Sheep for meat farming systems in French semi-upland area. Adapting to new context: increased concentrates and energy prices, and new agricultural policy

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Abstract: *French sheep-for-meat farming, especially in disadvantaged areas, is under strong economic pressure, with a significant increase in grain prices and looming changes in the CAP. We used simulation to study possible adaptations of three contrasting production systems to the new context defined by a surge in cereal prices (40% increase in the price of concentrates) associated with two distinct types of public aid. The evaluation criteria were economic performance (net income per worker), energy efficiency, emissions of greenhouse gases (GHGs), and sensitivity to technical and economic fluctuations, partly connected with fodder and food self-sufficiency level. Results show that the "3 lambings over 2 years" system (3/2) is the most strongly affected by this new context unlike less intensive systems. The Small system, with small size and a lower level of animal productivity, offers a good income through very low inputs. Hence it can also be less sensitive to rising production costs and unforeseen events, while optimizing various public support provisions. For farms that have this possibility, the production of part of the grain needed for the flock, with a concomitant decrease in sheep numbers, not only strongly mitigates the drop in income, but also reduces sensitivity of income to unforeseen events, by significantly improving food self-sufficiency and by an overall decrease in inputs and outputs. If the newly emerging context is confirmed, a prompt response will be needed by farms to consider adjustments that may, for the most productive systems, challenge intensification at the animal level and involve solutions to optimize the use of forages. The most self-sufficient system that could be set up showed a theoretically more favourable environmental balance, especially in terms of energy efficiency and biodiversity (crops), although declining flock productivity could bring about an increase in the emission of GHG per unit carcass weight.*

Keywords: *sheep for meat, farming system, economics, energy, adaptation*

Introduction

The current context of livestock production in Europe is changing rapidly, particularly through an increase in the price of raw materials, primarily that of grain. After the 2007 harvest (August, September, October) wheat and barley have shown an increase of 120% compared with the years 2004-2006, at a comparable period (AGRESTE 2007). Some of this increase may be lasting because of the strong world demand for agricultural products (population growth and the improving standard of living of emerging countries, and energy requirements) and the increased frequency of adverse climatic events. French sheep production is strongly affected by this new context, particularly in disadvantaged areas and uplands. Lambs are fattened indoors and the consumption of concentrate for the mother and its lambs reaches an average of 150 kg, or almost one ton per livestock unit (LU). The direct cost of food represented 2/3 of operating expenses in 2006. Sheep farming is also being strongly challenged the current oil prices in terms of economic impact.

This context amplifies the chronic economic difficulties, which were particularly acute in 2007, faced by French sheep-for-meat production. Besides new financial support necessary in the very short term, it is necessary to rethink the usefulness of breeding systems that have proved their worth over the past decade. Numerical productivity (number of live lambs per ewe per year) has up to now been a determining indicator of economic success (Bellet et al 2005), despite significant reliance on external inputs in particular for flock feeding. The grain prices on the introduction of the CAP in 1992 had remained very low over the past decade. The recent change in the price ratio between inputs such as feed and energy, and the price of sheep meat, has prompted us to reappraise the utility of highly productive systems, which are more often strongly dependent on external sources for these inputs. Significantly, this line of reasoning is close to that taken to justify organic farming production (IFOAM 2000). Planning also needs to take into account, through assumptions, the impact of changes in the

CAP that could soon take place. Furthermore, in the context of climate change and dwindling fossil energy resources which are subsequently increasingly expensive, we study for each system their dependence on fossil energy. For this, we use the energy balance calculation that is based on the capacity of the farm to produce the maximum energy in the form of agricultural products with a minimum recourse to non-renewable energies (Pervanchon et al 2002); this approach is combined with GHG emissions calculation, that is a crucial issue in herbivore breeding (Casey et al 2006, FAO 2006). Most of the tools dealing with evaluation of environmental impact of farming systems take into account these approaches (van der Werf et al 2002).

Finally, we also sought to highlight the specific features of the systems studied in terms of sensitivity of their income to technical and economic hazards.

We studied traditional sheep breeding areas in central France, in the northern part of the Massif Central. In these areas, sheep farmers have no possible alternative production and so have to adapt to this new context.

To do this forecasting, we worked with modelling tools that allow the integration of changes in prices or in agricultural policy at the farming system scale, with both outputs on economic or environmental aspects, as used in other studies (Topp et al 2003, Matthews et al 2006).

Materials and methods

This work was based on three farms in a network of 40 followed by our unit in the long term. They were among the most successful economically, and were located in three distinct upland areas. They had contrasting sizes and operational patterns: different acceleration of reproductive rhythms, seasonally varied, different dependency on external inputs for flock concentrates, and different degrees of intensification of the fodder area. We compared their performances (technical, economic, energy consumption, GHG emissions) in 2006 and assessed the utility of various technical adaptations for less dependence on concentrates and energy needs. The economic impact of these adjustments was also studied in the new economic context (rising price of concentrates) and against likely changes in the CAP. Finally, we evaluated the sensitivity (in terms of net income) of these systems to technical and economic fluctuations.

Choice of three contrasting breeding systems (Table 1)

Accelerated production system (*3/2*)

This system is largely represented in the volcanic area of the Puy-de-Dôme (with the Rava breed). It is based on the exclusive use of permanent pasture, with a relatively high stocking rate. The flock breeding pattern is characterized by three lambings per ewe over two years (one lambing per ewe every 8 months: September, April, and December). The technical result is favourable, with a numerical productivity (NP) of 1.70.

Autumn lambing system and crops for the flock (*Aut*)

This system is somewhat typical of granite areas with dry land and arable land for the renewal of temporary pastures and crops (cereals). The production of cereals represents 27% of the needs for concentrates. The lambings take place in autumn, with a second small lambing period in early winter for empty ewes and ewes' lambs (White Massif Central breed).

Small-size farm with low inputs (*Small*)

The main feature here is small size (43 hectares and 300 ewes; Limousine breed), which first allows the farms to remain in a very favourable system for social contributions (a "fixed" system independent of income) and second significantly reduces fixed costs (buildings, equipment, management fees, etc.). The average numerical productivity of a flock is rather low (NP = 1.18), as is concentrates use (115 kg/ewe) thanks to efficient management of the forage area (rapid grazing and significant presence of legumes) without chemical fertilizer. The net income per worker is as high as that of the *3/2* system.

Adaptation of the systems (Table 1)

The new grain (and energy) price situation prompted us to consider several ways to adjust the *3/2* and *Aut* systems, for a constant farm area (total agricultural area: TAA).

Improvement of food self-sufficiency: greater independence from external supplies of concentrates

Lower concentrates consumption (simulation on 3/2)

The accelerated lambing system (*3/2*) requires providing a high overall concentrates intake to meet the production needs of the ewes. We consider a lower lambing rate by only accelerating the females who had a single lamb in the previous lambing (3/2Inf). The lambing rate decreases from 1.31 to 1.19 and the NP from 1.70 to 1.56. Meanwhile, the concentrates requirement declines by 40 kg per ewe (-22%).

Lower stocking rate (simulation on 3/2)

With precise technical management, decreasing stocking rate can lead to a significant decline in consumption of concentrates and fertilization (Thériez et al 1997). Nevertheless, for a set farm structure, it results in a significant decline in the number of ewes. This scenario was studied for *3/2* with the case *3/2Ext* where the 19% decrease in stocking rate (1.05 *vs.*1.30) is accompanied by a significant change in the lambing rate. This corresponds to a non-accelerated lambing system, based on a main lambing period in spring, in order to maximize the use of forage resources, in particular through grazing. The NP declines to 1.40 and consumption of concentrates to 129 kg/ewe.

Table 1. Features of the three farms studied and simulated cases (2006 situation)

	Observ				Observ			Observ
System	*3/2*	*3/2Inf*	*3/2Ext*	*3/2+crop*	*Aut*	*Aut+crop*	*Aut+Ccrop*	*Small*
Tot.Agric.Area Ha	69	69	69	69	98	98	98	43
Grain for flock (cash) Ha	0	0	0	10	5	11	8 (16)	0
Stocking rate LU/ha	1.30	1.30	1.05	1.30	0.80	0.78	0.72	1.05
Ewes (+ 12 months)	560	564	451	476	470	428	333	287
Workers	1.50	1.50	1.50	1.50	1.20	1.20	1.20	1.00
Labour product. EqLU/W	59	59	48	54	64	61	54	45
Lambing rate	1.31	1.19	1.06	1.31	1.04	1.04	1.04	1.06
Numerical Productivity	1.70	1.56	1.40	1.70	1.47	1.47	1.47	1.18
Concentrates kg/ewe	181	141	129	181	159	159	159	115
€/kg	0.183	0.183	0.185	0.154	0.175	0.141	0.141	0.196
Of which bought kg	181	141	129	96	119	63	63	115
Of which produced kg	0	0	0	85	40	96	96	0
Fodder self-suff. %	70	76	77	69	72	70	70	80
Feed self-suff %	70	76	77	85	79	89	89	80
Energy efficiency	0.48	0.49	0.56	0.50	0.33	0.34	*2.29*	0.48
Equiv.fuel litre/kg carc	1.89	1.85	1.61	1.80	2.74	2.67	2.67	1.92
GHGE EqCO2 kg/kgcarc	23	25	28	24	38	41	NS	28

Grain production (simulation on 3/2 and Aut)

In the context of rising grain prices leading to a narrower profit margin per ha of fodder area used by sheep and a wider profit margin per ha of crops, we seek to replace pasture by grain crops. This leads to a reduction in the size of the flock (constant Total Agricultural Area (TAA)). For *3/2* we obtain *3/2+crop* where the grain area for animal feeding reaches 10 ha (corresponding to half of the required concentrates), with a decline of 15% in the number of ewes. For *Aut* we obtain *Aut+crop* where the area of grain crop for home consumption goes up from 5 to 11 ha (60% of the required concentrates) with a decrease in flock size of 9%, the proportion of rangeland in the total fodder area being greater than previously (temporary grasslands turned into crop land). To emphasize the impact of crop production, we raised the proportion of crops in *Aut* with a further increase in grain for sale (16 ha), leading to a further reduction in the flock of 22% (333 ewes) (*Aut+Ccrop*).

Decrease in energy consumption

Three energy factors account for 60% of energy expenditure of the farm (study on 948 French farms, Bochu 2006): purchases of feed, fertilizer and fuel. In suckler systems, the weight of these factors is increased. It represents 96% of the total (not including building and equipment) in suckler cow systems (Galan et al 2007). In sheep-for-meat farms, three factors have a major influence on the energy balance of the farm: food self-sufficiency, limited use of chemical nitrogen fertilizer and reduced fuel consumption (Benoit 2007). Most of the adaptations above discussed tend to reduce the impact of these factors.

Economic climate and CAP assumptions (Table2)

We chose the year 2006 as the baseline economic situation. We first considered only the increase in the price of concentrates, estimated at +40% (farm network observations, between 2006 and 2007). The selling price of lambs was unchanged. The TFC (Territorial Farm Contracts) premium was replaced (contracts end in 2006) by less favourable AEGP (Agro-Environmental Grass Premium). Partial decoupling of the Sheep Premium (50%) and crops (25%) was retained, along with the amount of the SFP (Single Farm Payment) of each of the three farms chosen.

In a second step, we successively evaluated two CAP guidelines and public support: (i) a short-term orientation, which could take the form of emergency assistance (national) to producers with 2000 € per farm (difficult economic context, announced by the Ministry of Agriculture in September 2007). We added the regionalisation of the SFP (theoretical amount in the Auvergne region of € 264 €/ha; Chatelier, personal communication, Guyomard et al 2007); (ii) a longer term orientation with the favourable assumption of a partial recoupling of sheep premium (25 € / ewe) via Article 69 of the CAP, with a nationalization of SFP on the basis of 251 € per hectare of TAA.

Table 2. Public support and economic climate assumptions

Economic climate		PAC		
C1(2006)	C2	P1 (2006)	P2	P3
	Concentrates +40% Grain crops +100%	Coupled sheep premium 50%	Total decoupling and regionalisation (Auvergne 264€ /ha)	Coupled Sheep Premium + nationalisation Single Farm Payment

Allowing for fluctuations

The range of criteria for evaluating livestock systems is broad. We aimed to extend the classical techno-economic assessment (including the criteria of self-sufficiency and energy efficiency) through analysis of the sensitivity of the final economic result (net income) to unforeseen events. Three types of fluctuations were studied:

- Technical: they concern (i) the fertility and prolificacy of the females, with separate fluctuations for three reproductive periods and (ii) mortality in lambs. The range of variation from baseline levels are +- 10% for the fertility and prolificacy, and +-15% for mortality in lambs.
- Economic: price of concentrates and fuel vary by +-20%, meat by +-10%; 4000 successive iterations were made to assess the range of variation of the net income. This was done for 2006.

Modelling tool used

This task was carried out with the simulation tool OSTRAL developed in the unit. It integrates the operation of the flock (seasonality of the production, composition of the batches of animals, food needs for each kind of animal, etc.; Benoit 1998), the calculation of profit margins for each production unit (crop, sheep), taking into account the structural features of the farm (land, buildings and machinery) required for the calculations of overall economic performance and energy balance. The calculator PLANETE developed by Solagro (Bochu 2007) is integrated into OSTRAL for the calculation of the energy balance and GHGs budget. OSTRAL was run under ® EXCEL.

Results

Economic performances in two cyclical situations (Figure 1)

In the 2006 situation (C1, see Table 2), none of the adaptations designed for *3/2* brings about a significant improvement in income (Table 3), the relationship between concentrates and sheepmeat prices maintaining the utility of intensified reproduction with a significant dependence on external supplies for feeding the flock. In this 2006 situation, the numerical productivity remains the determining factor of net income, and *3/2* remains one of the most powerful systems from an economic point of view (net income: 17360 €/worker (NI/W)). Also, the net income falls significantly for *3/2Inf* and *3/2Ext* (-13% and -24%), although their fodder self-sufficiency is better (respectively 76% and 77% *vs.* 70% for *3/2*). The cultivation of cereals (*3/2+crop*) does not allow an increase in net income.

When the grain prices are higher (C2; Table 4), the high levels of fodder self-sufficiency explains the smaller differences in net income between *3/2Inf* or *3/2Ext* and *3/2* (respectively -6% and -15%, compared with -13% and -24% in the 2006 situation). Similarly, cereal production for the flock becomes very favourable, the net income in *3/2+crop* being higher by 28% from the baseline (15600 *vs.* 12100 for *3/2*). We note here that the farm is partly self-sufficient for straw (78%), which saves 2100 € in inputs.

*Table 3.Features of the three farms studied and simulated cases (**2006 situation**)*

	Observ				Observ			Observ
System	*3/2*	*3/2Inf*	*3/2Ext*	*3/2+crop*	*Aut*	*Aut+crop*	*Aut+Ccrop*	*Small*
Sheep product €/ewe	143	132	115	143	126	126	126	96
Sheep Inputs €/ewe	56	48	43	51	60	54	54	34
Gross Margin /ewe €	**87**	**84**	**72**	**92**	**66**	**71**	**72**	**62**
Net Income/worker €	**17400**	**15100**	**13200**	**17500**	**12000**	**12600**	**13000**	**17400**
Fixed Costs/EqLU €	443	464	436	454	460	486	459	296

*Table 4. Features of the three farms studied and simulated cases (**situation C2**)*

	Observ				Observ			Observ
System	*3/2*	*3/2Inf*	*3/2Ext*	*3/2+crop*	*Aut*	*Aut+crop*	*Aut+Ccrop*	*Small*
Sheep product €/ewe	143	132	115	143	126	126	126	96
Sheep Inputs €/ewe	74	62	56	68	73	69	69	44
Gross Margin /ewe €	**69**	**70**	**60**	**76**	**52**	**57**	**57**	**52**
Net Income/worker €	**12100**	**11400**	**10200**	**15600**	**9000**	**11100**	**14900**	**14600**
Fixed Costs/EqLU €	421	440	421	445	449	480	497	296

In the 2006 situation, the *Aut* system, with a lower numerical productivity than *3/2* (1.47 *vs* 1.70), and despite slightly higher labour productivity (64.1 Eq LU/worker *vs* 59.4; Benoit 2004) and a good cash price for lambs produced in off-season (autumn), the net income per worker is lower by 31% (12020 € / W *vs* 17360 in *3/2*). A slight increase in income occurs when the grain self-production increases (*Aut +crop:* +5%) and when there are also cash crops (*Aut+Ccrop*: +8%). These differences are much more significant in situation C2: the net incomes of *Aut+crop* and *Aut+Ccrop* are then respectively higher by 24% and 65% than that of the basic system (*Aut*).

In the 2006 situation, the *Small* system surprisingly showed a net income comparable to *3/2* in spite of a significantly lower labour productivity (45.2 LU/W *vs* 59.4, or -24%) and above all in spite of a lower numerical productivity (-30%). This good result is firstly explained by very low fixed costs (296 €/EquivLU *vs* 433). The small size of the farm meant small investments in both machinery (low harvested surface, no temporary grasslands) and in buildings (“tunnel” type). In addition, the low turnover reached (44000 €) allows the choice of a contribution system (a “fixed” system independent of income, possible below 76000 € of turnover). This is very favourable in the present case because the high level of net income achieved would lead to much greater contributions in the case of the classical contribution system, called “real income” (contribution = 42% of net income). In addition, the “fixed” system does not encourage significant investment as in the “real income” situation.
This system, with high fodder self sufficiency (80%) is one of the least sensitive to an increase in grain prices (situation C2), with a reduction in income by “only” 16%.

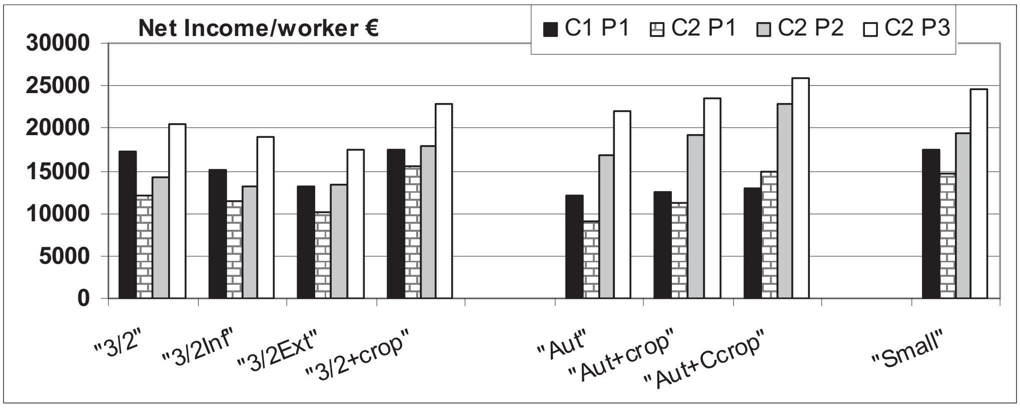

Figure 1. Compared net incomes for three basic systems and their adaptations, in two economic situations (C1 and C2) and in three public support situations (P1, P2, P3)

Economic performance in three public support situations (Figure 1)

These comparisons are made in the case of high grain prices (C2+P1, C2+P2, and C2+P3). In scenario P2, the safest systems are those with the lowest stocking rates, which corresponds to low starting levels of SFP per ha, the new premium per ha (total decoupling and regionalization of SFP) being greater than the initial support situation. This is the case for *3/2Ext* and *Small*, but especially *Aut*, whose rising net income is the largest (+88% to 16940 €/W), the NI/W being finally higher by 19% than that of *3/2* (14190 € /W) in this situation. The stocking rate levels are very different (0.80 *vs* 1.30).

Under this assumption C2+P2, the differences in NI/W between *3/2* and *3/2Inf* and *3/2Ext* are reduced and represent no more than 920 € and € 840 or 6%, compared with 13% and 24% in the initial situation (C1+P1). Given the theoretical lower workload in *3/2 vs*. 3/2Ext (48 Eq LU/W is -19 *vs* 59.4%) and lower capital requirement (-28%), the incentives could be high for systems with classic *3/2* to switch to *3/2 Ext*.

The scenario P3 significantly strengthens the utility of *3/2* through the partial return to a premium per animal. Also, for *3/2*, the NI/W increases by 6270 € between situations P2 and P3 (+44%), whereas it increases only by 5139 € (+30%) and 5142 € (+26%) for *Aut* and *Small*. Nevertheless, the net incomes of these last two systems remain higher than *3/2* (respectively +1623 and +4180 €).

Comparison of energy efficiencies and GHG emissions (Figure 2)

The *3/2* energy efficiency (EE) is similar to that of *Small*, and fairly high, at 0.48, thanks to a high level of numerical productivity (Benoit 2007), allowing a much larger energy production in the form of meat (9255 kg carcass per worker against 4960). This compensates for higher input use (concentrates: 181 kg / ewe *vs* 115; nitrogen, fuel). By contrast, *Aut*, with an intermediate level of productivity and significant use of inputs, displays an EE limited to 0.33.

The cultivation of grain in *3/2+crop* allows a gain of 2 points on EE (0.50), thanks to the reduction in the quantities of concentrates and straw purchased, and despite fuel consumption linked to the cultivation of cereals. The greatest gain is achieved with *3/2Ext* EE (0.56), the consumption of concentrates and stored forage being in sharp decline, with respectively 129 kg of concentrate per ewe *vs* 181, and 204 kg of fodder per ewe *vs* 316, grazing being maximized.

Greenhouse gas emissions are generally fairly well correlated negatively with EE (Figure 2). For example, emissions of CO_2 equivalent ($EqCO_2$: impact of CO_2, N_2O and CH_4) per kilogram carcass produced reach, for *Aut,* the high level of 38, with a low EE of 0.33. The level of weight productivity per ewe (numerical productivity x weight of the lambs) has a decisive impact. Thus there is an increase in $EqCO_2$ /kg carcass in the case of *3/2Ext* (28 kg /kg carcass *vs.* 23 kg for *3/2*), as falling numerical productivity is not compensated for a sufficient decrease in input use. $EqCO_2$ emissions from mother ewes (forage production, CH_4 emissions, etc.) constitute most of the $EqCO_2$ production, and a high numerical productivity (large quantity of meat produced) allows this high basic $EqCO_2$ production to be "diluted". This factor is essential; as an illustration, *Aut+crop*, despite 89% food self-sufficiency, has

41kg $EqCO_2$ emissions per kilogram carcass, i.e. 78% more than *3/2,* which displays only 71% food self-sufficiency (no crops), but produces 24.8 kg carcass per ewe against 20.8 for *Aut*. These levels of $EqCO_2$ emissions, between 23 to 41 kg/kg carcass represent nearly 10.3 to 18.5 kg/kg live weight (LW). That is in accordance with international literature on suckler production as Casey (2006) gave the figures of 7.56 to 11.26 kg $EqCO_2$ per Kg LW for suckler beef production in Ireland. Bochu (2007), on a French national synthesis on the subject of energy efficiency and GHG emissions, gave the average figure of 20 kg $EqCO_2$ /kg LW for both cattle and sheep for meat farms.

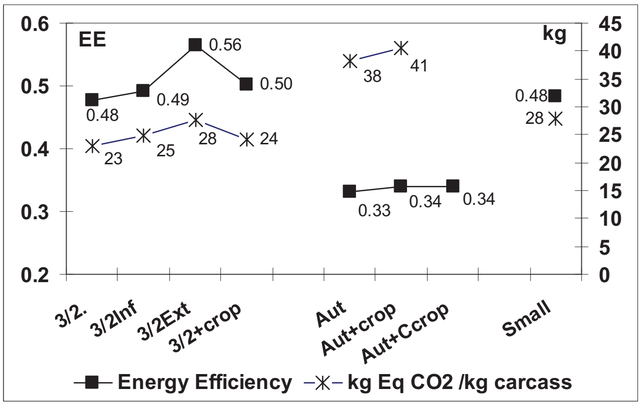

Figure 2. Energy efficiency and GHG emissions (Eq CO2 per kg carcass), basic and simulated systems

At constant farm area, the cultivation of cereals to improve flock food self-sufficiency, although it improves energy efficiency, does not lower and actually raises EqCO2 emissions per kilogram carcass (+1 point between *3/2* and *3/2+crop* and +3 points between *Aut* and *Aut+crop*). One explanation lies in the overall decline of meat produced (to leave area for crops), although emissions are finally not very different. Note that we take no account here of the very negative impact in terms of EqCO2 emissions of the introduction of crops with ploughing of long-term or permanent meadows. This could lead to a massive release of CO2 into the atmosphere, with the loss of about 20 tons of carbon per hectare in the medium term (Seguin et al 2007).

Discussion

Sensitivity of the systems to technical and economic fluctuations

Given the fluctuations of the values of components of numerical productivity, of the selling price of lambs, of concentrates and fuel, the systems that were both more productive and more dependent on external inputs saw their income vary over a wide range (2006 situation): 11700 € to 22500 € per worker for example for *3/2*, against only 13700 to 21300 for *Small*. Indeed, the less dependence on external inputs is an element of farm resilience (Milestad 2003). Figure 3 shows that the variations in net income per worker (in particular the difference between minimum and maximum observed) are greater for *Aut* and even more so for *3/2* than for *Small*. Given the lower profitability (median net income) of *Aut*, this kind of system would be theoretically more sensitive to changing economic circumstances or technical fluctuations. Indeed, the coefficient of variation (standard deviation divided by the mean, over 4000 values) reaches 0.133 for *Aut* against 0.097 for *3/2* and only 0.077 for *Small* (Figure 4). This criteria is in close relation to the ratio Net Income/Turnover, which reaches only 0.17 for *Aut,* 0.25 for *3/2* and 0.40, an exceptional level, for *Small*. The correlation is also very high with the ratio of EBE/Gross Product (EBE = net income - amortization-financial interest) (Figure 4).

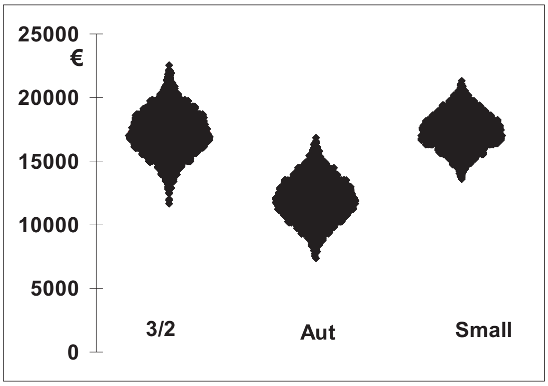

Figure 3. Scattergrams (®XLTSAT) representing the frequency distribution of the net income obtained with fluctuation on six variables (4000 iterations and three systems compared); 2006 situation

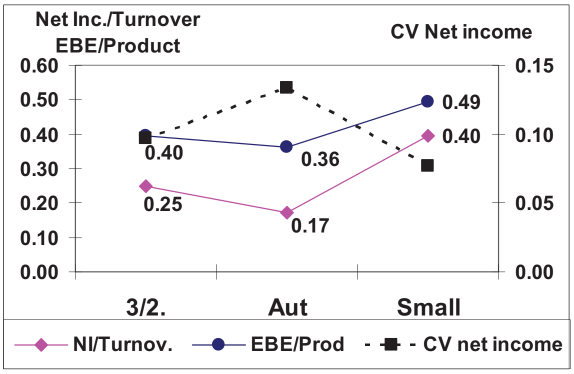

Figure 4. Coefficient of variation of the net income (Standard Deviation/Mean; 4000 iterations); Net Income/Turnover and [Net Income-amortization-interest (EBE)] /Gross Product; 3 systems compared; situation 2006

In economic situation C2, the net income decreases, particularly for *3/2*, and leads to an increase in the value of the coefficient of variation. Thus *3/2's* CV increases from 0.133 to 0.176 between C1 and C2, making *3/2* not only less profitable in this context, but also subject to greater variations in net income (Figure 5).

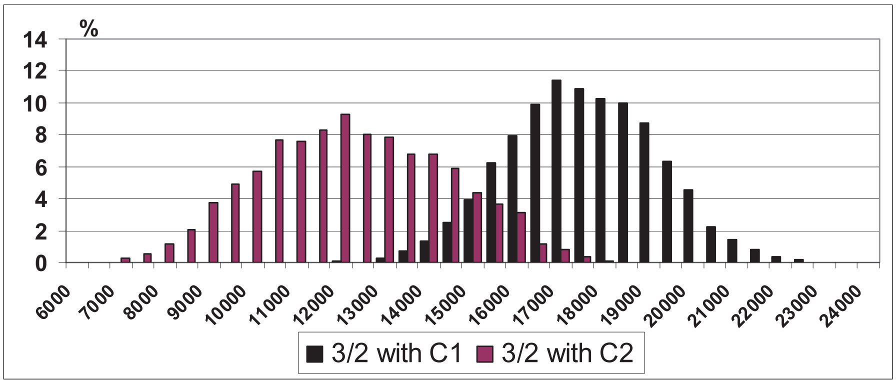

Figure 5. For 3/2, distribution of the net income (frequency) in two situations: C1 (2006) and C2 (high price of concentrate), with fluctuation on six variables

Consequences for the industry, upstream and downstream

The most likely assumptions made for the economic situation (increased grain prices, stable meat prices), and for public support (continued decoupling of aid, redistribution by regionalization or nationalization) both call for reconsideration of the *3/2* reference system strongly promoted for many years as the most successful system. This reappraisal, either with the setting-up of a less productive or more self-sufficient alternative system, or with fewer sheep on farms to reduce production costs or increase food self-sufficiency through cereal crops, could lead to a significant reduction in both the number of lambs produced per farm and in the inputs used. These reductions would result in a significant decline in the turnover of cooperatives associated with these farms, whether marketing the production or providing inputs. Thus the adaptation of farms may have significant economic and social impact upstream and downstream of the sheep farming itself. Matthews (2006) concluded that in the framework of the CAP reform, adaptation of farming systems in Welsh uplands could be made by extensification of land use and then can lead to a reduction of employments within agricultural services and processing industries.

We worked on the assumption of a constant agricultural area. If we consider an expansion of the farms, the adaptations can be considered feasible, maintaining the same number of ewes, or even the number of lambs produced, as the cultivation of cereals need not be at the expense of fodder area, and the drop in stocking rate could be achieved with new land. However, sheep farmers are now in fierce competition for the acquisition of land with dairy and cattle farmers for whom the circumstances are more favourable, particularly with a very strong foreseeable increase in the price of milk.

In addition, despite the reservations expressed, we must note that the *3/2* could still have a recognized place in the future, to the extent that:

- Producers could, with the help of technicians and researchers, improve self-sufficiency by maximizing forage grazing, introducing suitable forage varieties, using high quality harvested forages, etc.
- Agricultural policy measures to come could, through subsidies for the animal or per LU, acknowledge the socio-economic efficiency of these systems that are capable of generating high income per ha, maintaining a farming population on the basis of medium-sized farms, and contributing to the sustainability of economic tools upstream and downstream.

Strong expansion of the farms, another route to explore

Beyond the adjustments studied at constant farm size, it is necessary to consider the usefulness of adopting more "radical" solutions by challenging the "modernization" of the systems through strong expansion combined with a sharp increase in labour productivity, an approach that seems to prevail today in the livestock environment. Initial findings suggest that such an approach, in the context taking shape (C2), and needing investment particularly in buildings and machinery, could significantly increase sensitivity to change while having at the same time a negative environmental (and even social) impact, without guaranties of a significant gain in income per worker. It would be necessary to invent large productive sheep farming systems, with very low production costs. But is this possible in conditions so different from those of the major sheep producing countries in the southern hemisphere?

Conclusion

The evolution of the economic context may cause sheep farms in semi-upland areas to challenge the most productive system that has been a standard reference since the implementation of the CAP in 1992. This coincided with historically low prices for cereals and the strengthening of direct aid for production, which favoured such a system. The surge in grain prices may now lead these farms to seek greater food self-sufficiency, which would result in a significant decrease in meat sales. Implementing adaptations such as production of grains when possible, lower stocking rates or lower animal intensification, could allow easier maintenance of the net income of the farms and better resistance to technical or price fluctuations. Also, it could result in the improvement of environmental criteria such as energy efficiency or biodiversity (cultivation of grain). However, there might be an increase in GHG emissions per kilogram of carcass produced.

The study highlights the value of small-size farming systems, less productive but extremely thrifty. Their small size allows them to optimize the granting of certain subsidies limited to acreage or number of animals, to take advantage of a favourable contribution system, and finally to be relatively insensitive to technical and economic fluctuations.

Overall, we note that the new context of sheep production may now more easily revive the economic utility of less intensive production systems, with generally positive environmental impacts. A total decoupling of aid would only strengthen this trend.

Maximal use of forages is one of the essential levers to cope with the current situation, limiting consumption of energy and improving energy efficiency. If it can be combined with a high level of numerical productivity, the GHG emissions per kilogram of carcass can be greatly reduced.

A double challenge also seems to be emerging: (i) how can high animal productivity be combined with very high fodder self-sufficiency? and (ii) for much larger farms, what systems of operation can be devised, based on low inputs use, and on maximum self-sufficiency of environmental resources use?

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