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Integrated modelling of farmers' decision making on pesticides' use. The case of Vereda La Hoya, Colombia.

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Introduction

Pesticides' use in agriculture poses serious threats to human health and the environment in rural areas all over the world, but particularly in developing countries (WHO, 1990). Nevertheless, the use of crop protection products seems unavoidable in agriculture, in a context of growing world population and slowing agricultural production, which raises fears about the possibility of future populations not being fed enough (FAO, 2002). Therefore, even if environmental protection is a widely acknowledged priority, the most urgent issue is not represented by a short-term shift to pesticide-free production techniques. Instead, it is represented by the diffusion of a more sustainable use of pesticides, here defined in terms of its environmental and health effects and related to pesticides' management practices; that is farmers' behaviour in last request. In order to foster such diffusion, which requires a structural change in production management, policies are needed, which should be based on in-depth knowledge of farmers' decision making.

Theoretical and methodological challenges

Scientific investigation, while identifying many factors affecting pesticides' use in different agricultural contexts, has until now showed some common features. In particular, current approaches often study pesticides' use from a mono-dimensional perspective, i.e. environmental, economic, social, technical, or psychological. Even when more dimensions are considered, a scarce consideration is given to social structures as determinants factors. Moreover, the explanation of the decision-making process tends to be focussed on one social scale of analysis: i.e. micro- (psychological and socio-psychological), meso- (social groups, networks) and macro- (institutional). From a theoretical perspective, scientific investigation on pesticides' use has usually adopted the simplistic model of the "economic man" and a static perspective. Thus, the approach outlined above has reinforced the conventional policy approaches based on linear explanations, command-and-control interventions and static optimization of some social, economic or environmental functions.

We argue that a different conceptual framework has to be adopted in order to understand farmers' decision making on pesticides' use. In particular, pesticides' use can be conceptualized as a form of interaction between coupled social and natural systems and sustainability as a process of transition characterised by dynamic interactions taking place at multiple spatial, social and

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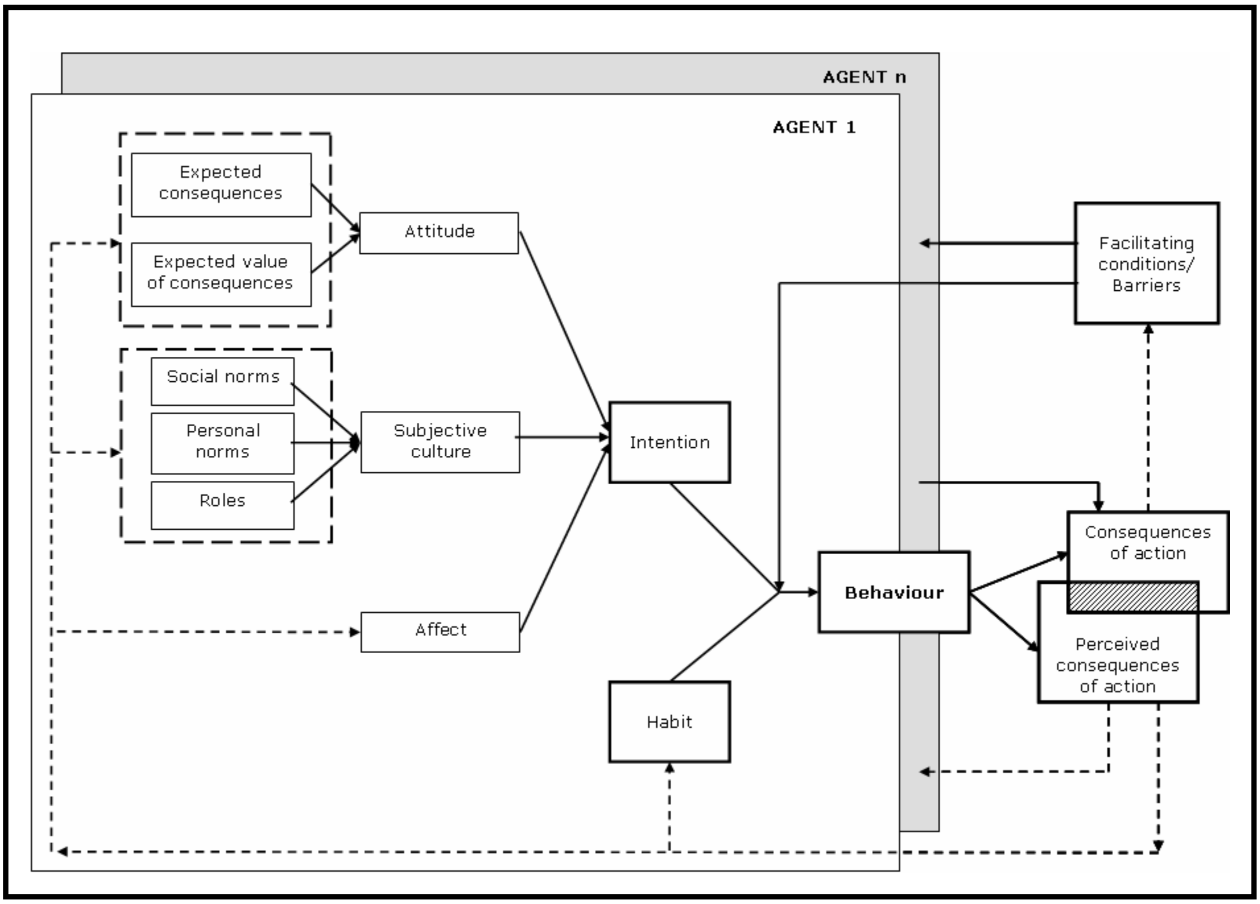
temporal scales among those systems. In this respect, there is reason to believe that a dynamic and integrated approach to modelling farmer's decision-making in pesticides' use can improve knowledge in this field, i.e. identifying the contribution of the micro-behavioural decision-making process to the meso- and macro-scales, and allowing for catching potential complex dynamics and identifying feedback effects occurring over time among them and among social and natural systems (Rammel et al., 2007). Moreover, the oversimplified model of the "economic man" has been proven to be ineffective, specifically in relation to modelling socio-ecological interactions (Janssen, Jager, 2000) and a more complex model of human behaviour has to be considered. Finally, a dynamic, integrated and complex approach could be coupled with recently developed methodologies, such as agent-based modelling, in order to provide knowledge and tools to be directly used in the governance of coupled social and natural systems, which has to be "adaptive, flexible and experimental at scales compatible with the scales of critical socio-economic functions" (Rammel et al., 2004).

The behavioural model

As seen in the previous paragraph, both micro- and macro-scales are involved and must be taken into consideration in modelling farmers' behaviour. Giddens' Structuration Theory (ST) (Giddens, 1984) provides a framework to unifying both levels, while understanding individuals' contribution to social structures reproduction (and change) and social structures influence on individuals' actions. Structural change can therefore be defined, in Giddens' terms, as change occurring in social structures (values, norms) as a product of agents' actions by mean of, and at the same time bounded to, social structures themselves.

Figure 1: representation of the behavioural model



In the proposed approach, H.C. Triandis' theory of Interpersonal Behaviour (TIP) (Triandis, 1979), that provides a more detailed, although comprehensive, theory of human behaviour, integrates ST. According to TIB, the probability of certain behaviour to be enacted is influenced by intention, habit and (external) facilitating conditions. Intention itself is determined by attitude (defined as the expected consequences and their value), subjective culture (product of personal and social norms and roles) and affect (the feelings associated with the act). In ST's terms, according to the concept of duality of structure, the actors at the same time are constrained and rely on social structures (here represented by subjective culture) and their behaviour is always spatially and temporally located (here represented by the contextual factors).

Consequences of "n" actors' behaviour always aggregate to a certain extent, and produce feedbacks. According both to ST and TIB, consequences of action can be intended or unintended and perceived or unperceived. The feedback process is characterized by a double loop. The first one connects the consequences of action to the facilitating conditions, and corresponds to what Giddens calls homeostatic loop. The second one connects the consequences of action to the internal drivers of behaviour, and is called reflexive self regulation in ST's terms. The latter is driven by the actors' implicit control over their own performance. Only the perceived consequences are likely to produce the latter feedback.

Being it conceived in general terms, this behavioural model requires an operationalization with reference to a specific behaviour and context. The following paragraph describes the operationalization for the case study of Vereda La Hoya, Colombia.

Operationalization of the model

The selected study area, Vereda la Hoya, is located in the rural part of Tunja, Department of Boyacá, Colombia, in the eastern chain of the Andes at an altitude of 2,800 m. above sea level. It is a watershed with an area of 840 ha and a population of about 747 inhabitants. The main income source is farming (minifundios of about 6.6.ha). The main agricultural product grown is potato, which in this region is vulnerable to two major pests, the soil-dwelling larvae of the Andean weevil and the late blight fungus. For controlling these pests, both farmers and agricultural scientists consider the use of insecticides and fungicides as necessary. However, due to the use of pesticides, health, environmental and economic problems have been observed (Ministerio de Agricultura y Desarrollo Rural de Colombia, 2006).

In the model, farmers' behavioural options are defined as quantity and typology of pesticides applied and choice of using safety practices. Farmers' behaviour can cause different kinds of consequences, namely: economic (e.g. agricultural production and consequent income), environmental (e.g. reduction in biodiversity and ecosystem services), health (e.g. eyes irritation), and social (e.g. social status). The consequences can occur in the short temporal scale (e.g. income) or in a longer one (e.g. neurological problems). Similarly, they can occur spatially at local (e.g. parcel) or larger (e.g. watershed) scale and socially, at individual (e.g. health problems) as well as at collective (e.g. growing pest resistance) level. The consequences can produce feedbacks on the external and internal behavioural drivers. Notably, the feedbacks can produce change at short (e.g. the price of potatoes) or long term (e.g. social norms).

The external factors can be subdivided into different categories: economic/financial (e.g. access to credit, price of pesticides), wealth (e.g. income), technical (e.g. equipment used to apply the pesticides, seeds used, technical assistance received), land and soil (e.g. extension and fertility of the parcels), environmental (e.g. pest resistance), weather/climate (e.g. humidity, wind), social (e.g. social networks, education, family characteristics).

The internal factors are organized like in Figure 1. The expected consequences correspond to the consequences of behaviour, to which each farmer gives values. The normative factors can be subdivided into social norms, specified in descriptive (e.g. the behaviour of other farmers), prescriptive (e.g. the judgment of reference groups), formal (e.g. governmental legislation) and informal; personal norms (the feeling of personal obligation regarding the performance or not of the behaviour) and roles (the one of farmer and the one on head of family). As final determinant of intention, the emotions connected with the application of pesticides are considered (affect). Habit (e.g. number of cultivation cycles in which the farmer has been using a certain type or quantity of pesticide) is the last internal behavioural driver considered.

Conclusion and outlook

The model has been operationalized for the study area of Vereda La Hoya, and applied for data collection with reference to a specific crop (potato). Behavioural data have been collected on a parcel and cultivation cycle basis. The collected data are under analysis.

The first application of the model has shown its potential to frame the analysis of farmers' decision-making process on pesticides' use as an interaction between coupled social and natural systems. The potential interactions among the different behavioural drivers are thus organized and the potential drivers themselves translated into variables in the operationalization and investigated through research on the field. In particular, the link between environmental and health aspects and farmers decision-making can be analyzed integrating multiple dimensions (psychological, social, economic, environmental, technical) and scales of analysis: social (individual, collective), temporal (cultivation cycles), spatial (parcel, region). Thus, it provides the basis for a comprehensive quantitative analysis of farmers' decision-making process.

Due to its integrative, complex and dynamic perspective, the model not only provides insight into the investigated issue, but can also be used as the basis for dynamical modelling techniques such as agent based modelling, in order to explore, potential trajectories of change and transition in the coupled social and natural systems under different scenarios, (eventually to foster participatory processes) thus providing support to the governance of complex social and natural systems towards more sustainable states.

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