MULTI-AGENT BASED MODELING OF THE TUNISIAN PASTORAL DYNAMIC
Multi-level Organization

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Abstract: Pastoral systems in arid and semi arid areas are characterized by a continued deterioration. This degradation is the result of the mismanagement of resources in response to natural, economic and social mutations. These systems are considered as complex systems, given the large number of stakeholders in interaction and levels of granularity. To address this situation, analytical and systemic approaches are no longer adequate. In this paper, we propose a multi-agent based model of Tunisian pastoral dynamics taking into account the interaction dynamics of the different stakeholders and the different levels of granularity. The completion of this work is within the scope of the development of the Intelligent Decision Support System PASDES (Pastoral Strategies Definition System). PASDES aims to support pastoral strategic decision making in short and long terms.

1 INTRODUCTION

Tunisian rangelands spread over almost one third of the country's area. Almost half of these rangelands are collectives. These figures reflect the importance of the pastoral activity. However, the Tunisian pastoral resources are in a continued deterioration. This deterioration is caused by the inappropriate strategies undertaken to address climate (high temperature, unstable precipitation) economical (increase in grain prices, global crisis) and social changes (privatization, competition over resources). The sustainability of the system is threatened.

The pastoral system is a complex system characterised by a large number of interacting entities (plants, animals, shepherds, economic actors, state, etc) and different levels of granularity (vegetation dynamics, animal dynamics, shepherds interactions and negotiations, etc). Thus, the study of such a system is conducted in the context of solving complex problems. In literature, three approaches are mainly used to study such a system. First, the analytical approach was adopted by economists. It focuses on the elementary study of the system components. For example, the study can be based on the maximizing of an objective function on a particular element of the system (Lalba, Zoundi and Tiendrebeogo, 2005) (Dutilly-Diane, 2006). This approach deals with one variable at a time which prevents the study of the overall system dynamics. Second, the systemic approach was adopted by ecologists. It is based on the study of the overall system behavior (Costanza, Wainger, Folke and Mäler, 1993) without taking into account the micro-dynamics. In this context, the emergence of global properties is evoked (Bergandi , 2000) (Oprisan and Oprisan, 2006). Third, the constructivist approach brings together the contributions of the analytical (micro-level study) approach as well as the systemic approach (macro- level study). It focuses on the study of micro-order interactions of different entities as well as the global system behavior. In this approach, we can distinguish the use of cellular automata (Soares-Filho, Cerqueira and Pennachin, 2002) and multi-agent systems. When using cellular automata, the environment is represented by a set of cells. The behavior of individuals is defined by a finite set of states, transition rules and neighbourhood relationship. However, cellular

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automata are unable to take into account the complexity and heterogeneity of stakeholders' behaviors. On the other side, multi-agent systems are characterised by their ability of modeling interactions between autonomous agents and with their environment. In this work, we opted for the use of multi-agent systems. In fact, using multi-agent systems in a complex system solving context takes benefits of (1) ease of modeling of distributed systems (2) possibility of modeling of the cognitive decision processes (3) explanatory ability of dynamics and micro and macro variables (self-organization, emergence). The completion of this work is within the scope of the development of the Intelligent Decision Support System PASDES (PAstoral Strategies Definition System). PASDES aims to support pastoral strategies decision making in short and long terms. In this paper, we propose a multi-level modeling of the Tunisian pastoral system taking into account the interaction dynamics of different stakeholders and climatic, economic and social variables. Such multi-level organization allows design and modeling of each level in its own. It allows understanding more the system dynamics. When modeling all levels of granularity is achieved, prediction of the future system evolution becomes possible. Defining adequate strategies is then feasible. In this paper, we propose our multi-level model and we detail the first level modeling. The paper is organized as follows: section 2 presents a state of the art of multi-agent works studying the management of renewable and pastoral resources, section 3 describes our multi-agent model of the pastoral dynamic using multi-level organisation and interaction and introduces our first level multi-agent based model, and we end this work with conclusion and perspectives.

2 STATE OF THE ART AND EXPECTED CONTRIBUTIONS

The pastoral system is a complex system characterized by a large number of entities of different nature (reactive: plants, animals, cognitive: shepherds, state). These entities interact with the environment or with each other to achieve their goals. In a multi-agent context, some models of natural resources management focused on modeling the interaction between human and resources. These models are based on the stigmergy notion; that is a change in the environment by an agent affects the decisions of other agents (Omicini. et al, 2004). Other models are based on interactions (conflicts, negotiations, etc.) between agents to make collective use of resources. In this context, note the role playing games used to evaluate the impact of negotiations and decision taken by various stakeholders on the development of common resources. In literature, role playing games were used to study individual and groups behaviors in economic social context. During such games, each actor plays the role of the realist stakeholder in a fictive environment. Role playing games are a powerful tool to support negotiation process and participant training (Guyot and Honiden, 2006). In a multi-agent context, several works tried to jointly use multi-agent systems and role playing games. For example, Dray, et al. (2006) introduced the role-playing game "AtollGame" based on a multi-agent system to study the problem of drinking water supplies. The Role playing game "SylvoPast" proposed by Etienne (2003) studies the negotiation process between farmers and forestry in order to prevent fires in Mediterranean forest areas.

Note that most multi-agent systems modeling natural and pastoral resource management focus on decisions making and negotiation between economic and social actors, using variables of macro level (e.g. hydraulic state of the year: wet year; dry year). These variables are empirical or dependent on a number of assumptions. Therefore, such approach can lead to biased results that can be the cause of non-adequate decision making. However the ecological literature is rich on studies of the micro dynamics of such a system. For example, the study of hydraulic dynamics provides us with information about runoff emergence. It is then possible to take advantages of such information to define with precision the best shepherd displacement. Such information is much more interesting then characterizing the hydraulic state by criteria such as “dry year” and “wet year”. The study of animals behavior (imitation, displacement behavior, grazing) can also be used for space management. For example, studying the behavior of selectivity (animal preference) supports reflexions on introducing mixed herds (with different preferences) instead of working on criteria such as “dense vegetation cover” and “naked ground”.

Throughout this work, we opted to go down to the micro-level modeling of the Tunisian pastoral dynamics. Taking into account the different levels of granularity allows best comprehension of the system dynamic and adequate decision making.

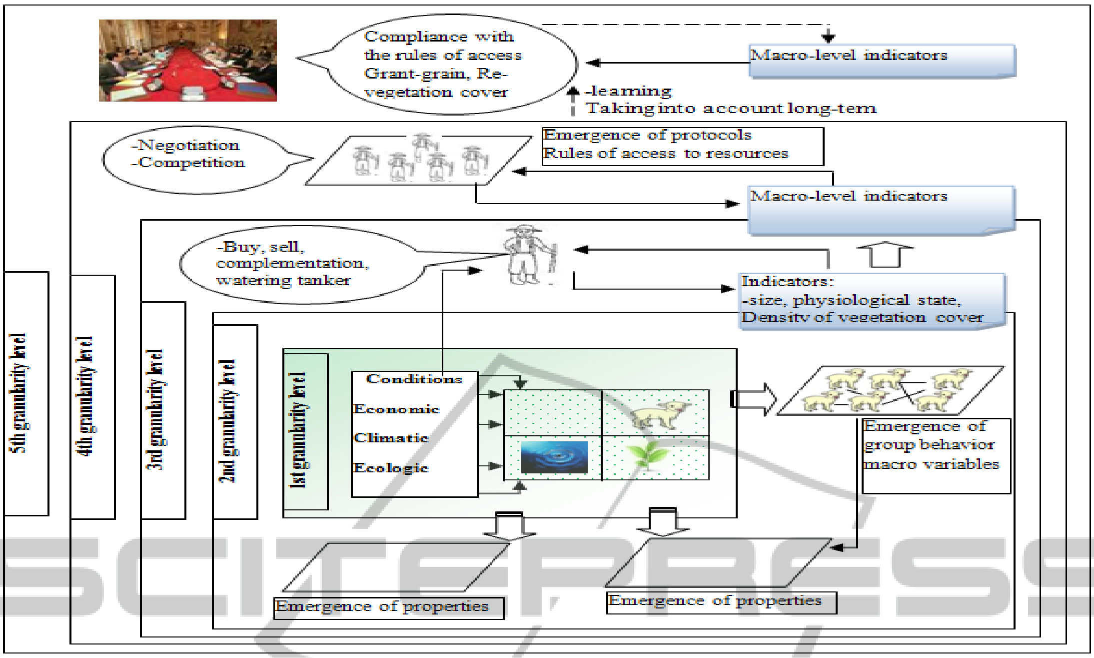

Figure 1: Pastoral system: Multi-level organization.

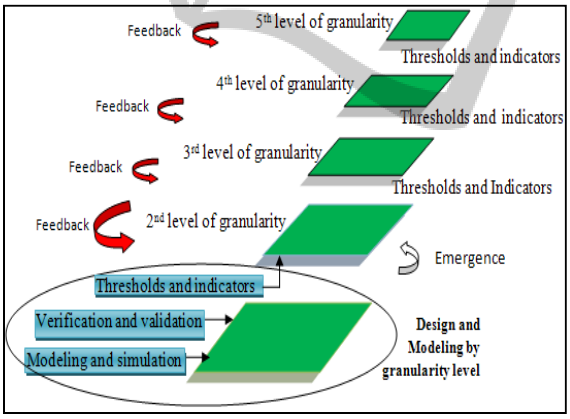

Figure 2: Pastoral System: Design and Modeling by organization level.

3 MULTI-LEVL MODELING OF THE PASTORAL SYSTEM

3.1 Multi-level Organization

In order to manage our system complexity, the basic idea is to make a multi-level modeling (shown in Figure 1). This organization will enable us to make the design and modeling of each level of granularity in its own (See Figure 2). The model includes five levels of granularity. The first level of granularity includes three sub-levels:

- The dynamics of soil affected by climatic conditions (hydrology, fertility, water infiltration, runoff).
- The vegetation dynamics (plant growth, physiological and chronological cycle, phytosociology).
- The Animal agent behavior (food needs, preferences).

The interaction dynamic of the soil, vegetations and climatic variables lead to the emergence of global properties such as the hydraulic state of the soil and vegetation density. In order to validate results at this level, we consider the use of GIS

(Geographic Information System).

The second level of granularity focuses on animals' group behavior (imitation, leadership, competition over resources). The interaction dynamics in this level of granularity lead to the emergence of the groups' displacement and consumption behavior.

The third level of granularity focuses on modeling the decisional behavior of the cognitive Shepherd agent in response to the macro-variables values provided by the lower level of granularity (size of the herd, vegetation density).

The fourth level of granularity focuses on modeling the interactions between Shepherd agents (negotiation, competition over resources). In order to stick with reality, we consider the use of participatory simulation in this level. The simulation results on the emergence of collective behavior (e.g. rules of access to resources).

The fifth level of granularity focuses on the strategic decision level of the State agent defining the strategies to meet the needs of different stakeholders while maintaining the sustainability of the system (grain subsidy, renewal of vegetation cover).

In this model, the different levels of granularity are fed by the macro indicators of lower levels (see Figure 2). Note that indicators are macro variables or emergent properties resulting of the underlying local dynamics. The higher levels take into account these indicators and act by feedback. Taking into account this feedback, the lower layer dynamics proceed by adaptation to the occurred changes. In addition to these indicators, we define for each level of granularity thresholds. When indicators exceed the thresholds values, alarming situations are risen (land cover degradation, soil degradation), so the underlying higher levels make decision to manage situations.

3.2 Modeling Multi-level Interaction

To simplify access to data of the different layers of our model, we opted for the use of an Observer agent by each layer (See Figure 3). An Observer agent is characterized by an overall perception of its layer. It detects the emergence of global properties. It collects the values of macro indicators, makes comparison with the thresholds defined to indicate an alarming situation (as soil degradation). The Observer agents are charged of the communication between the different layers. Agents from layer A, requiring information on a layer B, ask the Observer agent A for it, which sends a request to the Observer agent of the layer B. So, this agent responds to the request. The agents of the A layer act according to information provided by feedback (flow of action).

When studying interaction between levels of granularity, we have not taken into account the notion of time. In fact the appearance of emergent properties and the establishment of macro variables require consideration of the underlying dynamics. It is undeniable that the decision of agents at higher levels can only be made if there is stabilization in the variables studied. They subsequently react with feedback.

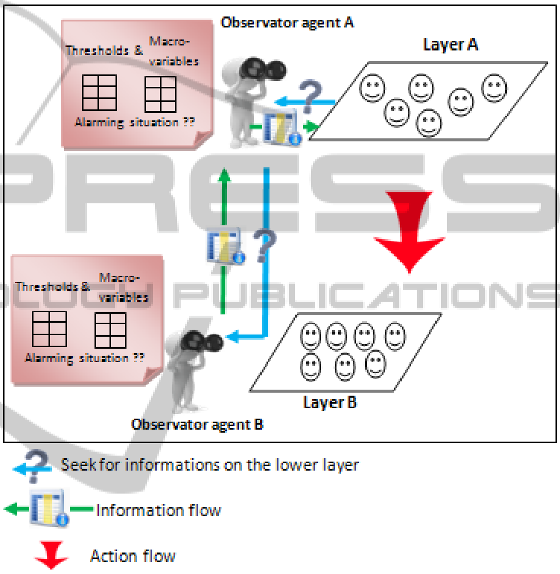

Figure 3: Multi-level interactions.

3.3 Micro-level Modeling

In this section, we focus on modeling the first organization level of our system architecture. Our efforts are concentrated on soil hydraulic processes and more specifically the dynamics of infiltration. To do this, we are inspired by the principle of eco-resolution (Ferber, 1995). Our basic model consists of two agents (see Figure 4): Drop of Water agent and Air Bubble agent. Initially, the Air Bubble agent is occupying a pore in the soil, The Drop of Water agent is on the soil surface. The Drop of Water agent moves to achieve its satisfaction which is occupying a pore. The Air Bubble agent leaves the pore if it is attacked. Since we are interested to infiltration dynamic, we are limited to study the case that. The Drop of Water agent has a speed which is lower than the runoff speed. In this case, the Drop of Water agent attacks close Drop of Water agents. If there is no Drop of Water agent in its neighbourhood, it attacks the nearest Air Bubble agent occupying a pore forming positive angle with the current position of the Drop of Water agent.

Figure 4: Infiltration process.

4 CONCLUSIONS AND PERSPECTIVES

We presented a multi-agent multi-level model of the Tunisian pastoral system. The multi-level organization allows best comprehension of the pastoral dynamics. In terms of development, such organization offers the possibility to design each granularity level in its own. The validation of each level allows moving to the next level of granularity. Simulation taking into account all levels of granularity allows the future system dynamics prediction. This aspect will provide our system PASDES with the ability to define adequate strategies taking into account micro- level indicators. Up to now, we have started the first level of granularity modeling, we have attacked the soil hydraulic dynamics and more specifically the infiltration process. A very important step at this level is the acquisition of ecological and climatic data needed to supply our first level models, hence the need of the collaboration with experts in the field. The use of GIS for the validation of the ecological model will allow us to stick well with reality. Interactions between cognitive agents in participatory simulation will take advantages of efficient data provided by this model.

REFERENCES

Bergandi, D., 2000. Eco-cybernetics: the ecology and cybernetics of missing emergences. *Kybernetes* 29 (8).

Costanza, R., Wainger, L., Folke, C., Mäler, K. G., 1993. Modeling complex ecological economic systems: toward an evolutionary, dynamic understanding of people and nature. *BioScience*. 43(8), pp. 545-555.

Dray, A., Perez., P., Jones, N, Le Page, C., D'Aquino, P., White, I. and Auatabu, T., 2006. The AtollGame Experience: from Knowledge Engineering to a Computer-Assisted Role Playing Game. Journal of Artificial Societies and Social Simulation, 9 (1).

Drogoul A. and Guyot P., 2004. Multi-Agent Based Participatory Simulations on Various Scales, In: Ishida, T., Gasser, L. and Nakashima H., eds. *Massively Multi-agent Systems (MMAS), 2004*. Lecture Notes in Artificial Intelligence, Springer-Verlag Berlin Heidelberg, pp 149-160.

Dutilly-Diane, C., 2006. Gestion collective des parcours en zone agro-pastorale : le cas de Ait Ammar (Maroc). *Afrique contemporaine*, 3(219), pp.103-117.

Etienne, M., 2003. Sylvopast: a multiple target role-playing game to assess negotiation processes in sylvopastoral management planning. *Artificial Societies and Social Simulation*, 6(2).

Ferber. J., 1995. *Les systèmes multi-agents. Vers une intelligence collective.* InterEditions. Paris.

Guyot, P. and Honiden S., 2006. Agent-Based Participatory Simulations: Merging Multi-Agent Systems and Role-Playing Games. *Journal of Artificial Societies and Social Simulation*, 9(4).

Lalba, A., Zoundi, J. S., Tiendrebeogo, J. P., 2005. Politiques agricoles et accès aux parcours communs dans le terroir de Ouara à l'ouest du Burkina Faso: une analyse économique et environnementale à l'aide de la programmation linéaire. *Biotechnologie, agronomie, société et environnement*, 9 (1), pp.43-52.

Omicini, A., Ricci, A., Viroli, M., Castelfranchi, C. and Tummolini, L., 2004. Coordination Artifacts: Environment-Based Coordination for Intelligent Agents. In *Proceeding of AAMAS*, July 2004, pp.286-293.

Oprisan, S. A., and Oprisan, A., 2006. A computational model of oncogenesis using the systemic approach. *Axiomathes*, 16 (2).

Soares-Filho, B. S., Cerqueira, G. C. and Pennachin, C. L., 2002. DINAMICA - a stochastic cellular automata model designed to simulate the landscape dynamics in an Amazonian colonization frontier. *Ecological Modelling*, 154(3), pp.217-235.