Local Knowledge, Agents and Models for the adaptation to climatic variability of livestock farmers in Uruguay

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Abstract

Basaltic soils in Uruguay occupy 3.5 million hectares, 25% of the country, and are mainly exploited by extensive family ranching production systems. These shallow soils have an extremely reduced capacity to accumulate water that make them more sensitive to drought with negative consequences in: forage production, animal production, feeding security, and high consequences on the economy and welfare of livestock farmers and the local communities living conditions, then on the whole beef supply chain and on national exports. Extreme events will be more frequent in the future as a consequence of current climatic changes. It is thus necessary to improve the adaptive capacities of the livestock producers.

In order to understand the past effects of droughts, we developed an interactive agent based simulation model and we compared two different farmers' archetypal strategies. The design of the model was conducted in four steps: 1) we simulated the grass growth using a logistic growth equation calibrated with data originated from the MODIS satellite, 2) the natural dynamic life cycle of the cattle was collectively designed, 3) we simulated the interaction between the grass and big grazers, 4) we designed different strategies of farm management, by using the information gathered in 8 workshops with the participation of 156 livestock farmers. Thus, we collectively examined the simulation results with livestock farmers and development actors. Now, we are constructing a "serious game" called "Ganaderos y sequía" that will be accessible in our web page. The purpose is to get a flight simulator like game that will speed farmers' learning and adaptation to droughts.

Introduction

Uruguay is probably one of the countries that is most dependent on rainfall due to two factors; i) the production of hydro-electric which at the time of normal rainfall provides nearly all of the electricity consumed by the country, and ii) the prime importance of export of agricultural products which are produced on dry land. The inter-annual variety in rainfall and consequently plant production in Uruguay is very high (Baetghen and Carriquiry 2006) and this has major implications for the present systems of production. In recent years the episodes of drought have been relatively more frequent than in the past, and this, combined with raised interest from the scientific community, has increased the search for tools that can accelerate knowledge accumulation and improve adaptation. Facing this type of problem, the institutions that intend to participate in the improvement of adaptation must produce relevant statements which are credible and legitimate. Moreover, motivation, information and capacity are three of the essential components that can explain the interactions which are produced within a socioecological ecosystem (Lambin 2005), and in general it can be said that we face a period of drowning in information while starving for wisdom (Wilson 1998).

In the case of the droughts in Uruguay there are some peculiarities in that they are a normal component of the ecosystem, and are of a frequency, duration and intensity that is impossible to predict, although in recent decades they have been associated with the presence of the phase of La Niña of ENSO. This has created high levels of uncertainty (Bartaburu et al. 2009). The material losses are serious with diverse local estimations as high as several hundreds of millions of dollars. At the same time, the serious effect on the activities of people who see their projects being complicated to various degrees, and the ongoing extended periods of high levels of tension are having damaging repercussions where psychiatric and psychological issues go well beyond trivial anecdotes. In workshops with producers drought frequently appears as one of the principal factors that affects the way farms are run (Bartaburu et al. 2009). This phenomenon is particularly relevant in the north-east of the country, an area of basaltic soils comprising 25% of the total area of Uruguay, where the water holding capacity of soils is less than 40 mmts and evaporation can be five times above this figure in the month of January (INIA 2012).

Previous generations remember that the last great drought occurred in 1942, and when a phenomenon of a similar intensity returned in 1988, 46 years later, there was almost no memory of a drought of that magnitude, and as indicated by March (1994) and Kaneham (2011), previsions normally taken by people do not include unknown situations. This meant that in the face of the unexpected magnitude of the phenomenon reactions were slow, inefficient and late, and the losses large all over the country, especially in the north. In a survey in 2006, 54% of the farmers said that they had known two severe droughts with disastrous consequences for 22% of them and bad consequences for 52% (Bartaburu et al. 2009). Moreover, supplementation with grain or other feed, which was a non-existent practice, began to spread during this opportunity and its use as a practice to deal with droughts has progressively strengthened, which gives an example of the evolution of practices and how they can be learnt through experience (March 2010).

The frequency and intensity of droughts seems to have increased according to the perception of different stakeholders who identify 2000, 2006 and 2008 as years of drought, and they know the ongoing climate change forecasted by experts will result in an increased variability of rainfall in the south-east of South America.

1. Models and multi-agent simulations

The initial hypothesis is that the reproduction of the phenomenon in silico from its elementary components and the interactions present, confirms that it is understood how the set of variables involved operate. At the same time, there are a number of background frameworks in the approach “Commod” (Bousquet 2006, Etienne 2010) that indicate the participation of stakeholders in defining the model results in a learning process that facilitates collective action, especially when it comes to highly complex events, where the contribution of scientists is one among others. In addition, McCown (2002a) indicated that a key conclusion was that it is only through the existence of a partnership between researcher and practitioner, within the research project developing the agricultural decision support system (aDSS) and its operational deployment, that there is much hope of effecting strategic changes. This analysis was further developed by McCown (2002b) in arguing that for DSS to be successful they should try to empower decision makers rather than forcing them to cede agency to black-box tools developed by others. The appropriate roles identified for the flexible-simulator based DSS were as a tool for consultants to use in systems analysis with land managers and as a learning environment for a range of stakeholders concerned with land management issues (Mathews et al. 2008). The participatory modeling aims to open the black box used in the simulations and to allow different users to review the assumptions included in the model and the mechanisms used by the simulation to obtain the results (Morales et al., 2009, Bommel et al. 2011). In this article we present and discuss the main characteristics of a multi agent system constructed to study the effect of drought and the using participatory modeling and multi-agent simulations to address complex problems characterized by Ison (2011). In a vision of long-term development of this work, the realization of surveys and studies on secondary information to characterize the phenomenon and to define its approach, and the development of the model and its simulation as a multi-agent system using Comas platform (Bousquet 1998) have been included. Nowadays we are proposing the development of video games that can foster virtual experiences from which lessons that favour adaptation can be drawn. The phase that is described in this article was carried out within the framework of a project titled “Validation of a methodology for participatory modeling and simulation to improve the communication of the phenomenon of drought and learning to livestock producers”. Its specific objectives were: 1. Develop a multi-agent simulation model that favours the best communication and represents the local knowledge of adaptive strategies for facing droughts. 2. Validate and communicate the adaptive strategies for facing droughts. 3. Evaluation and systematization of the project actions. Its proposal was to identify the principal questions regarding how livestock producers of extensive zones of Uruguay can cope with drought and deal with them together in a process of integration of knowledge, proposing the UML models and the simulations as tools to support this activity (Le Page and Bommel 2006, Fowler 2002). Traditionally, from a scientific point of view, the objective of the models can be to predict, explain or describe (Grimm and Railsback 2005, Beinocker 2006). Moreover, the simulations with multi-agent systems permit careful examination, of at least one part of, the implications present in the developed models (Janssen 2002). At the same time, the multi-agent systems enable the production of coherent information from diverse origins, insomuch as putting different components of the model that is being simulated into both qualitative and quantitative interaction. The resulting simulation is difficult for the modeler to manipulate and depends on the consistency of the sub-models that are used and of the interactions considered.

There are numerous arguments that support that the multiagent systems (MAS) approach is suitable for modeling agro-ecosystems, like those presented in (Miller and Page 2007), but nevertheless it is worth analyzing how the MAS approach specifically addresses the following issues, which characterize an agro-ecosystem: (a) Emergence: MAS allow to define the low-level behavior of each individual agent in order to let them interact to see whether some emergent property arises or not, and if it does, under which circumstances; (b) Self-Organization: MAS do not have any kind of central intelligence that governs all agents. On the contrary, the sole interaction among agents along with their feedbacks is what ultimately ‘controls’ the system; (c) Human-Natural Systems: MAS allow considering together both social organizations with their human decision-making and social communications and biophysical processes and natural resources. This conjunction of subsystems enables MAS to explore the interrelations between them, allowing analyzing the consequences of one over the other; and (d) Spatially Explicit: the feature of MAS of being able to spatially represent an agent or a resource is of particular interest when communications and interactions among neighbors is a key issue. This feature is of special interest in the case of agro-ecosystems (Corral and Calegary 2011)

2. Simulations to support decisions

The possibility to support decision making is a discussion that has been well established for many years in the area of natural grasslands. (Stuth andStafford Smith 1993), while at the same time the link between the construction of models and learning has been a motive for recent discussions and analysis (Johnson Laird 2010; March 2010, National Research Council 2011), and it is noted that there is controversy surrounding the relevance and effectiveness of using simulations (Mathews et al. 2008).

In the face of highly complex phenomena that can be characterized as complex problems (Ison 2010), a sequence of actions to understand the past, characterize the present and explore the future have been proposed (Norberg and Cumming 2008; Gunderson and Holling 2002) in that the use of present knowledge can be improved if sufficiently pertinent models are produced which trigger a reflection and an action that improves the situation in the opinion of those involved (Roling and Wagemakers 1998, Checkland 1999). We argue that sustainable development cannot be imposed through top-down regulations only and that some type of participatory process must be present (Bommel et al. 2012; Etienne 2010).

To explore the possibility of accelerating the learning and adaptation of the farmers in the region being studied we proposed to reproduce the performance of farms with different management strategies, in a process that was highly interactive with those involved, during both the process and in the evaluation of the results. The results obtained provided us with new perspectives on the complex topic of climate variability, the construction of farmers' strategies and the use of models and simulations to improve adaptation. There is extensive evidence that climate change has been a factor that triggered diverse types of crisis in the past. The use of scientific knowledge for the management of ecosystems at different levels and its complement with that provided by local knowledge (Gunderson and Holling 2002, Norberg and Cumming 2008) is a topic which has high priority, and in our case we explored the situation of use of knowledge for the taking of decisions at the level of farms, e.g. by the farmers, and we advanced in the use of these models as a basis for learning (Bousquet 2006, Mc Cown 2002b, NRC 2011). To do this, we used the UML diagrams as a way of having a shared representation of the models that were going to simulate and represent the knowledge in use by the stakeholders.

3. Basic ideas in our model

In situations of cattle almost exclusively on rangelands, as is very predominant in the cattle farms of Uruguay, the actions that are taken are about the animals. This reflects the general pattern of extensive cattle farming (Balent and Stafford Smith 1994, O'Reagain et al. 1999) where the actions that the farmers take are about the animals and never directly about the vegetation. The vegetation is affected through the animals. This implies that the simulated decisions are about livestock management.

4. Advances in the simulation of the grazing animal-herbage interaction.

The management decisions affect the long-term evolution of the farms and their economic viability. To be able to simulate this evolution we have developed a synthesis of the empirical and experimental information that allows us to examine the evolution of different farm 'types' where different management strategies are applied in different scenarios. In order to do this, we utilized the abundant experimental information about the performance of grazing animals (Soca et al.

1994, Dieguez et al 2012). The difficulty that we faced was that the experimental data is varied and corresponds to different situations.

We decided that in the case of simulating the consequences of the farmers' strategies it was convenient to represent the interaction between the animals and the pasture with high "resolution" (Norberg and Cumming 2008). Especially, the direct simulation of the effect of the grazing animal on the growth of the pasture is very complex and there is only very limited data about the consumption of grazing ruminants. We have developed a set of partial models that when interacting with each other consider this retroaction, as shown in the figure below.

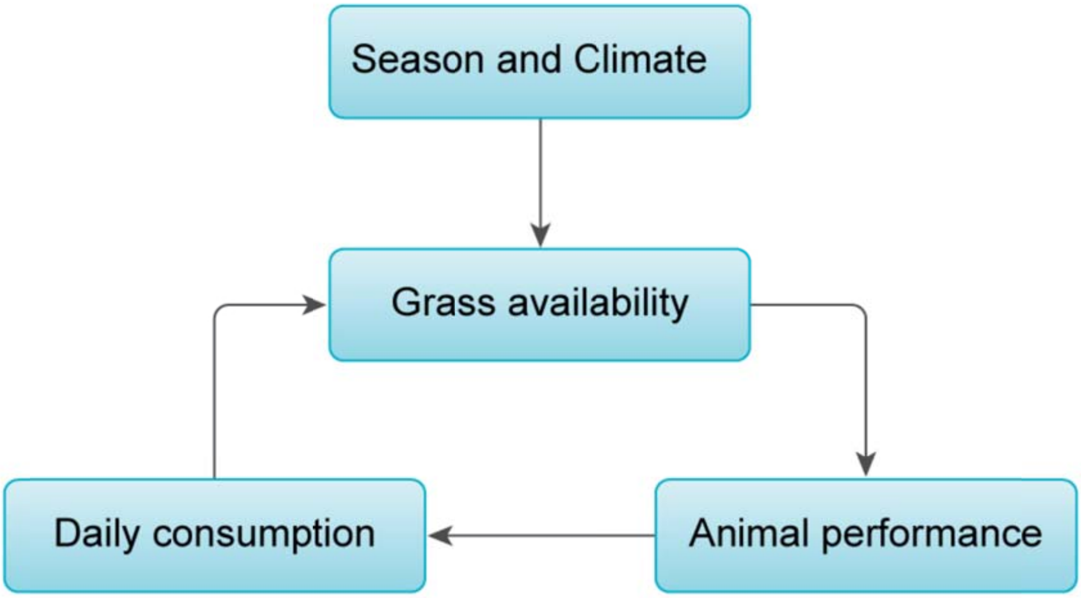

Fig 1. The biophysical model.

The grass availability affects animals through consumption and the cost of harvesting the forage, and the pasture growth. Therefore, we propose a formula that relates the daily growth of the pasture with the season and with the amount of forage present (Dieguez et al. 2012). The forage of day t is equal to the forage of the previous day plus daily growth and less the consumption of that day.

The total production of forage and its annual distribution were adjusted to a measurement taken from the images from the Modis satellite (Paruelo et al. 2000) to a representative paddock of the area of study. The average annual production for the period 2001-2009 was of 3864 kg of MS, of which 17% was in autumn, 12% in winter, 37% in spring and 33% in summer. The coefficients of variation were 43%, 21%, 13% and 33% for the respective seasons, reflecting that spring is the least variable season and autumn the most variable. At the same time, the paddock reflected an extremely unfavourable situation in the autumn of 2006 when the seasonal growth was 0.66 kg MS/ha/day, which represented less than 10% of the average growth of this season.

5. The animals' performance

To include the animals' performance we initially took into account the published data that related this performance with the height of the pasture. These models do not consider the effect of competition between animals, which is why we considered a set of results published by Nabinger and Carvalho (2009) which include the effect of competition. At the same time, to estimate the effect of the animals upon the pasture, once the productive performance in each simulated situation was known, we calculated animal consumption from published data (Dieguez et al.2012) which had its origins in non-pastoral situations, and discounted this amount of forage present, including a grazing cost which is variable according to the facility of the harvest.

6. Particularities of the model

6.1 Simplification with sheep

As the data referring to the performance of sheep in different situations is scarce and given the necessity to keep the model relatively simple, the flock has a very simple structure and its production is not seen as affected by the amount of forage present except in very extreme conditions. It is a simplification that was easily accepted by livestock farmers.

6.2 The vegetation composition does not vary due to the effect of management

The vegetation of this region has shown itself to be extremely resilient and there have been no documented changes in its composition throughout the centuries. However, anecdotal evidence exists of some changes. Despite this, we understand that in the range of the usual management and in the period that we studied, it is an acceptable supposition to maintain a constant vegetation productive capacity, that varies according to the season, the climate and the management.

6.3 The last 10 years are represented

Simulations of complex systems can give unexpected or aberrant results, which can be due to errors in the procedures, in the suppositions or in the implementation of the model, or can be the valid result that represents situations unimagined by the experimenters. To control this type of error we chose a situation which is well known to modellers, and allows them to evaluate the plausibility of the results and the reliability of the model.

6.4 The time step

Initially, the proposed period of time was seasonal, being that it was certain that the irregularities in the growth of grass interacted differently with the strategies of producers according to the growing season in which it was happening. However, the simulations proved to be unrealistic, which is why in the advanced versions of the simulation time step is daily for the biophysical system and weekly for the decisional system.

7. The inclusion of the human dimension

The types of strategies used by farmers to face drought vary depending on the intensity of the production system, and in general, the more intensive, as is the case of dairy production, inputs from outside the farm is resorted to more frequently and in greater volume (Bartaburu et al. 2009). Moreover, on extensive farms we find ourselves, in agreement with O'Reagain 1999 that the farmers rely much less on conserved forage or cultivated pastures, and one of the most frequent strategies is de-stocking. We also find differences associated with the size of the farm. The producers that farm areas less than 500 ha have higher stocking rates, with a higher proportion of sheep, have fewer propensities to reduce them, and maintain closer control regarding the evolution of each animal. Farmers with a greater area have difficulty tracking animals and show a greater propensity to reduce the stocking rates (Bartaburu et al. 2009).

7.1 The strategies chosen to be simulated.

Based on the series of workshops that had been previously conducted and knowledge of the authors of the region and the farmers, it was proposed to simulate two contrasting archetypal strategies, which differ in that the indicators used for decision making are the corporal condition of the animals (cattle CC) or the grass height (farmers P).

8. The calibration/ validation / corroboration workshops.

The advancement of modelling was shared with farmers at various stages in a series of workshops held with producers' organizations in the cities of Salto and Artigas. In the second round of workshops the producers had the opportunity to interact with the model proposing simulations of situations that were of interest to them. Two important results can be cited from these workshops. The producers identified the strategies as valid and present in the region, and had sufficient understanding of the model functioning that allowed them to experiment with a series of very slight modifications, such as changing the maximum load with which the simulated strategies began each winter.

9. Discussion

About twenty years ago with the advent of personal computers a new era seemed to open in terms of the possibility of supporting decisions with a large quantity of data that would be easily accessible in a permanent and ubiquitous form (Stuth and Stafford Smith 1993). However, there is a growing sensation that there are fundamental errors in this way forward so that the majority of proposed decision support systems are not used, at least directly (McCown et al. 2012) This leads to the suggestion that its usefulness is limited to improving the understanding of the processes involved for those who participated in its construction 'At best, … models .. give structural insights to their developers. At worst, they are merely time-wasting ceremony' (Passioura 1996:692), or to allow the construction of a common vision that triggers a collective action that improves the situation in the opinion of those involved (Checkland 1999, Etienne 2010). In our case, it seems to us that the use of models should be considered as part of an 'environment' which triggers a reasoning that may eventually be richer, or reveal aspects of a problem that had not been considered as relevant. Two aspects can be considered as significant: i) Representing decision models explicitly can have benefits that justify the time required in that, as March (2010) explained, the shared understanding promotes a collective action. ii) Additionally, the interactions proposed by the model and its results, as well as the identification of the principal entities that can be considered for representing them, (ontology) can be considered as "black swans" (Taleb 2007) insomuch as they only appear as evidently relevant after many hours of hard work and interaction, without having been previously identified (Kahneman 2011). The results of the simulations can, therefore, propose new ways of making coherent a collection of data that those involved possessed but had not been able to relate between them until they interacted with the simulation (Morales 2007). The proposal of participative modelization faces the inconvenience exposed by Passioura (1996:693): "So far, the part played by the large mechanistic simulation models …., seems to have been largely one of self-education for the developer… these models are typically so complex that nobody but the developer is likely to have the enthusiasm to dip inside them. They are not transmissible to others in the sense that the research described in a typical research paper is transmissible". However, we agree with these authors in that, "Good farmers are generally good observers of what is happening in their fields, and involving them with models, at least models with an easily satisfied thirst for data, may make them even better observers".

10. Concluding remarks

Decision support systems fail due to lack of pertinence and communication. Both problems can be avoided if the development of a discussion is achieved, insomach as a conversation is only developed if the problems of pertinence and communication are avoided. In our case there are advances in the realism of the simulations and with regard to the complexity of the system that it purports to represent. So, it should be easier to propose "credible stories with the maximum comprehensible complexity" (March 2010). Currently, we have integrated professionals in communication to develop a video game that should operate like a "flight simulator" in line National Research Council (2011) who discuss the use of models to learn science. On balance, we have advanced in understanding, in the sense of being able to reproduce the past in silico (as argued by Epstein (2006) which gives us an appropriate platform to explore the future. The challenges are to increase and accelerate the collective learning that is already naturally in process, as is shown by the change in practices such as supplementation or the use of moderate stocking rates. Our aim is not that our video game is used at the time when drought exists, but to provide a virtual experience that includes episodes of drought within plausible scenarios for farmers, March (1995) and Kaneham (2011), and illustrates to them its possible development and consequences, promotes dialogue with other stakeholders and the exchange of experiences as a way to facilitate adaptation to these events. In a variable environment, where retro-actions can be distant and difficult to identify, it is not possible – or very difficult - to find strategies that can appear as robust in any circumstances (Kaneham 2010, March 2010).

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