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Management of Technical Systems on the Farm

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In the context of Europe's new and fluctuating agricultural production situation, R&D agencies must help farmers set up sustainable production systems that are in keeping with today's requirements, environmental requirements especially. With regard to technical management of a crop or product, the research institutes' approach is changing. It is no longer enough to provide technical references designed to optimise productivity; the focus must shift towards designing decision making aid systems that enable farmers to cope with uncertainty and adapt to many different possible situations. The essential first step in designing such decision making aids is to understand and formalise the farmer's own technical decision making processes - processes which underlie the great diversity of farming practices observed in France. Research conducted in recent years, particularly by the Agrarian Systems Department (SAD) of the National Institute of Agronomic Research (INRA) (Papy, 1994), has given researchers a better understanding of these processes and a better ability to describe them. In this paper, we illustrate this theme from studies made of three different technical systems.

Technical decisions that can be formalised

Technical decisions on the farm have two essential characteristics: (i) they are cyclic[1], so that technical operations can be partly planned in advance and decision making rules drawn up; (ii) they are subject to hazard and uncertainty (in particular, they are at the mercy of the climate); they therefore have to be flexible and adaptable to some extent.

To formalise farmers' technical decision making, we have drawn up a representation framework, which we call a "model of the farmer for action" or an "action model" (Sebillotte & Soler, 1988, 1990; Duru et al., 1988). In this framework, technical decision making processes are represented by (i) general objectives regarding the system or product concerned, (ii) a forward planning schedule of operations to reach these objectives, incorporating a division of time into phases (each guided by sub objectives) and a set of decision making rules that are activated by indicators, and (iii) specific adjustment rules enabling the farmer to adapt his/her planning schedule to eventualities (in the weather particularly) that are considered to be possible. To many authors, this forward planning of decisions in the form of objectives, planning schedules, rules and indicators is analogous to the way production decisions are taken in industry.

[1] For example, for annual crops, the farmer knows that each year he/she must plough, sow, weed, fertilize etc. at roughly the same dates, according to the average climate of the region.

These findings have been established for specific technical decisions such as those involved in establishing a crop (Cerf & Sebillotte, 1988) or organising farm work at certain times of year (Papy et al., 1988). To test their relevance to overall technical management of a given crop or product on the farm, we studied three technical systems: management of the wheat break on arable farms; management of rotational grazing in cattle farming; and management of a greenhouse tomato crop (the latter two examples being considered in comparison with the first).

Management of the wheat break in a rotation

Wheat is a long-cycle crop requiring many different technical operations at different times of year, some of which can compete with other farm activities. In field crop systems, the wheat break is often grown on many different fields (one commonly finds more than ten), which differ in terms of soil type, preceding crop and the history of the field. The problem of organising technical decisions in time and space is therefore a practical problem. Our study of technical management of the wheat break was based on an in-depth survey among a small number of farmers over several successive years, as follows: surveys of farmers' expected schedules of technical operations (before they actually began); recording of operations as actually carried out on all the wheat fields; and interviews with farmers to pinpoint the reasons for any discrepancy between their expectations and the actual course of events. The results show that technical management of the wheat break on all the farms in the study can be represented by a common structure, which also concords with that of an action model. Further, they enable us to detail the content of the structure, the decision making rules particularly (Aubry, 1995). To describe the planning schedule for technical management, we formalised the decision making rules and classified them into several types, covering both the expected schedule of technical operations and the particular modes of the operations, e.g. the choice of inputs (see Figure 1).

Three types of rule determine the timing of operations: sequencing rules (the chronological order of operations in each field), activation rules triggering an operation on a given set of fields (when an indicator specific to the operation reaches a certain threshold value); and arbitration rules defining, at certain times (t1, t2) priorities between concomitant operations when the labour and equipment available on the farm do not allow them to be carried out simultaneously. One finds rules for arbitration between concurrent crops, dividing time into periods[2]; rules for arbitration between wheat fields competing for a given operation; and rules for arbitration between operations on a given set of fields. Two types of rule determine the intended mode of an operation: rules for establishing modes (defining their intended characteristics, e.g. type, number and, for inputs, dosage); rules for attributing the modes so established to the different fields in the break, according to certain indicators.

Some unexpected management objectives emerge from this representation. In particular, the farmer rarely draws up his/her planning schedule field by field, as it would be too complicated to bring all the decision making rules into operation for each field in the break. We observed that farmers simplify the process by grouping fields into sets: grouping rules divide up the break according to particular criteria, which differ according to the operation in question. Over the entire cropping season, one can distinguish the fields belonging to the different sets, i.e. the fields where the same mode of the same operation has been implemented during the

[2] A period here is thus a lapse of time when a given crop takes priority over at least one other.

same period. We have called sets these "wheat field types". Some of these wheat field types are so perceived by the farmer, while in others cases, although there is no deliberate decision to group these fields together, they are so grouped in practice by successive operational decisions. The types of wheat field in the wheat break vary from farm to farm but there are never very many, always fewer than the number of fields in the break.

Furthermore, for some technical operations, the farmer must gather indicators through observation, either of the environment or of the wheat in the field. As a rule, he/she gathers these indicators only from certain fields, which we have called indicator fields and which are each representative of a field set within the break. This use of indicator fields cuts down the time farmers have to spend in observation and simplifies information processing.

Comparison with the other two technical systems

The complexity of wheat break management is due to the number of fields involved, their differing characteristics and the number of operations to be carried out on each one. Farmers' technical decisionmaking, like any management activity, seeks to reduce this complexity. The complexity involved in managing rotational grazing on cattle farms (Chatelin & Havet, 1992; Mathieu, 1990) is different, as it combines management of herd feeding with management of the farm's fodder area. There are thus two interacting biological systems: (i) the cattle, whose nutritional requirements differ over time and from one animal to another, and (ii) the fields, each with its own pace of production, which must be managed with an eye (a) to ensuring high quality sward for grazing at certain times of year for certain types of animal, and (b) to producing conserved fodder stocks for the winter.

Management of a greenhouse tomato crop (Navarette, 1993) depends on two interacting decision making systems: (i) that of the grower, who manages computerised greenhouse climate control systems and defines the broad rules for crop husbandry and (ii) that of the workers in charge of the many manual operations carried out on the plants themselves. As with wheat, these technical systems have to be managed in uncertain and changeable conditions - weather conditions especially for rotational grazing, and an unstable marketing situation for tomato growing.

Studies of these two technical systems, taking the same approach as described for wheat, show that, here too, one finds the structure of an action model with objectives, planning schedules, decision making rules and indicators (see Figure. 2). In particular, one finds, as with wheat, (i) a prior division of time into periods, each characterised by the application of a certain set of rules, (ii) decision making rules concerning (a) the course of operations over the season (sequence, triggering factors, arbitration) and (b) establishment and choice of the particular modes of these operations. One also finds that management of these systems can be simplified by grouping. However, some specific features emerge that raise further questions.

Simultaneous management of a herd and of a number of grassland fields is less easy to control than management of a farm area under a single annual crop. Given their uncertainty over conditions in two different biological systems, farmers allow themselves more room for manoeuvre: rules laid down for different possible circumstances therefore have an essential role to play in decision making. Moreover, simultaneous management of two systems leads farmers to divide both their animals and their fields into groups or sets: how does the stock farmer see the interrelations between the two types of grouping?

As regards greenhouse tomato growing, where two, hierarchically ranked decision making centres (grower and workers) coexist, one must examine the decision making processes of both and how they relate to each other. The two systems are at least linked by the general plant management instructions which the workers receive from the grower. The *objects* of management thus seem to differ: in one case groups of plants, in practice different parts of the greenhouse (the grower's general instructions), in the other individual plants within each group, which is the domain of the worker and his/her manual techniques.

Conclusion

This work on technical decision-making shows that the scales of work and objectives pursued differ between the technical experts who work out references and the farmers who manage the technical systems. The farmers have their own objects of management, which the technical experts rarely consider: sets of fields within the area sown to a given crop; areas within a greenhouse; groups of animals within a herd, etc. Similarly, those who design new modes of production generally take little account of the fact that farmers, when making technical decisions, must arbitrate between concurrent activities in organising farm work, simplify management of the crop or product as a whole, and establish links with other spheres of decision making such as commercial and financial management, etc. To provide decision-making aids that are suited to farmers' management habits, it therefore seems to us essential to model the management of technical systems as perceived by the farmers themselves.

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Annexes

Planned Sequence of events

Rule	*Formula*	*Example*
Sequencing Operations O1,O2 field p	For all p, O1 before O2	For all fields allocated to wheat break (Harvest of preceding crop) before (Sowing of field)
Activation of operation O on a groups of fields Ep	Let I be the activation indicator of O Let Vs be the threshold value of I If (I > Vs), then (Start of O) on Ep	If (Date > 10 October), then (Start of wheat sowing) on (Fields cleared of preceding crop)
Arbitration between two groups of fields (Ep1,Ep2) for two operations (O1,O2)	During time period (t1,t2) (O1 on Ep1) takes priority over (O2 on Ep2)	During period (10 October, 25 October) (Wheat sowing on free fields) takes priority over (Beet harvest on fields ready for harvest) and (Sowing on fields following potatoes) takes priority over (Sowing on fields following other crops)

Modes of farm operations

Establishing modes Mi for each operation O	Number of modes Mi For each Mi, [Type, dosage]	2 modes of N fertilisation on wheat break M1 = (180 units, 2 applications in liquid form) M2 = (200 units, 3 applications in liquid form)
Attributing an Mi to each part of the break	let {C} be a set of criteria if {C}={Cn}, then Mn	{C} = {soil texture} if {texture sandy or sandy loam} then M2 otherwise M1

Figure 1: Types of decisionmaking rules for management of a wheat break

System	***Wheat break***	***Rotational grazing***	***Greenhouse tomatoes***
Sources of complexity	many fields many operations heterogenity within wheat area	2 biological systems interacting: animals and	decisionmaking systems Grower and workers grassland fields
Points in common	Time divided into **periods** characterised by particular sets of arbitration rules Existence of decisionmaking rules concerning * planning schedule * intended modes of operations Complexity of management reduced by **grouping**		
Specific features		Major adjustments Two interacting types of grouping (animal groups)*(set of fields)	Communication between the 2 systems at least by general instructions different objects of management (groups of plants) / (individual plants)

Figure 2: Comparison of three technical systems