Brigham Young University
BYU ScholarsArchive

International Congress on Environmental Modelling and Software

4th International Congress on Environmental Modelling and Software - Barcelona, Catalonia, Spain - July 2008

Jul 1st, 12:00 AM

Towards a simulation-based study of grassland and animal diversity management in livestock farming systems

G. Martin

Michel Duru

Roger Martin-Clouaire

JP Rellier

JP Theau

See next page for additional authors

Follow this and additional works at: https://scholarsarchive.byu.edu/iemssconference

Martin, G.; Duru, Michel; Martin-Clouaire, Roger; Rellier, JP; Theau, JP; Thérond, O.; and Hossard, L., "Towards a simulation-based study of grassland and animal diversity management in livestock farming systems" (2008). *International Congress on Environmental Modelling and Software*. 102.
https://scholarsarchive.byu.edu/iemssconference/2008/all/102

This Event is brought to you for free and open access by the Civil and Environmental Engineering at BYU ScholarsArchive. It has been accepted for inclusion in International Congress on Environmental Modelling and Software by an authorized administrator of BYU ScholarsArchive. For more information, please contact scholarsarchive@byu.edu, ellen_amatangelo@byu.edu.

Presenter/Author Information
G. Martin, Michel Duru, Roger Martin-Clouaire, JP Rellier, JP Theau, O. Thérond, and L. Hossard

This event is available at BYU ScholarsArchive: https://scholarsarchive.byu.edu/iemssconference/2008/all/102

iEMSs 2008: International Congress on Environmental Modelling and Software
Integrating Sciences and Information Technology for Environmental Assessment and Decision Making
4th Biennial Meeting of iEMSs, http://www.iemss.org/iemss2008/index.php?n=Main.Proceedings
M. Sànchez-Marrè, J. Béjar, J. Comas, A. Rizzoli and G. Guariso (Eds.)
International Environmental Modelling and Software Society (iEMSs), 2008

Towards a simulation-based study of grassland and animal diversity management in livestock farming systems

G. Martin[1,2,*], M. Duru[1], R. Martin-Clouaire[2], JP. Rellier[2], JP. Theau[1], O. Thérond[1], L. Hossard[1]

1: INRA, UMR 1248 AGIR, F-31326 Castanet Tolosan, France;

2: INRA, UR 875 UBIA, F-31326 Castanet Tolosan, France;

**: guillaume.martin@toulouse.inra.fr*

Abstract: In less-favored areas, livestock production involves the management of native vegetation as a resource base. A challenging issue in such systems regards the design of efficient and sustainable management strategies that make it possible to exploit the diversity of grasslands and herd batches over different time scales. This paper describes the conceptual approach that supports the representation and simulation of farm-scale models of grassland-based livestock systems in the SEDIVER project. It enables the coupling of species-rich grasslands and livestock models with sophisticated decision-making models. The latter embed a representation of management strategies that specify in a flexible and adaptive manner what activities are intended to be done. Once implemented, the SEDIVER model will provide guidance for a robust and improved exploitation of grassland and animal diversity at farm scale.

Keywords: Conceptual model; grassland/animal diversity; farm management.

1. INTRODUCTION

In less-favored areas e.g. semi-mountainous regions, agriculture plays a crucial role among other things for biodiversity conservation. In such areas, livestock production involves the management of perennial species-rich grasslands as a resource base (grazing or fodder) for animal production. Farmlands quite often include a diversity of perennial grasslands (regarding productivity, plant diversity and topographic/farming properties). It is now widely recognized that plant and/or grassland diversity has potentialities at field and farm scale (e.g. White et al., 2004) regarding a number of aspects e.g. flexibility gain in management, improved tolerance to extreme climatic events, complementarities between species... However, managing grassland diversity is a rather complex issue as it implies satisfying production and management objectives on different temporal scales and coping with farmland spatial heterogeneity which is characteristic of less-favored areas. Farmers need to satisfy animal feed requirements, which requires dealing with weather uncertainty. Taking into account long-term consequences, farmers have to manage carefully the technical operations on each field so as to ensure the sustainability of vegetation properties. For a given form of land use, depending on the grassland community characteristics, there is an optimal time window for using the grassland resource. Definition of this time window is based on biomass availability and/or herbage quality according to the herd feeding objectives. When organizing their production system, farmers also have to cope with the spatial heterogeneity of the farmland i.e. topographic and farming properties of individual fields (ease of access, suitability for mechanization…) as well as fields' potential production permitted by vegetation types. The combination of these two variables determines the single or various forms of land use a field can fulfill in the feeding system.

Herd batching that exploits animal diversity is of major interest to diminish herbage losses and to exploit all kinds of grassland communities by matching animal batch needs to herbage feeding value. Batch re-composition can also be used as a regulatory process to cope with yield variation. Consequently, as demanded by farmers and farm advisors, bio-technical and organizational guidance is needed to improve current management practices. This entails developing and integrating on a farm scale a coherent set of management practices for each grassland community type and herd batch over different time scales. Such integration can be used to identify particular farming system management strategies suited for specific contexts, and to characterize the consequences of these potential re-organizations on the land use, given the grassland community types present.

Forward looking strategies are needed in order to support adaptability and reactivity of the farming systems. Such management strategies might be obtained by harnessing organizational flexibility and biological buffering capabilities. We define organizational flexibility as freedom in the implementation and modification of a management strategy under a given set of topographic and farming constraints. We call biological buffering capabilities the farmer's ability to modify the target performances or the state of the plant and/or animal material; such changes of plant or animal target state have to remain within a specific feasibility range to benefit from the buffering capacity of these biological entities. Such buffering capabilities differ according to categories for these biological entities based on selected indicators, for instance functional plant ecology markers in this paper. When looking for such new management strategies, one should consider concomitantly those two dimensions, i.e. the exploitation of biological buffering capabilities and organizational flexibility, to devise management strategies that make good use of this leeway. In this context, farm scale simulation modeling is of major interest to study the consequences of management changes on simulated farming systems. For achieving the design of farming systems, a lot of attention has been given to improvement of biophysical simulation models. However, it is to a large extent the complexity of setting up coherent management options that make farming systems so complicated (Thornton & Herrero, 2001). This is why a number of authors (e.g. Garcia et al., 2005) call for more elaborate consideration of management aspects and for a better coupling between biophysical and decisional models to study farmer's management and its consequences on the biophysical system, such as in FARMSCAPE (Carberry et al., 2002). Research has produced several simulation-based farm models for beef and dairy farming systems such as SEPATOU (Cros et al., 2004) focused on rotational grazing management. To our knowledge, no example has focused on the efficiency of grassland and animal diversity exploitation through innovative management strategies centered on organizational flexibility and on the use of biological buffering capabilities. The present paper provides basic insight into a conceptual description of the SEDIVER approach, a farm-scale modeling and simulation approach designed to study the dynamics and interactions between biophysical and management processes in different weather scenarios. This conceptualization step is a necessary preliminary to the simulation-based investigation of the behavior of specific farm instances. At the core of this step lies the representation of the production management behavior and its linkages with the biophysical system, in particular grassland and animal diversity. Section 2 describes the background knowledge involved in the modeling process. In Section 3, we outline the necessary steps towards the design of a management strategy. Section 4 presents the main features of the SEDIVER conceptual model.

2. BACKGROUND KNOWLEDGE INVOLVED IN THE SEDIVER APPROACH

2.1. Simulation-based study of management strategies

The complex interaction between biophysical processes and those under human control is at the very heart of agricultural production. As a production manager, the farmer makes decisions about land use and the timing, combination and implementation of the associated technical operations (e.g. harvesting, feeding animals, etc.) in the hope of achieving his objectives. Clearly the important question of production management, dealing with risk control, change as new practices, products and techniques appear requires innovative approaches that recognize and focus on the holistic, dynamic and human dimension of farming systems.

Management strategies are ways of structuring things one intend to do, or ways in which something is done. It deals with the organization of work activities across time and space. Studying management strategies implies a strong emphasis on what activities are deemed relevant for a production objective, what is the interdependence between them, what are the preconditions to their enactment and how they should be structured in time and space to tackle the constraints to the desired outcome. Prior to the execution of technical operations, management can be broken down into two steps: configuration and planning. Configuration consists mainly in sizing production units and herd batches concomitantly. Planning leads to determine the relevant technical activities and the key dates and conditions involved in their structuring in a production plan. Farmers implement on a field-scale management practices that they have devised by integrating considerations on a farm scale. To deal with the spatial dimension of farm management decision-making, Coleno and Duru (2005) introduced the concept of a production unit, i.e. the functional entity characterized by a single land use on which a farmer works out his management practices. A livestock farm is therefore considered as an aggregation of spatially organized production units.

Elaborate decision-making models rely on the decision-making context, for instance the farmer's material or physical constraints, his beliefs about what biophysical indicator is relevant to a decision or his personal know-how and preferences. In some cases, the complex issues of dynamic work scheduling and resource allocation may need to be considered. Thus a farm management strategy is perceived as the specification of a temporally-structured decision process, together with its context-dependent adaptations (Cros et al., 2004).

Computer-based simulation is one of the commonly approach used to aid in the design and evaluation of production management policies (FARMSCAPE: Carberry et al., 2002, SEPATOU: Cros et al., 2004). Simulation approaches have traditionally focused on isolated agronomic and technological aspects of the production processes, e.g. crop or animal responses to particular farming operations. Surprisingly, little attention has been paid to the realistic modeling and simulation of management strategies of farmers. Studying and supporting the design of management strategies by means of computational tools has rarely been addressed directly and systematically as an issue in its own right (Garcia et al. 2005). This is precisely what the SEDIVER project is intended to do in the case of grassland-based farming systems. Any SEDIVER model is an instantiation of a SEDIVER metamodel that offers abstract representation patterns enabling to capture the description of a particular farm configuration and management strategy set up to control the production process. The metamodel relies on an ontology dedicated to the domain of production management. An ontology (Smith, 2003) seeks to describe or posit the kinds and structures of the concepts, properties and relations in the domain of interest. This ontology takes the form of a set of classes that describe the structural components of the domain and a set of procedures that describe the inferential mechanisms applicable to instances of these components and representing how they might change over time. The ontology has been implemented in the modeling/simulation framework, called DIESE (Martin-Clouaire and Rellier, 2003). The central concept of the ontology is the notion of activity, the characterization of an operation to do on something. An activity has some attributes that specify, in particular, its relevance in a working context and the triggering conditions that control its execution status. A set of operators are used to represent various kinds of dependences among activities. These operators enable to define composed activities by specifying sequencing, concurrency, synchronization or delay enforcement. They also include a kind of programming construct able to specify for instance that an activity should be iterated or that an activity is optional.

Composed activities may describe nominal plans with the inherent and necessary specification of the sequence of activities that will eventually be executed. The vagueness of a plan is not a fault, but provides the flexibility needed to cope with the huge number of actual circumstances unfolding during its situated enactment, especially in agriculture where uncontrollable factors play a key driving role in many production processes. On the other hand, a nominal plan may encounter situations where it is beyond its bounds, notwithstanding its flexibility. To account for this need, our ontology is equipped with the concept of conditional adjustment.

2.2. Functional approaches to cope with the diversity of grasslands and animals

Perennial grasslands are complex agrosystems to model as they include a diversity of species. Recent simulation models describing herbage growth and/or digestibility developed for species-rich grasslands adopt a functional representation of grassland vegetation (e.g. Jouven et al., 2006). The functional composition is based on the definition and the measuring of value, range, and relative abundance of plant or animal functional traits (morphological, physiological and phenological) in response to availability of resources and perturbations. Thus, in these recent simulation models, vegetation-related inputs are provided in terms of grass functional groups distributed along a leaf dry matter content (LDMC) gradient. On-field grasses weighted mean LDMC ranking is well correlated with agronomic characteristics like organic matter herbage quality and timing of herbage growth pattern in relation to plant phenology and leaf lifespan (Al Haj Khaled et al., 2006). Vegetation agronomic characteristics are mainly determined by management i.e. practices regarding resources availability and land use (grazing/cutting). Based on such concepts, grasses weighted mean LDMC at plant community level provides a powerful descriptor of grassland vegetation for modeling the dynamics of growth and digestibility. In addition, it is especially suited for characterizing the time course of herbage production and consequently the latitude offered by each vegetation type to exploit its buffering capabilities through the time windows for grazing or cutting.
Functional classification of cattle categories has led to the identification of animal classes as proposed in dynamic models of herd demography. Based on this functional classification of animal categories and breeds, available feed evaluation and rationing system for protein and energy can be used to model animal feed intake and animal production.

3. DESIGNING A LIVESTOCK FARMING SYSTEM

The SEDIVER approach puts emphasis on decisions at the operational level at field and herd batch scales to evaluate management strategies at farm scale. Thus, the two dimensions of a management strategy, configuration of the system and initial planning of the activities, are model inputs that have to be designed prior to simulations and then incorporated in an instantiation of a SEDIVER meta-model. Configuration and planning must take into account uncontrollable aspects such as the topographic properties of the fields (e.g. area, slope) and induced farming constraints (e.g. suitability for mechanized harvest), agronomic characteristics of the fields (e.g. initial vegetation type) as well as general objectives related for instance to labor or profitability. Figure 1 outlines how the above aspects affect the design of a management strategy.

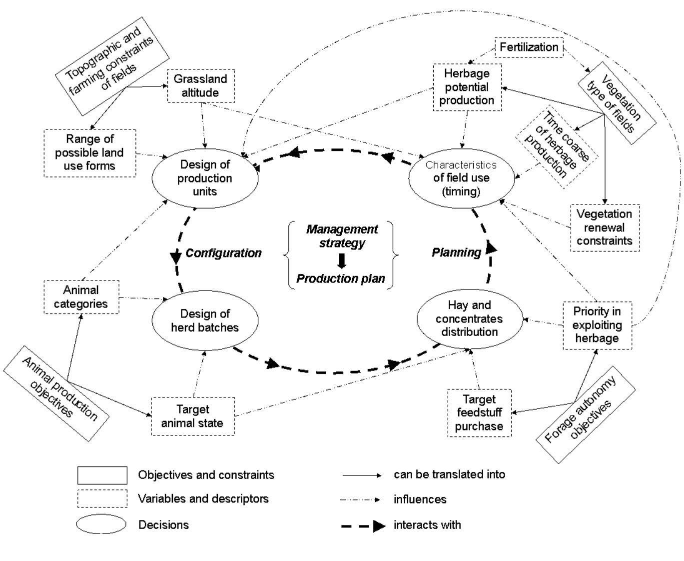

Figure 1: Factors involved in configuring and planning a livestock farming system to build the production plan used as inputs in a SEDIVER simulation run.

3.1. Base configuration of the farm system

When configuring a livestock farming system, considerations of topographic and farming constraints of the fields provide a range of possible forms of land use on these fields. One may set up groups of candidate fields likely to be allocated to the different production units. In addition, animal production objectives that can be translated into herd composition (animal categories and target animal state) affect the batching options. Batching decisions aim to optimize feeding conditions for the various animal categories to achieve their expected target states. Farmers may consider grassland community types to match herd feeding objectives to the potential herbage production permitted by these vegetation types, taking into account that fertilization is a leeway to modify this herbage yield as well as the encountered vegetation type in case of lasting change of fertilization practices. The farmer's priority in optimally exploiting herbage may also influence the configuration. For instance, if optimally exploiting herbage is not among a farmer's priorities, he may form production units with an above-average stocking rate and then feed bought-in hay and concentrates if necessary.

3.2. Planning and exploitation of organizational flexibility and biological buffering capabilities

The configuration decisions yield a set of candidate fields for each production unit. Planning restricts these sets by introducing timing considerations. To this end, grassland community types provide indications on the time course of herbage production and consequently on the thermal time windows for grassland use whereas field altitude can be used to map these thermal time windows to periods expressed in Julian dates. Thus farmers get an idea of the Julian period at which herbage will be available for given types of land use. They can arrange their grazing and cutting sequences by considering the successive time windows for using the candidate grassland fields identified in the configuration phase. Moreover, vegetation types and fertilization practices provide information on the attainable yield at any given moment. For a single field, successive activities can correspond to different forms of land use and therefore to different durations for herbage re-growth on the field. For instance, after the first cutting activity, a field can join a grazing sequence or it can be harvested a second time. This corresponds to re-growth durations ranging from one to twice. In this way, the farmer organizes the sequences of grazing and cutting activities over time and space. Depending on the priority he gives to exploiting herbage resources, he may decide to counterbalance a non-optimal timing for field use by an adjustment of fertilization practices or by the distribution of hay and concentrates. This may influence decisions about activities related to the distribution of hay and concentrates. In order to ensure the renewal of grassland vegetation, the timing of the grazing and cutting activities should be kept quite stable from one year to the next.

The result of the planning step is a plan of activities, a set of conditions that control their execution and, if needed, some state-dependent adjustments that enables plan or configuration adaptations in exceptional situations. The conditions may concern dates or restrictions for the execution of an operation, e.g. sward height of the next field to be grazed and phenological stages. It thereby includes information about the intensity of grazing and the range of intensities associated with a grazing activity performed on a field by a herd batch. In addition to the constraints imposed by the sequencing of activities, each activity is usually assigned opening and/or closing conditions such as a time window between two dates, a biophysical condition or a threshold (e.g. a degree day sum). For instance, opening-closing conditions can be used to differentiate between "normal grazing" and "topping" which actually are both grazing activities. Topping is a light grazing thereby corresponding to higher residual biomass when specifying closing conditions assigned to this particular grazing activity. More generally opening and/or closing conditions may involve any indicator, that is, any piece of information collected or synthesized for use in decision-making. Then the use of biological buffers lies in the specification of intervals of indicator values for activating production activities. These may be time windows determined according to the encountered vegetation types. Target animal state can also be specified as an interval of body condition score to benefit from the biological buffer capacity of animals if needed.

Some fields are not fully committed at planning time. Their role is to enable the combined exploitation of organizational flexibility and biological buffering capabilities. Depending on the conditions, such uncommitted areas can be switched easily from one production unit to another. Such a switch has to remain in an acceptable range of frequency not to jeopardize buffering capabilities of herbage and to avoid irreversible side effects on grassland community characteristics. Organizational flexibility can also be exploited through batching in the course of the year. This may have consequences on stocking rates and subsequently on (i) the associated grazing practices thereby involving buffering capabilities of herbage, (ii) target performances of animals and their buffering capabilities. Suitability of fields for a range of land use forms, yield, quality and time course of the herbage production are considered in revising the base plan in the course of the year thanks to adaptability provided by such uncommitted areas. The latitude for revision of the production plan is largely dependent on organizational flexibility permitted by topographic and farming constraints.

4. OVERVIEW OF THE SEDIVER CONCEPTUAL MODEL

4.1. Biophysical system

Conceptually, the biophysical system is seen as composed of biophysical entities (fields, herd batches, etc.) that may have one or several descriptors (e.g. dry matter available, population size, etc.) and their own processes (e.g. plant development, animal intake and production). The processes are controlled by events such as a birth event which is programmed to occur every year and induces the firing of a process of creation of animal entities and a feeding process applied to these new animals. From a modeling point of view, the above entities, descriptors, processes and events can be defined as particularizations of ready-to-use DIESE classes and instantiated as needed for specific farm cases.

Fields are mainly described by a set of topographic and farming properties that determine the range of possible land use forms, a surface area, an altitude and a type of grasslands expressed through a descriptor of grassland vegetation (a grasses weighted mean LDMC). Then, the values of the descriptors (e.g. water stress index, leaf area index) involved in the processes governing the field dynamics are specific to each field. Daily plant growth and herbage quality dynamics are the main processes modeled at field scale using available models (e.g. Jouven et al., 2006). Linked to daily plant growth is sward height that make sense for farmers in grazing management. Thus, sward height is commonly used in the conditional adjustments involved in management strategies that deal with biological regulations.

Herd batches are mainly described by an average animal state and a size with target objectives for the modeled state variables (weight or milk production) over a given period that can be modified to account for the buffering capacity of cattle in the system, e.g. when the farmer decides to decrease animal state targets so as to save available herbage during drought. Simulated processes are daily intake, evolution of daily energy requirements, energy conversion and production (milk and/or fattening) for each animal batch using the INRA fill unit system. Moreover an available but unpublished demographic module will be used to simulate the ageing process of animal categories.

Hay stocks are described by the nature of the feedstuff, its available amount, herbage quality, feed and fill value using available models (Duru and Colombani, 1992). Modeling available amount of hay stocks has an interest for accurately representing management strategies in the model. When stocks become scarce, farmers are used to modify their plan, e.g. by advancing in time the date for turnout. Concentrate stocks are modeled with the same variables.

4.2. Decision system

One of the most attractive features of the DIESE modeling framework is its capacity to easily represent flexible production plans. Making a model of an executable plan is a matter of instantiating the abstract primitive activities provided as a library and articulating them using the composition operators. SEDIVER activities include:

- grazing, that applies to a herd batch and to a set of fields visited in turn;
- distributing hay and concentrates, that applies to a herd batch;
- cutting that applies to a set of fields.

Taking the example (simplified for the sake of clarity) of a farm with three production units, Figure 2 provides an example of a plan written in a similar way to the plan representation of DIESE. The operator "`and`" in the first line permits the aggregation of the primitive or composed activities specified in each subsequent line. For instance, lines 3-7 refer to a sequence of activities of topping and iteration of normal grazing by the H1 batch and the cutting of the field F1 topped by this herd batch. The "`meeting`" operator on line 3 has two arguments that are composed activities, the first one (lines 3-5) starting with an "`include`" operator, and the second one (lines 5-7) starting with an "`and`" operator. Semantically, "`meeting`" specifies that these two composed activities are contiguous in time: right after the end of the first one, the second one is activated. Similarly, the operator "`include`" has two arguments consisting of composed activities, the first one being a "`meeting`" sequence and the second one an iterative hay-distribution activity. The operator "`include`" forces the opening period of the second one to be included in the opening period of the first one. It is used to specify that the activities referring to this operator are concomitant at least over part of the time period over which the first one is open. Coming back to the grazing activity of line 3, the H1 batch should first be put to graze on field F1. Right after this (according to the semantics of the "`meeting`" operator) the same herd batch should be moved onto field F2 if the conditions specified with the operator "`optional`" are met. In the meantime (according to "`include`"), the farmer should distribute hay repeatedly. Some opening and closing conditions (not shown here) restrict the period and/or situation in which this should be done. Once these one or two fields have been grazed, the second argument of the "`meeting`" activity becomes "open". The herd batch should be moved successively to fields F3 and F4 and this same grazing sequence should be iterated (as specified by the operator "`iterate`") until a termination condition (not shown here) is met. In the meantime, field F1 should be cut by the farmer. The operator "`before`" in line 10 means that the H2 batch should first graze fields F6 and F7 and then the farmer should consider the state of field F8 to determine whether this uncommitted field is grazed or cut after fields F6 and F7. Finally, the operator "`equal`" on line 15 means that both the grazing sequence on the fields F10 and F11 and the distribution of concentrates should begin and should end together.

```
1  and(
2  //--1st production unit-----------------------------------------------
3      meeting (include (meeting (grazing (F1, H1)),
4                                 optional(grazing (F2, H1))),
5                       iterate (distributing_hay (H1)),
6              and (iterate (grazing ({F3, F4}, H1)),
7                   cutting (F1))),
8  //--2nd production unit-----------------------------------------------
9      meeting (grazing (F5, H2),
10             and (iterate (before (grazing ({F6, F7}, H2)),
11                                   or (grazing (F8, H2)),
12                                      cutting (F8)))),
13 //--3rd production unit-----------------------------------------------
14     meeting (grazing (F9, H3),
15             and (equal (iterate (grazing ({F10, F11}, H3)),
16                         iterate (distributing_concentrates (H3))))),
17     )
```

Figure 2: Example of a plan written in a similar way to the plan representation of DIESE. F and H refer to Field and Herd batch and are followed by the corresponding Field and Herd batch numbers. The indentation helps in identifying the arguments of the composition operators (`and`, `or`, `meeting`, `before`, `include`, `equal`, `iterate`, `optional`).

Decision-making modeling can consist in strictly applying the plan when the weather conditions are within the envelope of the average year. On those fields that were not fully committed at planning time, we considered the switch of land use form as the exploitation of the latitude permitted by the base plan (using the "`or`" operator, line 11). However, in some situations, more profound adaptations should be implemented using conditional adjustments. For instance, batching could be used to organize the herd into two batches only, thereby implying a complete revision of the grazing sequences planned. None such conditional adjustment is presented in this example.

5. CONCLUDING REMARKS

In this article (see (Martin et al., 2008) for an extended version), we discussed the management issue of exploiting grassland and animal diversity in a livestock farming system, and how to address this issue using a farm simulation model.

At the time where research projects focused on climate change flourish, we believe that the prime need of farmers is to get support in dealing with climate variability and especially extreme conditions. Such support might be obtained by comparing alternative management options through computer simulations. To cope with weather uncertainty, managing the within-farm functional diversity of grassland community types is of major interest from the practical, economical and ecological points of view. Moreover, farmlands especially of less-favored areas are characterized by a strong heterogeneity in resource use in particular herbage, which results in high variability of yield and income in time and space. Common farm-scale modeling approaches are based on farm-encompassing indicators such as stocking rate or amount of fertilizer per hectare. We argued that the design of agri-environmental schemes should explicitly consider the within-farm diversity of grasslands and their practical use.

Most research approaches dealing with the design of farm management strategies are typically based on linear programming models that suffer from too unrealistic assumptions with respect to the importance of dynamics and uncertainty in farming. Keating and McCown (2001) already suggested that challenges for farming system modelers are "not to build more accurate or more comprehensive models, but to discover new ways of achieving relevance to real world decision making and management practice." In this sense, the SEDIVER project is the result of consistent efforts to improve the representation of farm management strategies and get closer to the questions raised in practice. In their day-to-day management, farmers are coping with unpredictable events which call for flexible plans and conditional adjustments that yield different sequences of actions depending on the course of events met. Indeed there are some turning point events in the course of the year at which the farmer has to review part of his base plan.

The conceptual model of a management strategy presented in this paper is inherited from the ontology underlying the DIESE modeling framework. The level of detail of the knowledge that is dealt with by SEDIVER is totally in line with the expressive power of the modeling framework. Moreover, DIESE plays an important role in guiding the model design through ready-to-use representation patterns. For instance, compared to the widely used "`IF…THEN…ELSE…`" approach, the formal representation of management strategies exploited by the SEDIVER approach provides an intelligible and rigorous conceptual framework that can capture timing dependencies and concurrencies between farming activities.

The metamodel SEDIVER presented in this paper is still to be implemented in the DIESE modeling / simulation framework. This essentially amounts to create the entities, processes and events involved in the biophysical system and to particularize the necessary notions of activities and operations of the grassland-based livestock system domain. These models account for different biophysical processes and production management processes and can be used to perform *in silico* (i.e. computer simulated) experimental investigation of the merits and limits of different grassland and animal management strategies.

Once implemented, this model will be suitable for modeling real farm cases. Still, dealing with real cases implies to cope with the specificities of each case and important data gathering for being able to run the model. Instead of trying to reproduce very closely real cases, the project will focus on characterizing and designing virtual innovative farm types. In the field of agronomy, research has almost always used farm types based on structural criterion. In the course of this project, to enrich the range of simulated cases and to cope with the complexity of the management choices observed on field, a typology based on the farming style concept (van der Ploeg, 1994) will be elaborated in partnership with experts to be crossed with a typology based on structural criterion. By providing a quite detailed overview of the possible trajectories of farms on a territory, this combination of typologies coupled with the SEDIVER approach will provide the necessary elements to deal with land use issues at regional scale.

ACKNOWLEDGEMENTS

This study is partly funded by the French ANR ADD (Agriculture et Développement Durable) programs, in the framework of the projects TRANS (TRANSformations de l'élevage et dynamiques des espaces - ANR-05-PADD-003) and VALIDATE (Vulnerability Assessment of LIvestock and grasslanDs to climAte change and exTreme Events).

REFERENCES

R. Al Haj Khaled, M. Duru, V. Decruyenaere, C. Jouany, and P. Cruz, Using leaf traits to rank native grasses according to their nutritive value, *Rangeland Ecology & Management,* 59, 548-654, 2006.

P.S. Carberry, Z. Hochman, R.L. McCown, N.P. Dalgliesh, M.A. Foale, P.L. Poulton, J.N.G. Hargreaves, D.M.G. Hargreaves, S. Cawthray, N. Hillcoat, and M.J. Robertson, The FARMSCAPE approach to decision support: farmers', advisers', researchers' monitoring, simulation, communication and performance evaluation, *Agricultural Systems,* 74, 141-177, 2002.

F.C. Coleno, and M. Duru, L'apport de la gestion de production aux sciences agronomiques. Le cas des ressources fourragères, *Nature Sciences Sociétés*, 13, 247-257, 2005.

M.J. Cros, M. Duru, F. Garcia, and R. Martin-Clouaire, Simulating management strategies: the rotational grazing example, *Agricultural Systems*, 80, 23-42, 2004.

M. Duru, and H. Colombani, Haymaking: risks and uncertainties in Central Pyrenees grasslands, *Agricultural Systems*, 38, 185-207, 1992.

F. Garcia, F. Guerrin, R. Martin-Clouaire, and J.P. Rellier, The human side of agricultural production management - the missing focus in simulation approaches. In: Proceedings of the MODSIM Conference, Melbourne, Australia, December 12-15, 2005.

M. Jouven, P. Carrere, and R. Baumont, Model predicting dynamics of biomass, structure and herbage quality of herbage in managed permanent pastures. 1. Model description, *Grass and Forage Science*, 61, 112-124, 2006.

B. Keating, and R.L. McCown, Advances in farming systems analysis and intervention, *Agricultural Systems*, 70, 555-579, 2001.

G. Martin, M. Duru, R. Martin-Clouaire, J.P. Rellier, J.P. Theau, O. Therond, and L. Hossard, Conceptualizing grassland and animal diversity management in livestock farming systems of less-favored areas – Overview of the SEDIVER approach. Submitted, 2008.

R. Martin-Clouaire, and J.P. Rellier, A conceptualization of farm management strategies. In: Proceedings of the EFITA Conference, Debrecen, Hungary, July 5-9, 2003.

B. Smith, Ontology, In: Floridi, L. (ed.), Blackwell Guide to the Philosophy of Computing and Information, pp 155-166, 2003.

P.K. Thornton, and M. Herrero, Integrated crop-livestock simulation models for scenario analysis and impact assessment, *Agricultural Systems*, 70, 581-602, 2001.

J.D. van der Ploeg, Styles of farming: An introductory note on concepts and methodology, In: J.D. van der Ploeg & A. Long (eds), Born from within: Practice and perspectives of endogenous rural development, pp 7-30, 1994.

T.A. White, D.J. Barker, and K.J. Moore, Vegetation diversity, growth, quality and decomposition in managed grasslands, *Agriculture Ecosystems & Environment,* 101, 73-84, 2004.