Modelling the cognitive decision-making processes involved in agricultural production management

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1 Les enjeux scientifiques et socio-économiques

The world we live in is changing at a very rapid pace. If agricultural production is to remain viable, it must adopt appropriate practices and adapt to new constraints and criteria concerning climate change, environmental quality, working conditions, energy prices and market demand. Agricultural production processes generally involve a number of coherently organised activities that are undertaken by a farmer to achieve his goals. Production management deals with how farmers combine land, water, machinery, structures, commercial inputs, labour and management skills to produce crop and livestock commodities, as well as other services.

In agriculture the amount and quality of output that result from a given bundle of inputs are typically not known with certainty, i.e., the production function is stochastic. This uncertainty is due to the fact that uncontrollable elements, such as weather, play a fundamental role in agricultural production. The effects of these uncontrollable factors are heightened by the fact that time itself plays a particularly important role in agricultural production, because long production lags are dictated by the biological processes that underlie the production of crops and the growth of animals. Price uncertainty is also a standard attribute of farming activities. Because of the biological production lags, production decisions have to be made far in advance of realizing the final product, so that the market price for the output is typically not known at the time these decisions have to be made. Policy uncertainty also plays an important role in agriculture.

Farmers have always had to manage uncertainties and adapt to changes. However, agricultural practices and knowledge were developed to deal with uncertainties within the limited range in which they usually occurred. Uncertainty is assuming a new dimension and the time available for autonomous adaptation is short.

Good management principles are critical to maintain or increase profitability and to improve the sustainability of any agricultural production system. An inadequate design of the production processes may lead to poor performance (Rougour et al. 1998), e.g., bad timing of activities, inefficient utilisation of resources or frequent failure to achieve goals. Consequently, agricultural production systems require enhanced analysis instruments that make it possible to represent their behaviour in different scenarios, and to identify possible flaws, vulnerability and performance before they are actually built. Such capabilities are extremely useful to understand and improve production systems and to adapt them to new conditions. Research has certainly a role to play in easing to cope with the increasing complexity of farm production management. This requires innovative approaches that recognize and focus on the holistic, dynamic and cognitive dimension of farm management.

2 La (les) question(s) de recherche

It is our belief that improving performance and adapting decision-making to new situations calls for understanding the full problem-solving context and the challenges inherent in it, examining how they drive and constrain farmers' decision-making and how information and judgment are integrated. Moreover, such a study makes sense only if it incorporates the full range of factors influencing farm households, which explain current management practices as well as potential changes in reaction to external circumstances.

The central question of the thesis proposal can be stated as: how is a farm manager cognitively approaching decisions. The investigation work will aim at characterizing and formalizing the types of information involved in the decision-making process and the mechanisms by which they are manipulated and combined. Particular attention will be paid to the following aspects:

- the dynamic generation of goals (objectives as state to bring about or as tasks to be carried out) and values (preferences, hierarchies, separation between preferences in the desirable and detrimental domains) and their processing especially when they are conflicting;
- the role of constraints (regulation, resource limitation) in the decision-making process (difference with goals if any);
- the augmentation of the anticipatory power of the temporal and procedural structures that orient and coordinate decision-making over a temporal horizon (plan-based structures on intended actions and

observations) without reducing the high flexibility incorporated in these structures to ensure their robustness to variability within a given range of situations;

- the articulation between observation (event monitoring and biophysical sensing), goal generation (or modification), plan adjustment and action generation;
- the incorporation of likelihood knowledge (relative frequencies) and conditional predictions in the decision process;
- the investigation of the way beliefs and preferences influence the decision maker’s attitude and its willingness to changes his practices.

The thesis project draws on theoretical and experimental results of various decision process studies (not only in agriculture). The expected output is a framework that extends the existing ones toward higher relevance to real production settings of farm managers.

3 Le contexte méthodologique choisi et les développements envisagés

Traditional studies of decision-making in economics, operations research and artificial intelligence have tended to view decision-maker as possessing supernatural powers of reason and limitless mental resources. Indeed perfect rationality is a crucial assumption in economics that assume agents make their decisions coherently with the utility maximization doctrine. Actually, Expected Utility (EU) theory remains the dominant approach for modelling risky decision making and is still the paradigm of reference in decision making. This framework addresses decision problems in which the decision setting does not change (goals do not shift or need not be redefined) and the decision options and consequences are completely known or assumed so. Despite its normative appeal, the EU framework has come under intense scrutiny because of its inability to describe some features of individual behaviour under risk as shown by several experiments and empirical observations. Several studies have proposed more general theoretical frameworks such as the Kahneman and Tversky's prospect theory (1992) that distinguishes between preferences in the gain and in the loss domains and assumes that the objective function is non linear in probability. However all these theories adhere to the paradigm of perfect rational decision maker. Moreover, the EU model has also been criticized on the framing aspect: the difficulty of getting the options, probability, and utility values.

Much of the decisions in agricultural production management (Nuthall 2011) concern dynamic decision problems: (1) a series of interdependent decisions and/or actions is required to reach the overall objective; (2) the situation changes over time, sometimes very rapidly; (3) goals shift or are redefined and are conflicting. Some developments made in artificial intelligence on agent modelling (e.g. Belief-Desire-Intention (BDI) architectures (Vikhorev et al. 2011)) provide a useful philosophical and concrete base for investigating human practical reasoning. Differently inspired research in a number of complex fields (not only agriculture) has demonstrated that under conditions of uncertainty, time pressure, shifting and conflicting goals, and high risk, experts seldom engage in highly analytic modes of decision making. These findings indicate that we need to better understand the full range of decision making and management strategies employed by farmers and the contexts of their use. One behavioural science framework, called Naturalistic Decision Making (NDM) (Klein et al., 1993), explores how experienced people make decisions to solve problems in real-world settings in dynamic, uncertain, fast-paced environments. It focuses on the mental processes of information processing and reasoning. The NDM approach of cognition and decision making has moved over the years to accommodate ‘real’ behaviour, following Simon (1996) who proposed a view of ‘bounded rationality’ (Cozic, 2008). As Simon stated it “a theory of rational behavior must be quite as much concerned with the characteristics of the rational actors—the means they use to cope with uncertainty and cognitive complexity—as with the characteristics of the objective environment in which they make their decisions. In such a world, we must give an account not only of substantive rationality—the extent to which appropriate courses of action are chosen—but also procedural rationality—the effectiveness, in light of human cognitive powers and limitations, of the procedures used to choose actions.” Simon introduced the notion of *satisficing,* contending that organizations deal with real-world complexity by using procedures that find ‘‘good enough’’ answers to questions when best answers cannot be obtained.

As shown by many studies decision-makers rarely are rational in the normative sense of the term. In practice, other disciplines (in particular artificial intelligence and cognitive psychology, inspired by Simon’s work) have tried to replace the economic rationality (the perfect rationality assumption) with other principles, rules, or heuristics that focus on getting the first workable option rather than trying to find the best possible option. Observing a similar phenomenon in agriculture, farming systems researchers studying production management strategies developed simple rule-based representation of the decision-making process (influenced by expert system research in early 1980s). This line of thought is still actively pursued and has fed the development of many decision support systems (DSS) and cognitive tools used to support participatory design tasks (Duru and

Martin-Clouaire 2011, McCown 2005). As outlined in the preceding section, this thesis proposal aims to overcome some of the limits of the current approaches in this family, in particular, the conceptualization of decision-making in a dynamic environment, and the explicit representation and processing of goals and uncertainty. Indeed, the study of decision making in the dynamic and real time context of a farm relocates the study of decision making and makes it part of the study of action, rather than the study of choice. Decisions are embedded in task cycles that consist of circumscribing the problem to the relevant pieces of information, setting up goals and intentions, searching a reasonable solution that is compatible with resources available, taking the corresponding action and, possibly, preparing to monitor the effects of that action. Recent developments (Martin-Clouaire and Rellier, 2009, 2011) and applications (Rellier et al., 2011; Martin et al. 2011) made in our laboratory provide a solid basis for this project but an encompassing theory of reasoned action in agricultural production management remains to be done.

4 Les pré-requis pour le candidat

- Required degree: Research master (or equivalent degree) in a cognitive science discipline (artificial intelligence, cognitive psychology) or behavioural economics or cognitive systems engineering (Woods and Hollnagel 2006) or complex system modelling.
- Familiar with theoretical frameworks of judgment and decision-making
- Familiar with modelling techniques (conceptual or computational)
- Programming abilities

5 Les perspectives professionnelles pour le doctorant

Enseignant-chercheur ou chercheur
Ingénieur dans un organisme ou société de conseil en gestion de production

6 Les propositions de noms pour le comité de thèse

J.-P. Amigues (INRA-SAE2, Toulouse)
J. Cegarra (LTC, Univ. Toulouse 2)
N. Girard (INRA-SAD, Toulouse)
J.-M. Hoc (Ecole Centrale de Nantes)
E. Hollnagel (Sécurité Industrielle, Mines ParisTech)
C. Monteil (ENSAT, Toulouse)

7 Le partenariat scientifique et industriel dans lequel s'inscrit le travail

At least one senior farming system researcher will be associated to the project, contributing with his/her expertise on a production domain and his/her network in the professional community.

8 Les publications du laboratoire d'accueil sur le sujet

Brunette M., Cabantous L., Couture S. (2011) Comparing group and individual choices under risk and ambiguity: an experimental study . Submitted to *Journal of Economic Behavior and Organization.*

Couture S. (2011) Les approches employées par les économistes pour étudier les risques en forêt : revue de la littérature. Forthcoming in *Comptes Rendus de l'Académie d'Agriculture de France*.

Couture S., Reynaud A. (2011) Forest management under fire risk when forest carbon sequestration has value. *Ecological Economics*, 70(11), 2002-2011.

Couture S., Reynaud A. (2011) Stability of risk preference measures: results from a field experiment on French farmers. At revision stage in *Theory and Decision.*

Duru M, Martin-Clouaire R. (2011) Cognitive tools to support learning about farming system management: a case study in grazing systems. *Crop and Pasture Science*, 62, 790–802.

Martin G., Martin-Clouaire R., Rellier J.-P., Duru M. (2011) A simulation framework for the design of grassland-based beef-cattle farms. *Environmental Modeling & Software*, 26(4), 371-385.

Martin-Clouaire R., Rellier J.-P. (2009) Modelling and simulating work practices in agriculture. *Int. J. of Metadata, Semantics and Ontologies*, 4(1-2), 42-53.

Rellier J.-P., Martin-Clouaire R., Cialdella N., Jeuffroy M.-H., Meynard J.-M. (2011) Modélisation de l'organisation du travail en systèmes de grande culture : méthode et application à l'évaluation ex ante d'innovations variétales de pois. In Béguin, P., B. Dedieu, and E. Sabourin (eds.) « Le travail en agriculture : son organisation et ses valeurs face à l'innovation », L'Harmattan, Paris, 205-222.

Ripoche A., Rellier J.-P., Martin-Clouaire R., Biarnès A., Paré N., Gary C. (2011) Modelling adaptive management of intercropped vineyards to satisfy agronomic and environmental performances under Mediterranean climate. *Environmental Modeling & Software*, 26(12), 1467-1480.

9 Bibliographie

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Kahneman D., Tversky A. (1992) Advances in prospect theory: cumulative representation of uncertainty. J. of Risk and Uncertainty, 5, 297-323.

Klein G., Orasanu J., Calderwood R., Zsambok CE. (1993). Decision Making in Action: Models and Methods. Ablex Publishing Corp:Norwood, NJ.

McCown RL. (2005) New Thinking About Farmer Decision Makers. In: The Farmer's Decision: Balancing Economic Successful Agriculture Production with Environmental Quality. J.L. Hatfield (ed.) Soil and Water Conservation Society, Ankeny, Iowa, USA, 11-44.

Nuthall P.L. (2011) Farm business management: analysis of farming systems. CABI, Wallingford, UK.

Rougour C.W., Trip G., Huirne R.B.M. and Renkema J.A. (1998) How to define and study farmer's management capacity: theory and use in agricultural economics. Agricultural Economics, 18, 261–272.

Simon HA (1996) The Sciences of the Artificial. 2nd ed, MIT Press, Cambridge, MA.

Vikhorev K., Alechina N., Logan B. (2011) Agent programming with priorities and deadlines. Proc. of 10th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2011).

Woods DD., Hollnagel E. (2006) Joint cognitive systems: Patterns in cognitive systems engineering. Boca Raton, FL: CRC Press.