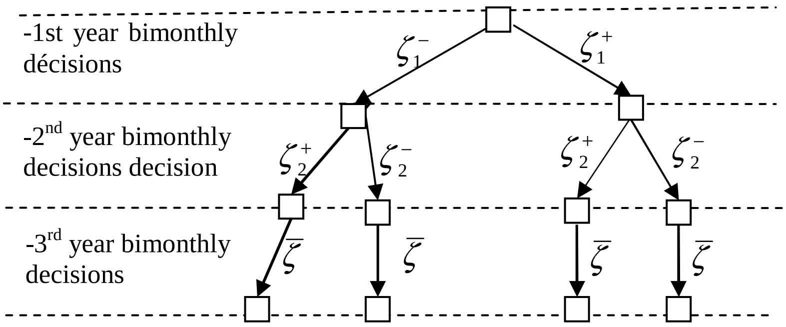
This modelling of the production system is based on the framework presented in Mosnier et al. (2009). Barn capacity, herd size and herd composition, herd live weight and animal feeding, haymaking and feed stock management are optimised for 100 ha of grassland. To represent farmers decision making, we assume that they optimise their decisions over a three year planning horizon. Over this horizon, farmers anticipate that grassland yield could be either favourable or unfavourable and that they will be able to adjust their decisions each two months. In addition, unexpected weather conditions can be simulated. Our model is parameterized to represent suckler cow enterprise of farms located in the Northern part of the French Massif Central. It is resolved by the non linear programming solver *CONOPT* run in *Gams*[1].

2.1 Farmers time and risk anticipations

Farmers decisions depend on their expectation regarding their future profit. The future encompasses two dimensions: the possible weather conditions anticipated 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 et al, 2004). Previous works (Mosnier et al., 2009 and Mosnier et al., 2010) emphasized that grassland yield shocks in the French Charolais area involve many adjustments of the production systems, namely adjustments of animal diet composition, of feed product trade and haymaking. Consequently, bimonthly decisions are differentiated after the realisation of the weather event. Such a risk representation is demanding in terms of computational capacity. In order to take into account impacts of successive weather events while keeping the model tractable, we introduce weather risk for the two first years of the planning horizon and we assume that farmers anticipate two states of nature for weather conditions: one corresponding to a favourable year and the other one to an unfavourable year. Let's ζ be the weather risk with $\zeta 1$ and $\zeta 2$ being the random weather condition for respectively the year *t1* and *t2*. They are characterized by two states of nature $\zeta 1$: $\{\zeta 1+; \zeta 1-\}$ and $\zeta 2$: $\{\zeta 2+; \zeta 2-\}$ (figure2). Weather conditions directly influence grassland yields that are used as our indicator. Grassland yield distributions correspond to annual estimation by Agreste (statistics from the French ministry of agriculture) in the Charolais area, over the period 1990-2007. Unfavourable event is set to average yield plus one standard deviation and an unfavourable one equals to average yield minus one standard deviation. A very long planning horizon is often thought preferable since it can influence the long term equilibrium and how fast it is reached (Dawid, 2005). However, in our case, the initial state of the system is optimised and no long term adaptations are expected. The issue is then to set a time horizon long enough to enable the system to recover from shocks while not giving too much weight to non risky years compare to risky ones. We fix the planning horizon at three years.

[1] GAMS development Corporation, 1217 Potomac Street W; Washington, DC 20007, USA. www.gams.com

Figure 2: anticipation of two embedded weather risk over the three year planning horizon



☐ State of the system at the beginning of each year

$\zeta_1^+, \zeta_1^-, \zeta_2^+, \zeta_2^-, \bar{\zeta}$: resp. fav. and unfav. conditions for year *t1 and t2*; average conditions for year *t3*

2.2 Description of the production system

2.2.1 Animal production

To cover the range of animal production in the Charolais production area, thirteen annual animal classes characterized by sex (male, female or castrated male), age (from new born to mature) and production objective (fattening or storage) are introduced in the model. Classes, indexed by a, are described by two endogenous dynamic variables: the number of animals and their average live weight. The initial number of animals in each class is optimised under the constraint that the repartition of animals could be maintained over time i.e. that there is for instance at least as many new born heifers and one year old heifers than two year old heifers. This initial repartition is chosen once for all. However, the 1/ bimonthly control of animal sales, 2/ bimonthly choice of animal diet composition and diet energy content and 3/ annual fattening objectives could be adjusted to face weather events.

The intra year animal number dynamics are defined by a motion function that draws the balance between past number of animals, sales decisions and mortality. Since animals are seldom purchased in our database, we do not introduce the possibility of buying animals. At the beginning of each year (in April), an animal may change from one class to another because of natural ageing process (the number of 1 year old heifers at the end of a year becomes the initial number of 2 year old heifers the following year) and because of fattening objectives. The model can choose for instance to convert part of the number of two year old heifers into fat heifers and the remaining part into primiparous cows. In the studied area, females calve for the first time at 3 years old and then once a year, on 1st February. In our model, the number of cows must be high enough to suckle young animals until weaning (8 months) and no sale of calves is allowed before their fifth month which corresponds to early weaning. Number of calves born per reproductive female (0.96), sex ratio (0.5) and mortality rates (9% for calves, 1% for the other) correspond to average annual records on the 'Charolais' database. Mortality is assumed to be spread evenly over the year except for calves for which we observe higher mortality rates after birth.

Theoretical live weight and theoretical weight gain are calculated with a sub model which draws standard growth curves according to animal sex, age and production objective. These growth curves are based on equations exposed in Garcia and Agabriel (2008) for females (cows and three year old heifers) at fattening and for other animal classes on Gompertz functions defined in INRA (2007). In order to give flexibility to the model to adjust animal live weights according to market or weather conditions while not threatening reproduction performance and animal health, live weights are allowed to vary from +/-5% of the "theoretical" live weight and the weight gain (*ADG*) from +/-20% of the "theoretical" gain. For mature cows, we set gain interval at [-0.6; +0.4] kg per day. The ADG variable is a function of the daily net energy balance (NEB). Parameters of this function have been obtained from INRA (2007). NEB is the difference between on the one hand net energy intake which depends on quantity of feed and milk ingested by each animal and on their energy content, and, on the other hand, net energy requirement that comprises net energy for lactation and pregnancy and net energy to maintain live weight constant. Maintenance requirements are set according to animal theoretical live weight, to animal activity and to stage of lactation. They increase if animals are fatter and decrease if they are thinner than theoretically. The power function provided by INRA, 2007 is linearized. The fill value of the diets cannot exceed the intake capacity of the animal. This capacity corresponds to the amount of Cattle Fill Units[2] (CFU) an animal can eat when fed *ad libitum* (Jarrige et al., 1989).

2.2.2 Grassland production and feed Stock

For this study, we simplify the cropping systems of the previous version of this model (Mosnier et al, 2009): we consider only 100 ha of grassland area. Animals graze from April to November and are fed inside at trough in winter. Grassland production is divided into production that can be grazed by animals or harvested to make hay. The average area of grassland cut every two month is optimized once for all. However, adjustments of these areas are possible to help facing hazards. In the model, decisions to adjust production grassland are taken knowing exactly what would be the production for the next two months which is only an approximation of the reality. We limit then the bimonthly adjustment at more or less 20% of the total grassland area. Moreover, modifying the initial harvest planning is assumed to have some drawbacks and is slightly penalized since to be efficient grazing or haymaking need to be anticipated. Two other products are considered: grain and straw (only used as litter). Feed products are associated with parameters of qualities: 1/ fill value; 2/ energy content expressed in accordance with the INRA feed evaluation system in net energy for lactation when animals are lean and net energy for meat when animals are fattened. Regarding grain and hay feed values are set according to INRA (2007). A basal value of 0.3 CFU/kg of dry matter is fixed for concentrate. Qualities of green forage depend on the average Organic Matter Digestibility of the different structural compartments (green and dead matters). They are calculated thanks to equations given in Jouven et al., (2008a).

Evolutions of the available quantity of feed products are described by dynamic variables. Stocks of conserved produce (all except grazed grass) are defined as the balance between inputs (production harvested and bought and withdrawals) herd consumption and sale, plus the stock remaining from the previous period. Secondly, 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), the grass produced not harvested and herd consumption. Delaying the use of grass production leads indeed to standing biomass losses because of senescence (deterioration related to ageing process) and abscission (shedding of dead matter) processes (Jouven et al., 2006).

2.3 Receipts and costs

Beef margin is calculated as the difference between yearly receipts (animal and hay sales plus Common Agricultural Policy payments) and costs associated to the beef enterprise.

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[2] 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)

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 (price per kg usually decreases with live weight for stored animals and increases for finished ones). For the year 2010, CAP payments encompass grassland area payments, suckler cow payments and Single Farm Payment (SFP). Suckler cow payments are upper-bounded by historical reference (80 for this simulation). Moreover under this scheme, direct payments are reduced in proportion to the modulation rate which is 10% in 2010. The recent French premium attached to grassland is introduced too.

Variable costs can be divided into grassland crop production and animal production costs. Crop production costs include fixed input costs for grassland (50€/ha) and haymaking costs (90€/ha). Animal production costs comprise value of purchased feeds and litter, diverse costs such as veterinary, vitamins and minerals (78€ /LU) and labour costs. The labour required corresponds to the estimated daily time spend to feed animals and improve the litter. The amount of 16 hours / LU/ year appears to be the average time (Réseau d'Elevage Viande Bovine, 2006). The cost per working hour is fixed at 12€. Fixed costs linked to animal housing are proportional to the housing capacity of the barn and equals to 65€/LU. Since, to a certain extent, it is possible for farmers to let some animals outside during winter time, the barn capacity is not binding. However, we suppose that the cost for farmers to let one animal outside is similar to the one of providing it a place inside. This possibility is somehow already taken into account in the 65€/LU since the annual barn costs are divided by the total herd size, irrespectively of whether they stay inside or outside during winter. Conversely, if farmers decide to have a herd size below barn capacity, we suppose that since the investment has already been done, fixed housing costs do not decrease.

2.4 The optimisation Program

In accordance with classic economic theories, optimal decisions are those that maximise the objective function *Z* which is equal to the expected (*E)* utility (*U)* of profit (*Π)* over a finite planning horizon. The utility function introduces farmer's preferences toward the distribution of profit. The utility function can be either modelled by a functional form such as the power function that assumes risk aversion decreases when expected wealth increases (Hardaker et al, 2004). It can also be summarized by its central moments. Although the "mean-variance" approach (equation 1) suppose that farmers has the same aversion for positive deviation from average profit as negative deviation, it appeared to us much more efficient to simulate the trade-off between expected profit and risks. The higher the Arrow-Pratt absolute risk aversion coefficient (r_a) is in the following utility function, the more risk reducing the production plan would be. Usually, the value of stock variation is optimised too. However, since the objective of this model is not to simulate long term adaptations but short term variations, we constraint the stock variation to be null. This avoid dealing with problem of valuing stock which leads to stock depletion when the closing value is lower than the selling one and conversely to stock accumulation if the closing value is greater.

$$\text{Max } Z = EU(\Pi_{t,\zeta}) = E(\Pi_{t,\zeta}) - \frac{r_a}{2}.E\left[\Pi_{t,\zeta} - E(\Pi_{t,\zeta})\right]^2 \quad (1)$$

2.5 Revisions of the production plan according to observed weather events: the recursive framework

To cover the entire period of the simulation (1990-2007) and to update information about current weather conditions, we follow Iglesias et al. (2003) and Barbier and Bergeron (1999) in using a recursive sequence of dynamic optimisations (figure 2). Model predictions for a given year are therefore optimal regarding the three year planning horizon but not necessary optimal regarding the entire period of simulation: if the 'modelled farmer' had anticipated that such a succession of shocks would have occurred, they would perhaps have opted for different production choices.

Not all the decisions can be revised. The initial herd size and animal live weight as well as the barn capacity are fixed once for all during the first optimization i.e. before the simulation of the 18 year sequence of weather events. Decisions depending on weather conditions, such as animal feeding and animal sales, feed trade or haymaking area, can be adjusted. Recursions are made at a bimonthly step in order to introduce real grassland production not more than two months in advance. In our model, the year starts in April. For the first optimisation of the simulated year, real grassland yields are known until May, for the second one yields are known until July etc. Once production is known, decisions are not differentiated anymore according to the weather conditions (*ζ1+ and ζ1-)* and they become definitive. Continuity within a year between the different optimizations is achieved by fixing the decisions that have been taken during the previous optimization. When one year has been covered, the whole planning horizon is shifted by one year. Starting values for dynamic variables are then set to their value at the beginning of the second year of the previous optimisation. This process is reiterated until the whole simulation period is covered. For each optimization, the constraint of null variation of stocks is resolved in reference to initial values set during the first optimization. The system can then benefit from hay stock accumulated previously.

3 Model Application

3.1 Scenario description

The objective of this paper is to better understand how on-farm risk reducing strategies can modify the production system and profit distribution of French suckler cow enterprises. The willingness of farmers to reduce profit variability due to weather risks depends on their risk aversion. We choose the value of risk aversion r_a in order that the anticipated variability of profit would be reduced by half. We compare then technical and economic results of beef enterprise under an absolute risk aversion coefficient 1/ null (i.e. r_a=0) corresponding to the absence of risk aversion and 2/ r_a=1. In addition, we test the impact of hay market price since the availability of off-farm feedstuff can supplement on-farm feed production and consequently impact on the risk management plan. The scenarios are summarized in table 1. Since farmers anticipation are only a partial representation of what could happen, we simulate a sequence of 18 years corresponding to the grassland yields observed over the period 1990-2007 in the Nièvre department, located in the Charolais area (the anticipation we have assumed for farmers are based on this sequence). Weather events are associated to a deviation of grassland yield from average yield. It includes the year 2003 characterised by a very important decrease of grassland yield (almost by half) and the year 2004 when yield reaches 140% of their average value.

Table1: Scenarios characteristics

	P_{90}	$P_{90}A$	P_{120}	$P_{120}A$
Market price for hay in €/t	90	90	120	120
risk aversion (r_a)	0	1	0	1

3.2 Results

3.2.1 The initial production plan

For a 'normal' market price of hay and no risk aversion (scenario P_{90}) expected profit reaches 32.3 k€/year with a variability of 9% (table 2). It is characterised by 103 calvings, no fattening of young animals (they are sold at 10 months) and an objective of 9% of the cows sold fattened (i.e. ready to be slaughtered). Herd size and animal live weight are planned to be adjusted to face weather variations. Although adjustments are in rather small proportions (<0.5% of average value), additional simulations indicate that they are significant. The possibility to adjust animal live weight increases for instance average profit by around 200€. Main adjustments concern however the grassland and feed management. Adjustments of the quantity of feed bought represents around 100% of their average value, varying between 0 ton of hay after a good first year to 108t following insufficient yield. Concentrate feed consumption also varies a lot according to weather conditions from 160kg/LU to 300kg/LU. The area of grassland is planned to be adjusted with a coefficient of variation around 40%. The risk reducing strategy (scenario P_{90}A) simulated for a hay market price of 90€/t, induces 600€ of foregone expected profit but reduces profit variability by more than half. To decrease exposure to weather risk, the option simulated consists in lowering the long term stocking rate from 1.28 LU/ ha to 1.21 LU/ha; the kinds of animal produced are however keep unchanged. The grassland area for haymaking is increased slightly and initial stock of hay is introduced. Adjustments of grassland and feed management subsequent to weather events are then smaller. When market price for hay is 30% higher (scenario P_{120}), the herd size shrinks by 7% compared to scenario P_{90}. The grassland area for haymaking expands by 30% and an important initial hay stock is introduced to secure the system. Adjustments by the quantity of concentrate feed purchased decrease a lot and hay is only purchased for the case where two bad years occur in a row. The risk reducing strategy (P_{120}A), enables to decrease variability by 3 in reference to scenario P_{120} for a foregone expected profit of 800€. Once more, lowering stocking rate and enlarging the area for haymaking help decreasing profit variability.

Table 2: Characteristics of the initial production plan according to scenarios

	P_{90}	P_{90}A	P_{120}	P_{120}A
average profit (k€/year)	32.3	31.7	31.7	30.9
s.d. of profit (k€/year)	*3.0*	*1.2*	*3.4*	*1.0*
variation of profit	*9%*	*4%*	*11%*	*3%*
average herd size (in LU)	128	121	119	106
s.d. of herd size (in LU/year)	*0.4*	*0.6*	*0.4*	*0.2*
s.d. of LW of animal (in %)	*0.5*	*0.3*	*0.3*	*0.4*
initial stock of hay (in t)	0	35	69	47
Av. concentrated feed (in kg/UGB/year)	230	231	251	208
Av. Purchased hay (t/year)	41	30	8	0
grassland harvested in May (ha/year)	42	48	61	63
s.d. of concentrate feed (in kg/LU/year)	74	50	90	36
s.d. of purchased hay (in t/year)	*46*	*31*	*19*	*0*
s.d. of grassland harvested in May (ha/year)	18	16	11	7

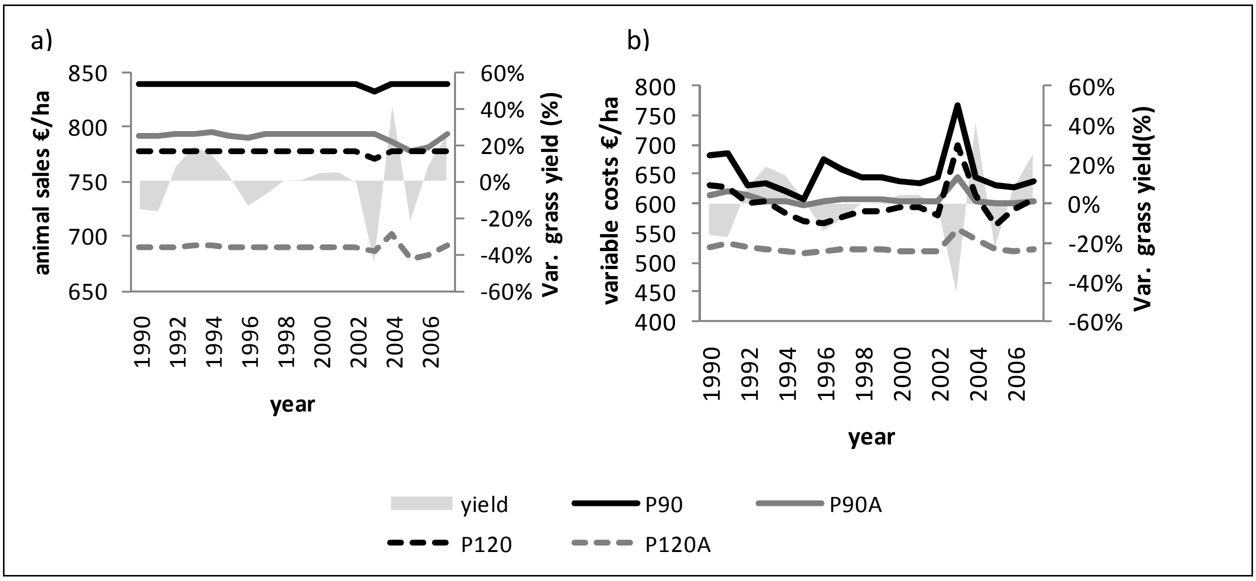
3.2.2 Impacts of a sequence of weather events on economic results

Over the sequence, regardless of the scenarios, we observe (figure 3a) a rather low variability of receipts from animal sales except for the year 2003 during which fewer cows have been fattened. Receipts for the scenario P_{90}A have been impacted for several years following the 2003 drought. A higher number of cows have indeed been sold, reducing the number of calves and the sales for the subsequent years. The variable costs fluctuate much more in general (figure 3b), but the risk reducing scenarios help smoothing these costs. The year 2003 swells variable costs a lot because of induced feed purchase, above all for the non risk reducing strategies. Regarding profit distribution over the 18 year sequence (table 3), the risk reducing strategy under high hay market price *($P_{90}A$)* performs better than the risk neutral one (P_{90}): average profit is very close while variability of profit is lower. Although farmers expectations for grassland yield have been based on this 1990-2007 sequence, we have only considered average profit plus or minus one standard deviation. Profit loss caused by the extreme 2003 year has not been compensated by symmetric gain in very favourable years such as 2004. In this case the more cautious strategy has been more adapted to the uncertain weather.

Table 3: Profit distribution according to the scenario over the simulated period of grassland yield 1990-2007

	Average profit (k€)	standard deviation (k€)	Coefficient of variation
P_{90}	31.7	3.7	12%
$P_{90}A$	31.7	1.0	3%
P_{120}	31.4	3.3	10%
$P_{120}A$	30.9	1.0	3%

Figure 3: Evolution of a) receipts from animal sales and b) variable costs over the simulated grassland yield sequence from 1990 to 2007 according to hay price level (P_{90}: 90€/t and P_{120}: 120€/t) and to risk reducing strategies (A : risk aversion r_a=1)



4 Discussion and conclusion

We presented in this paper an original bioeconomic model that takes into account both risk anticipation and risk adjustments and that details biotechnical relationships between the different components of the beef cattle production system and their dynamics. On-farm risk management strategies are endogeneized under weather uncertainty and tested on real observed weather sequences. We have simulated on farm risk management according to risk reducing objective and economic conditions of the feed market. Both risk adjustments and production decisions intended at limiting risk exposure have been simulated.

Results of our simulations emphasized that production adjustments, particularly the adjustments of area of grassland harvested and the possibility to purchase substitutes to on-farm forage production improve farmers profit under weather variability. These results are corroborated by empirical analysis (Veysset *et al.*, 2007 ; Mosnier *et al.* 2010) and by simulation studies (Sullivan et al., 1981 ; Gillard and Monypenny, 1990 ; Romera *et al* , 2005 ; Diaz-Solis *et al*., 2006 ; Kobayashi *et al.*, 2007; Jouven and Baumont, 2008). However, the highest the cost to buy feed is, the most incentives farmers have to be self sufficient under weather uncertainty.

Risk reducing strategies are characterized by lower amplitude of adjustments. Although choosing the appropriate combination of production adjustments to face weather variations improves expected farm profit for a given production system, limiting them helps decreasing profit variability. All simulated long term decisions associated to risk reducing strategies encompass a reduction of long term stocking rate. The importance of a strategy to constitute feed stocks in order to come through forage shortage has been underlined too. Better private insurance could then result in higher pressure on grassland, which could conflict with environmental goals. Risk reducing strategies induce trade-off between expected profit and variability of profit. However, in the case of the whole sequence of yield variation observed between 1990 and 2006, the risk reducing scenario simulated here performs better. This raises the problem of farmers' anticipation: how do and should farmers consider weather distribution when taking their decisions. Downside risks suppose indeed that extreme events should be taken into account in farmers decisions with more importance than average ones. For the simulated extreme event, even farmers with risk reducing strategies suffer from important profit loss. These events would require special treatments by policy makers or insurers to support farmers.

Conditions of the economic environment can also modify the long term strategy of farmers. We have analysed in this study the impact of price of purchased hay on the market but results could be extended to the question of availability (and price) of substitute to on-farm feed production such as cereals that are particularly expensive at the moment. The more expensive and scarce are feed products on the market, the more incentives farmers have to be self reliant for feed and to seek on-farm solutions to reduce their exposure to weather risk i.e. a lower stocking rate to favour pasture grazing and hay stock.

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