Fostering adaptation of livestock systems to climate change: implementation of Forage Rummy and implementation analysis in southeastern France.

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List of abbreviations

Av: average year
BS: Beginning Stocks
°Cdays: degree days
CO_2 eq or Ceq: carbon dioxide equivalent
DM: Dry Matter
Dry Su: Dry Summer year
Dry Sp: Dry Spring year
Etp: Potential evapotranspiration
FS: Final Stocks
Ghg: green house gases
ha: hectares
K: Potassium
L: liters
kg: kilograms
N: Nitrogen
P: Phosphorus
PG: Permanent Grassland
qx: quintals
R: rainfall
RGI: Solar radiation index
SAU: Surface Agricole Utile (Total cultivated area)
T: Temperature
t: tons
TG: Temporary Grassland
yr: year

List of acronyms

AOC: Apellation d'Origine Contrôlée (Appelation of controled origins)
ADEME: Agence de l'Environnement et de la Maitrise de l'Energie (The French Environment and Energy Management Agency)
CAP: Common Agricultural Policy
CLIMFOUREL: Adaptation des systèmes fourragers et d'élevage péri-Mediterranéen aux changements et aux aléas climatiques (Adaptation of peri-Mediterranean forage and livetsock systems to climate change and variations)
INRA: Institut National de la Recherche Agronomique (National Institute of Agronomic Research)
SWOT: Strength Weaknesses Opportunities Threats

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1.Introduction

1.1.Context of Forage Rummy development in Rhône-Alpes

Agriculture is going through a time of uncertainty and global change regarding a diversity of factors being climatic (climate change), economic (increase of cereal and concentrates prices), social (negative perception of agriculture and higher expectations concerning the quality of products) and environmental. This changing context, climate change in particular, makes the already difficult task of livestock farmers more complicated. Indeed, livestock systems of the temperate regions are increasingly constrained by the variability of forage crop (grasslands, maize, immature cereals, etc.) production (Faure and Compagnone, 2011).

1.1.1. Climate change and implications for forage crops production in southern France

Climate change at the Mediterranean-Temperate interface in southern France has for main impact the shift of the iso-climatic lines towards the North-North West. In the last 30 years, the geographic range of the Mediterranean climate extended over 40,000 km², 30% of which are grasslands (Lelièvre et al., 2010). This represents a progress of aridity: stations that were temperate in 1980 (such as Valence, Lyon and Colombier) are now sub-Mediterranean (Figure 1).

Increase in solar radiation (RGI), temperature (T) and potential evapotranspiration (ETp) from May to August is the main driver of this change, while rainfall (R) tends to decrease (Lelièvre et al., 2011).

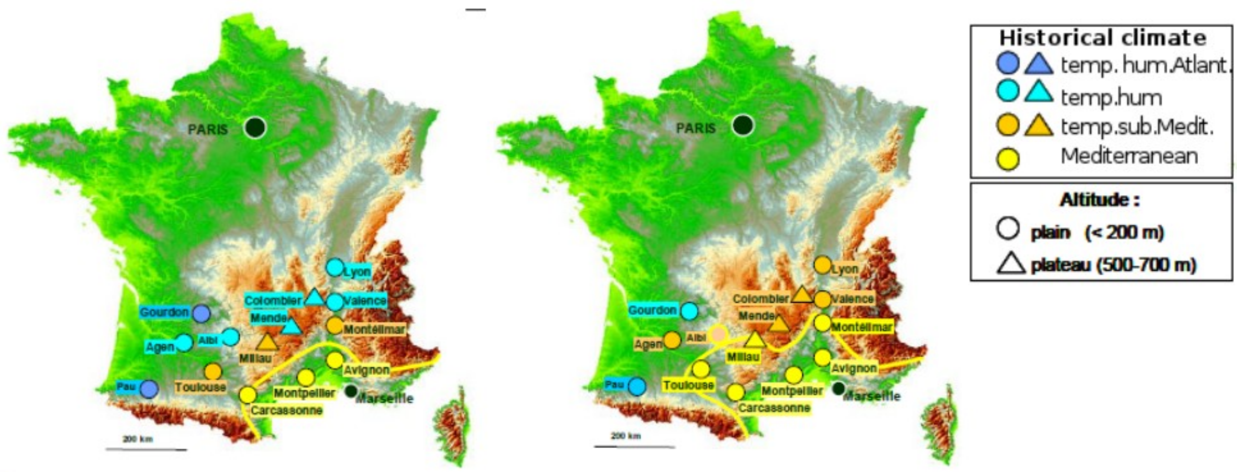

Figure 1: Climate evolution maps (left:1950-1975, right: 2009), (adapted from Lelièvre et al, 2011)

Climate change led to the modification of three main determinants of agricultural yields:

- Increase in CO_2 concentration in the air that stimulates photosynthesis and yield;
- Increase in air and water temperature resulting in higher precocity, greater photosynthesis and yield;
- Increase in climatic water deficit through the increase of the ETp. In regions where the water deficit frequency is high, the length and intensity of drought increases, meaning that dry years are dryer when compared to past dry years (Lelièvre et al., 2011).

Cultivated grassland production in the peri-mediterranenan region is being modified. The increase of temperature enables a greater precocity and growth in spring. Drought leads to a strong decrease of production in summer. In autumn, effects of drought are compensated by the effects of increase of CO_2 and temperature. This new climate imposes a decrease of annual grasslands' production (which dropped of 11% between 1980 and 2008) with a greater variability of production in summer and autumn.

So far, farmers' main response to this decrease of grasslands' production is purchasing forage as shown in figure 2. Livestock systems are not equally sensitive to drought. Two other options are explored by farmers displaying higher self-sufficiency for forage: over-storing forage by decreasing the number of animal per hectare, intensifying land use, and using irrigation to secure forage production (Moulin, 2011).

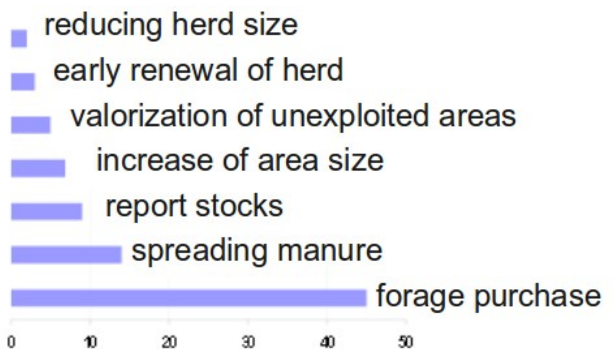

Figure 2: Actions to compensate the lack of forage (inquiry of 47 farmers in 2008, Ardèche), (adapted from Moulin, 2011)

Climate change, occurring both in tendency and variability, is not only impacting grasslands but all forage crops production (Felten et al., 2011). Thus it becomes necessary to adapt farming systems both in their management and structure to cope with changing conditions (Martin et al., 2011).

1.1.2. Evolution of advisory practices regarding livestock systems facing climate change

Herbage is perceived by farmers as an economic feed that contributes to animal welfare, giving a positive image to the end product in terms of quality (Frappat et al., n.d.). However grassland areas are declining since the 70's. The Common Agricultural Policy (CAP) (Dussol et al, 2003) and the decreasing number of agricultural workers (Huyghe, 2007) played an important role in this evolution. Grasslands are replaced by supposedly more productive forage crops and cereals (Dussol et al, 2003). Farmers also blame the complexity of grassland management, to achieve decent hay quality, and efficient grazing. Forage production is found to be too sensitive to climate variations and generate insecurity in stock production and grazing availability. Farmers feel that they are insufficiently supported by extension services. They expect farm advisers to facilitate communication between farmers and to organize farmers' groups in order to share knowledge on their practices to deal with issues such as adaptation to climate change (Frappat et al., n.d.).

These new expectations call for non-prescriptive collective advisory tools, favoring a systemic approach. The collective aspect responds to the need to detain a large range of knowledge regarding techniques, systems, regulations, etc to adapt to the diversified expectations of farmers. And the aim is to co-construct relevant solutions with farmers. The systemic approach allows to visualize farms as systems that need to be managed taking into account interactions, which is key to tackling environmental issues (Esposito Fava and Naïtlho, 2013; Frappat et al., n.d.).

In this context, CLIMFOUREL 1 (2007-2010), a project supported by INRA and three French regions (Rhône-Alpes, Languedoc-Roussillon and Midi-Pyrénées) was developed. It aimed at supporting adaptation of livestock systems to climate change in the peri-mediterranean area. The goals of this project were (1) to characterize the extent of the changes already happening, and evaluate the risks in the future, (2) to develop and propose relevant tools at various scales (plot, farm, small region) to reduce its impact and to adapt livestock systems, and (3) to transfer diagnosis and advisory tools to extension services (climfourel, 2007).

The Rhône-Alpes region wanted to reinforce and disseminate the work achieved during CLIMFOUREL 1. Therefore another project called CLIMFOUREL 2 started in 2012. One task in this project involves INRA and consists in adapting and implementing forage rummy (a tool developed during CLIMFOUREL 1) to the conditions of the Rhone-Alpes region with the support of several chambers of agriculture (climfourel, 2007).

1.2. Forage Rummy

1.2.1. Origins and Principles

Forage rummy is an advisory tool supporting farmers' reflections on forage based livestock systems to meet challenges or adapt to specific issues. It was initially created in 2010 by Guillaume Martin (INRA UMR Agir), to work on adaptation of livestock systems to climate change. Still, it can be used to tackle other issues such as adapting to a change in production requirements. Issues are identified collectively by farmers and synthesized by farm advisers. Forage Rummy is a board game that engages a group of farmers coordinated by a farm adviser in the design and evaluation of livestock systems. They co-construct the knowledge required to find locally relevant solutions to adapt livestock systems. Evaluation of the impact of these choices on agricultural and socio-economic aspects is also part of the process (Martin et al., 2011). Importance of the systems approach is stressed as forage rummy focuses on the equilibrium between production and consumption of forage depending on the herd production level .

1.2.2. The components of the game

-The **board** serves as physical support to the game. It is divided horizontally in two main parts: The upper part is where the forage sticks will be placed describing the forage crops; the lower parts is reserved for the herd. It is described as a set of herd batches and their feeding can be specified using the animal and feed cards. The representation of the farm system is done for a year, divided in 13 periods of 4 weeks each (and so the board is divided vertically in 13). See figure 3 for illustration.

-The **forage sticks** describe the forage production for each combination of a crop or pasture and its management in a given natural environment (soil and climate). Forage sticks display the available forage yield in kilograms per hectare and per day for each of the 13 periods when the pasture is grazed, and a yield in tons of dry matter per hectare for one to several periods when the pasture is harvested.

-The herd batches are represented by a**nimal cards** referring to a type of animal and its management characteristics (production level, feeding requirements, calving date, etc.)

-The **feed cards** enable to describe the year-round diet of the herd batches. Each card represents a type of feed and its nutritional characteristics.

-The **computerized support system** integrates the input information: key characteristics of the system (forage production, animals and their feed, …) and allows to assess the agreement between the feeding requirements of the herd batches and forage production resulting from choices of specific forage crops and grasslands. It also gives material for discussion through indicators addressing economic, agronomic and social aspects.

(For a more detailed description of forage rummy refer to appendix 1.)

Figure 3: Forage rummy board

1.2.3. Playing the game

The workshops are held in presence of a small group of people including farmers, advisers and facilitators. Usually workshops progress as follows: (1) expectations and opinion of each participant on the problem ; (2) information on the problem addressed, (3) presentation of the game, (4) presentation of the local context (climatic data), (5) game playing through successive rounds, (6) discussion on possible adaptations for the farm system studied. After the workshop, analysis is conducted on its format and its content, and synthesis documents are returned to farmers and advisers.

1.2.4. Forage rummy as an agroecological tool

Forage rummy seeks to bring out adaptations to climate change and agroecology may serve as a framework supporting the design of sustainable farm systems. Agroecology can be defined as the integration of ecological principles in agriculture to design sustainable agroecosystems (Wezel et al., 2009). Sustainability is applied to the farming system and thus implies system thinking integrating three perspectives: production, environment and social values. Production efficiency is seen in terms of efficient use of inputs and economic benefits, ecological concerns seeks the use of renewable resources and recycling to minimize the impact on the environment, and social dimension means contributing to support a self-reliable community.

Sustainability leads to seeing the farm as a system in constant evolution with its environment, should it be economic, ecological or social. And it was proven that action learning and participatory attitudes are relevant tools for farmers to improve their relationship with their environment, and so to meet sustainability (Sriskandarajah et al., 1991; Warner, 2007). Indeed, sustainability is not only an end results but also a learning process and participatory approaches become necessary to place stakeholders in this learning dynamic (Pretty, 1995).

Forage rummy implies the setting up of collective workshops of reflection to provoke change at the livestock system scale. Focusing on the adaptation of forage rummy to the Rhône-Alpes region and the systems designed during these workshops, it can be explored whether forage rummy contributes to the development of agroecology.

1.3. Objectives and research axis

The objective of the present work was to analyze both the use of the tool in the Rhône-Alpes region and the results obtained during the workshops.

The perception of forage rummy by the advisers was analyzed as well as the use they would make of it in the future, through open interviews. Focus was on the advantages of using forage rummy in a participation framework, the problems that hindered its development in the Rhône-Alpes region and how to overcome them. Reflection on scenarios to insert forage rummy in the advisers' activity was also central.

Concerning the workshops results, the aim was to assess whether the forage rummy workshops yielded adaptation proposals that put the participating farmers on the track towards more agroecological practices that are more robust in the face of climate change. For this purpose several aspects were analyzed such as autonomy, diversity and environmental impacts. This analysis was done looking at parameters for each initial system studied, comparing them, and then analysing the adaptation possibilities.

2.Materials and Methods

2.1. Coordination between three entities

The adaptation of Forage Rummy to the Rhône-Alpes region involves three parties: the INRA-Toulouse, 3 chambers of Agriculture (Ardèche, Isère, Drôme) and a master student in Agroecology. At the beginning, discussion between the three parties was necessary to define the number of workshops, the systems we would focus on and the topic that would be treated, as well as the data needed.

2.2. Implementation of Forage Rummy in southeastern France

2.2.1. Collecting information for workshop preparation

The adviser contacted farmers likely to be interested in forage rummy, being concerned by the impact of climate change and the reflection on possible adaptations. Adviser and student collected the information necessary to create the boundary objects for the rummy (list of elements are available in appendix 2 in French).

2.2.2. Construction of the boundary objects for Forage Rummy workshops

The student was in charge of constructing the boundary objects using the information gathered by the adviser and his technical knowledge to verify that the objects were matching the reality of the situation. The objects that need to be adapted for each workshops are the following:

- climate sticks: representation of the local weather data enabling to define climatic-years types;
- forage sticks: forage production modeled taking into account the pedoclimatic context and the farming practices, enabling to define the quantity and quality of food available year-round;
- animal sticks: animal type and production characteristics enabling to model the year-round feeding requirements ;
- computerized support system: including all the above data and issuing results.

For a more complete description of forage rummy's boundary objects refer to appendix 1.

2.2.3. Workshops facilitation

Workshops were facilitated in pairs with the adviser for each department. Groups were composed of farmers (1 to 5), dairy milk consultants (0 to 1), and interns (0 to 3). The facilitation involved presenting forage rummy, presenting the climatic context and guiding participants through designing the initial farm system and testing adaptations. With specific emphasis on encouraging discussion around the systems and their adaptations.

2.3. Implementation analysis of Forage Rummy in southeastern France

2.3.1. Analysis of participants' perception and future uses envisioned

Data was collected asking the same questions to each participant at the beginning and at the end of each workshop, filling out an observation grid during the workshop (filled by an observant or the facilitator) and questionnaires given to participants at the end of the workshop (documents in English and French in appendix 3). Analysis of the perception of forage rummy by the advisers and the use they would make of it in the future was assessed through individual open interviews on the phone in the presence of the INRA, and a collective reunion with all three advisers without the INRA.

Focus was on the advantages of using forage rummy, the problems that hindered its development in the Rhône-Alpes region and how to overcome them. Possibilities and ways to include forage rummy in the advisers' activity was also discussed. Interview guides are available in appendix 4.

2.3.2. Analysis of the farm systems designed and the adaptation possibilities

The objective of that part was to analyze the results in lights of the initial aim to reflect on adaptations to the changing climate. The approach was to look at agroecological aspects of the systems focusing on key elements such as autonomy, biodiversity and environmental impacts. This analysis was done using several criteria given in forage rummy and others selected from literature. Economic and social aspects are presented but far from being comprehensive. A real economic and social analysis would necessitate much more information than what was gathered during the workshops.

The original goal was to be able to analyze the performances of the initial systems with those of the systems designed during the workshop. But since whole systems were not designed during the workshops, this was not possible. The indicators were used to describe and compare further the systems, and adaptations possibilities were presented as opportunities through a SWOT analysis and discussed regarding their influence on the indicators.

Methods for each indicator is presented below:

2.3.2.1. Economy

The economic indicator chosen is the cost of the feeding of the animals per 1000L of milk produced. It is calculated in the “Bilan” part of forage rummy's interface. The sum of the cost of each food including the production costs , and the cost of the food bought if need be, is divided by the quantity of milk produced.

2.3.2.2. Social

The workload was evaluated using an indicator given in the “Bilan” part of forage rummy interface. It is the number of hectares to harvest per period. It is calculated summing for each period the hectares of the forage sticks chosen that have a mechanical harvest (hay, silage, or wrap) during that period.

The economy and social indicators can be used for comparison between systems of the same kind or between different years for a same system but cannot be taken out of that context.

2.3.2.3. Autonomy

The Autonomy of a farm system is its capacity to produce goods and services using its own resources and a minimum of inputs (Vilain, 2008). Here the aim is to asses the forage and protein autonomy using the percentage of concentrates produced on the farm and the forage autonomy index given by forage rummy.

The percentage of concentrates produced on the farm was calculated simply by dividing the sum of the concentrates produced on the farm by the total concentrate consumed by the animals. This gives a quick appraisal of the protein autonomy of the farm.

The autonomy index calculated by forage rummy is calculated in two steps. The actual carrying capacity of the farm is calculated (division of the bovine unit by the total forage crop area in hectares), and a corrected carrying capacity is calculated (division of the bovine unit by the . It is the maximum ratio necessary to provide fodder for the animals with the resources available. Then a comparison between the two is done, as long as the actual carrying capacity is under the threshold of the corrected carrying capacity, the system is considered capable of being autonomous forage-wise.

2.3.2.4. Diversity

Biodiversity can be divided in genetic diversity, ecosystem diversity and species diversity. In this report, species richness was the focus with the numbering of animal species and the calculation of the percentage of permanent grasslands over the total area of each farm system.

2.3.2.5. Environmental impact

2.3.2.5.1. Nutrient balance

The tool chosen to assess the nutrient balance of the farm systems was the N, P, K balance. It makes a balance between the inputs and outputs of the system for these three elements. The parameters taken into account for the inputs are the chemical and organic fertilizers purchased, the nitrogen fixated by the legumes, the food purchased and the animals purchased. Outputs are the organic fertilizers sold, the productions sold (forage, concentrates, meat, milk,...) and the animals. The values for each were given by farmers and completed by advisers. To simplify the calculation an excel sheet made by the INRA was used (Vertes, 2005).

2.3.2.5.2. Carbon balance

The carbon balance was evaluated using the green house gases emissions calculated and discussed in view of the carbon sequestration potential of each system.

Green house gases emissions were calculated using the method Bilan Carbone® of the ADEME (ADEME, 2007). It consists in making the sum of the emissions of the crops and animals.

The factors of ghg emissions for crops are the N_20 emissions due to the fertilization, the fabrication of chemical and organic fertilizers and the mechanization (direct fuel consumption and construction and maintenance of machines). The methods gives for each main crop average values of emissions in kilograms of Carbon equivalent for the N20 emissions linked to the fertilization, the fabrication of the fertilizers and the mechanization. These values were pondered with the area for each crop of the farm system. Calculations were equally made for the crops that are not produced in the system but consumed by the animals.

The methods also gives methane emissions in kilograms of Carbon equivalent for each animal type. These were pondered by the number of animal for each farm system.

2.3.2.5.3. Milk density

The milk density is the quantity of milk produced by the herd divided by the total area of the farm system. It is an indicator of the intensification of the farm system.

3. Perception of forage rummy by the participants and future uses

The word participants includes advisers, student facilitator and farmers. The perception of advisers is presented and analyzed from the view point of the student facilitator. The perception of farmers is also included when relevant but it is not the primary focus.

3.1. A unique and interesting tool

3.1.1. Visualizing climate change impact on a farm system

The advisers appreciated the systemic representation of the farm, enabling to visualize the forage production on one hand and the feeding requirements of the animals on the other hand. This is a required picture to support farmers in reaching the equilibrium. They find the periodical representation over time to be far more precise than what they are used to. This represents an advantage to them as they are convinced precision is key in the construction of adapted solutions.

They especially liked to see the impact of climate change on the farm system designed, meaning the impact of the change of climatic year on the forage available for the animals once the system is represented using forage rummy. The advisers do not have another tool that can characterize such a change in forage availability instantaneously. They qualify it as “rather brilliant” as it can lead to analyzing the potential of the farm system depending on the climate variations. The assessment of these responses can help redefine strategies or adapt them.

3.1.2. A new approach to the forage balance

For farm advisors, forage rummy was a new way of approaching a forage balance. From the advisers' point of view, it seems more appealing for farmers. They like the way it makes a forage balance more attractive through the use of a game, and in a dynamic and innovative approach. Giving a global view of the farm system enables to make emphasis on the advantage of using a systemic approach in a more pedagogic way. And the fact that the balance is dynamic (possibility to change the climatic year) is definitely seen as an advantage over other tools. The farmers seem to understand better the implications of their choices for their farm systems, and the interactions with the climate depending on the characteristics of climatic year.

3.1.3. Opening dialogue on multiple issues

Forage rummy was effective in opening dialogue on a series of issues related to forage balance and climate change during each workshop. The diagnosis of the whole farm systems enables to point out farming practices, production objectives, and other aspects that could be improved or that are simply different between farmers. Examples are harvest dates, irrigation possibilities, making of stocks... One of the farmers wrote in his post-workshop questionnaire that he would work on his dairy cows' calving dates.

Even the last workshop which was locked by problems related to inaccurate simulated forage productions was useful to identify an important issue in the farm system studied (soil depletion). The adviser mentioned that “forage rummy reminded us of this issue” when creating the forage sticks. Indeed modeling forage production requires knowledge over a certain amount of parameters and it served to remind that the value of the nutrition indexes were very low on the farm. During the workshop, this issue was confirmed by the choice of the forage sticks by the farmer. When trying to find some corresponding to the farm's conditions, he chose the ones corresponding to the lowest nutrition index.

3.2. Problems which occurred while adapting forage rummy to Rhône-Alpes

The problems that occurred were grouped into three categories: technical problems linked to the tool's objects, problems linked to lack of knowledge on specific matters, and organizational problems. For each problem identified, we specify during which step it occurred, and propose solutions in order to prevent it from happening again. Figure 4 gives an overview of all the problems that occurred, their classification and during which steps they presented difficulties.

It is important to note that some problems may have occurred because of the specificity of the testing phase (the intern being the facilitator in addition to the adviser), and may not occur again if advisers use the tool on their own.

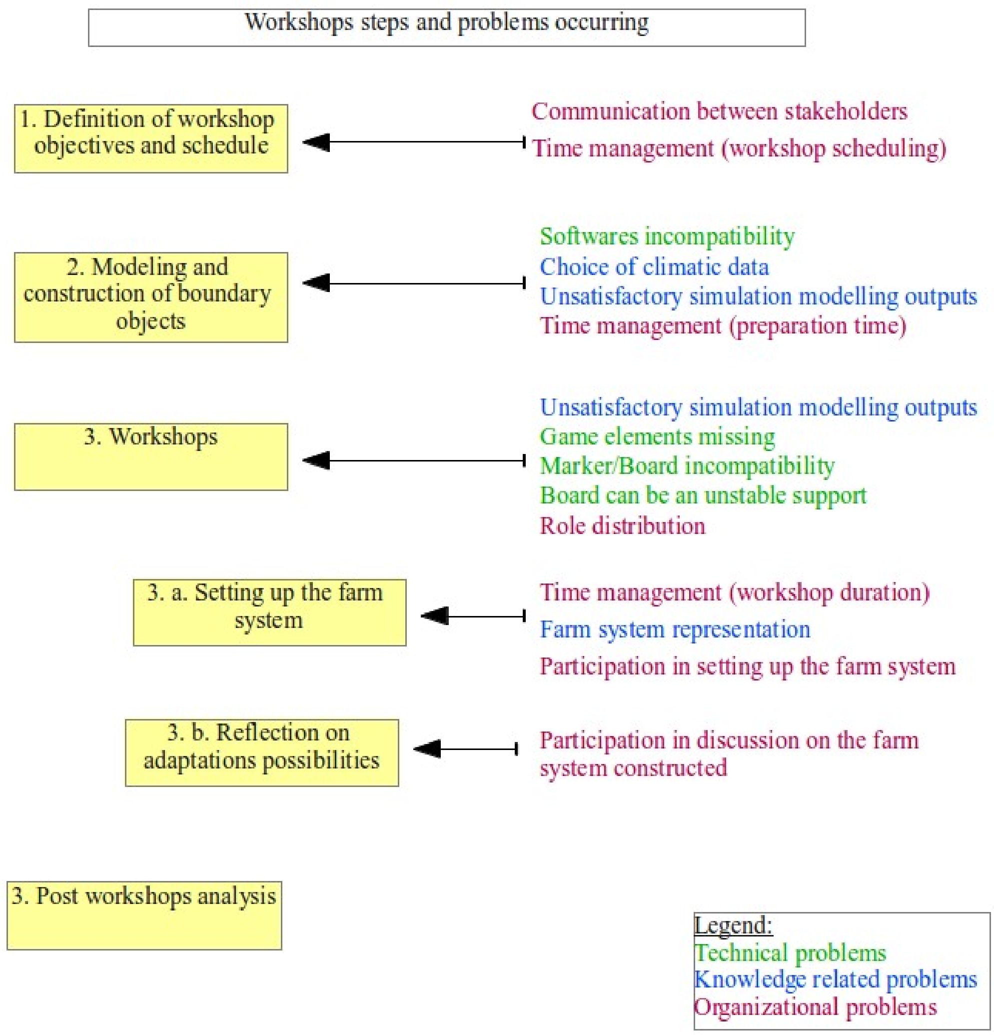

Figure 4: Workshop steps and problems occurring

3.2.1.Technical problems

3.2.1.1. Element of the game missing

A large number of elements (material and virtual) are necessary for the workshops. Out of the four workshops held, it happened once that the climate sticks were missing on the day of the workshop. This happened because it was the first workshop and the facilitator was not used to the procedure for organizing the workshops. This could happen again in a first workshop situation for advisers. To prevent any oversight a checklist was designed and should be filled before each workshop (Appendix 5 in French).

3.2.1.2. Marker/board incompatibility

Information (e.g. the number of hectares allocated to a given crop) has to be written directly on the game board. During two out of the four workshops, the marker proved difficult to erase, limiting the re-writing for bringing corrections to the initial information. Verification of the marker's compatibility with the board prior to each workshop should solve this problem. Otherwise, during the workshop, it is possible to write this information elsewhere (side sheet of paper, paperboard,...).

3.2.1.3. The board is splitted in two pieces and can be an unstable support

The fact that the board is in two pieces was disturbing for one of the adviser. He decided to tape the two pieces together just before the workshop. This problem originated from the board manufacturing and will subsist until it keeps the two pieces together.

3.2.1.4. The forage sticks and feed cards are not easy to handle

The forage sticks and feed cards were found uneasy to handle during the workshops. The feed cards are included in the tool's package provided by the designers of the game. The forage sticks are made by the advisers before the workshops and so should be printed on thick paper to get them rigid and easy to handle.

3.2.1.5. Softwares incompatibility

Forage rummy's computerized support system runs with Microsoft Office, whereas the Chambers of agriculture are all working with Libre Office now. Incompatibility between the two led to some delay during the preparation in the workshops. The student was able to work with Microsoft Office but it won't be possible for the advisers. To solve this problem, all the supports are being made compatible with Libre Office by the INRA.

3.2.2. Knowledge-related problems

3.2.2.1. Choice of climatic data

Both the choice of the weather station and the climatic years were problematic for the first two workshops held in Ardèche, and somewhat less for the other workshops. The choice of the weather station was conditioned by two factors:

- The vicinity to the location where the workshop was held;
- The availability of the weather data needed.

The vicinity turned to be a trade-off between using data from a station that was close enough to be adapted for a given local context and being able to use the resulting forage sticks over more than one situation. But the choice of the weather station must be guided by the aim of the workshop: working on a virtual case or on an existing farm. As the two approaches call for different levels of precision. It has to be higher when working on a real farm, orienting the choice of climatic data towards the closest station available.

It was difficult for all the advisers to identify the years they wanted to work on. The aim was to find representative years (for example a pretty favorable year vs. a year characterized by a long-lasting summer drought). It was proposed by the designers of forage rummy that they select the years according to their memory but it seemed too subjective to them. To overcome this difficulty, a number of tools can be used to characterize climatic years and to compare them. Three are listed below and display increasing levels of difficulty and work:

1-Rainfall diagrams (cf: climate sticks in appendix 1);

2-Graphs showing the dynamics of soil water availability and the average temperature (cf: climate sticks in appendix 1) or the temperature sums;

3-Simulated biomass production for a combination of a type of grassland vegetation, a soil type, and a set of management practices for a series of years).

Analysis of the weather data is time consuming and requires, for the last proposition at least, to have knowledge about the way to use the grassland simulation model. Nevertheless, it appears essential to simulate the variability of forage production between representative years to support the determination of the climatic years to choose.

3.2.2.2. Unsatisfactory simulation modelling outputs

Simulation modelling outputs of forage production proved unsatisfactory. This difficulty affected the adaptation of forage rummy to the Rhône-Alpes region during two steps: simulation modelling and workshop facilitation. The process of forage sticks design was slowed down with numerous feedback loops between the student facilitator creating the forage sticks and the advisers validating them.

Workshop facilitation was also more difficult in the phase when farmers are setting up the system. The facilitators felt uncomfortable because they feared that by not being close enough to the reality experienced by farmers, they would induce a mistrust in the tool. The farmers had difficulties to select the forage sticks as they did not always correspond to their farming contexts.

This sense of insecurity settled at different levels during almost all the workshops. In 3 out of the 4 workshops the farmers mentioned that the results of the simulations were a bit rough. If the simulation outputs and the resulting forage sticks are far from the reality perceived by farmers, it can totally lock the reflection on adaptation possibilities. In 1 out of the 3 workshops, the participants qualified the simulation outputs and the resulting forage sticks as “false” and “unlike the reality observed”. The design of the forage sticks also raises the issue of the level of precision expected, whether the aim is to work on an existing farm or not (this issue is addressed in part 3.3.1).

The main problems in the simulation modelling outputs are gathered in table 1.

Table 1: Simulation modelling problems encountered before and during workshops

	Ardèche (dairy goats and suckling cows)	Ardèche (dairy cows)	Isère (dairy cows)	Drôme (dairy cows)
A. Simulated yield of harvest (hay/silage/wrap) lower to observed	X	X		
B. Excess of available pasture after hay/silage/wrap harvest(s)	X	X	X	X
C. Excess of available pasture on solely grazed fields	X			X
D. Permanent grassland yields higher than sown grassland yields		X		
E. Yield difference between « normal » and « dry » years lower to observed	X	X	X	X
F. Dicots representing a substantial part of the vegetation but being neglected in the simulations				X
Forage sticks modified during the workshops				
Number of forage sticks modified during the workshops/total number of forage sticks selected (and reasons)	2/7(B) 1/7 (C) 2/7(not grazed after harvest) Total=5/7	2/7 (not grazed after harvest) Total : 2/7	None - Small anomalies but annual yield compensated between the sticks.	Did not overcome the modeling problems.

There were often more than one cause to each problem. For this reason, it was not possible to identify and solve all the simulation modelling problems within the time dedicated to this internship.

Three main causes may have led to unsatisfactory simulation modelling outputs:

- Unknown parameters;
- Gap between farmers' practices and advisers' perception;
- Model's hypothesis.

3.2.2.2.1. Unknown parameters

Some input parameters to the simulation model were not known by the advisers or at best guessed. One adviser recognized that “there are some parameters that we simply do not master”. Parameter values not being always known , the design of forage sticks was driven by yield objectives. When simulation modeling outputs did not match observed yields, parameter values were modified to fit the yields expected by advisers.

This approach tended to generate more problems. An example of a forage stick constructed for Ardèche workshop 1 is described in table 2 . The nitrogen index and the soil water storage capacity were set higher than observed to simulate the expected yield for spring harvests. But these increases generated excess of pasture availability in summer and autumn.

Table 2: Comparison of simulated forage production with references from the Chamber of Agriculture

	Parameters				Outputs		
	Flora	Fertilization (NI)	Water Holding Capacity (RU in mm)	Harvest date	Harvest yield (tDM/ha)	Pasture yield to October 30th	Total Yield (tDM/ha)
References CA Ardèche 1980	80% Grasses, no legumes	Little or not fertilized	RU= 50-80 mm	May 20th	3.8 tDM/ha	1.5 tDM/ha	5.3 tDM/ha
Simulation	Grasses 50% type A, 50% type B	NI=0.9 (heavily fertilized)	RU=90 mm	1000°CJ May 20th	3.7 tDM/ha	3.4 tDM/ha	7.1 tDM/ha

The lack of references is linked to this problem. Comparison between simulation modeling outputs and references was not easy as some references were missing information on the input parameters of the model. To remedy this problem, parameterization of the model for each area should be done referring to one set of references containing the maximum information possible. The parameterization should be done methodically for each combination of climate, soil, and vegetation before creating the forage sticks. This problem was partly due to the specificities of the testing phase. As opposed to the intern, it will be easier for advisers that are already aware of yield values and tendencies to assess more rapidly the likelihood of the simulated results.

3.2.2.2.2. Gap between farmers' practices and advisers' perception

There was sometimes a gap between farmers' practices and advisers' perception. The latter was not always entirely correct or accurate, generating misinterpretation of farmers' practices. For example, perceived dates of hay and wrap harvests were much earlier than actual harvests for one of the workshops. And this discrepancy was discovered during the workshop. Advisers need to be very close to the field and open to self-questioning to be competent in this.

This problem may have been amplified in this testing phase as the intern was the one using the model while the advisers were the ones communicating with the farmers. Direct communication between the person using the model and the farmers could help alleviate this problem. As the adviser would directly notice the output problem and more easily link it to the input by finding out about the discrepancy.

3.2.2.2.3. Modeling hypothesis

It may be that the model is not exactly adapted to the conditions of the Rhône-Alpes region. In particular, advisers did not observe the response of forage production to drought that they expected. They all three agreed that they would expect higher yield losses. For instance, for the year 2011, they experienced yield losses of 50 to 80% while simulated losses were about 50%. Moreover, the model simulates higher forage production in summer than in spring for most years. Which is contradictory to the trend they observe.

This may be due to the dynamics of water and nitrogen that are almost independent in the model whereas water stresses inhibit mineralization which in turn limits the nitrogen available in the soil for the plants. This characteristic may prove to be problematic when using weather data with extreme water stresses such as used in the Rhône-Alpes region.

The model also does not take into account thermic stress, while it was proven that grasses do not grow above the average temperature of 25°C, but such average temperature is not very frequent in the area so it shouldn't be the source of the problems (Martin, 2013 personal communication).

3.2.2.3. Representation of farm systems using the tool

The construction of the initial farm system during the workshop was sometimes difficult to achieve by the farmers and advisers. Participants (farmers and advisers) were not always at ease with the elements of the rummy used to describe the farm systems (for description of elements refer to appendix 1). Advisers will need to be fully familiar with them before the workshop. The fact that they were not was linked to the testing phase. In the workshops held, farmers knew how to describe their farm and farming practices using different terms and indicators than the ones in forage rummy. For instance, they found confusing that the forage sticks were not allocated to a herd batch, that the distribution between foodstuff was in percentage instead of kilograms, that the year was divided in 13 periods instead of 12 months...

Although explications on forage rummy functioning were given at the beginning of each workshops and were perceived as rather clear (although too long) by all the farmers questioned. To address this issue, the presentation leaflet should be sent to farmers before the workshop, the facilitator should give clear explanations at the beginning of the workshop and point out the main possible confusions he/she is aware of.

3.2.3. Organizational problems

3.2.3.1. Communication between stakeholders

Communication is central to this project as it is done in coordination between three Chambers of Agriculture (represented by three advisers from Ardèche, Drôme and Isère), the INRA-Toulouse (represented by a researcher and a project coordinator), farmers from the three departments and a student in agroecology. The communication fluxes were organized as shown on figure 5.

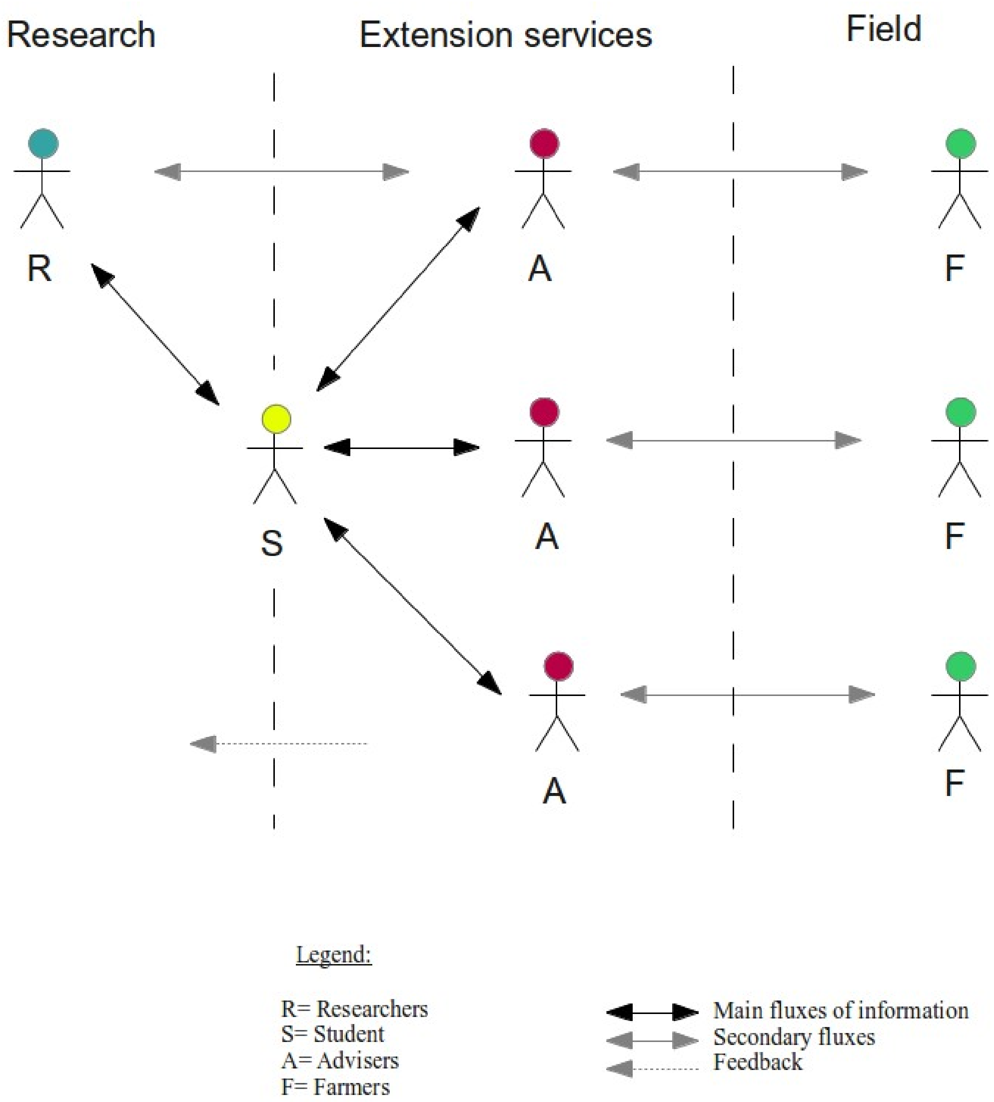

Figure 5: Communication between stakeholders during workshop preparation process

Since nor the INRA (designer of the tool), nor the student facilitator had any contact with the farmers, it fell to the advisers to invite the participants and to inform them about the content of the workshops. However, the advisers were also in the process of discovering the game and thus it was difficult for them to communicate on forage rummy. Two of them mentioned that "it was difficult to advertise". The advisers did not know how to present it to farmers when inviting them.

The farmers mentioned clearly a lack of information prior to the workshops. One of them said that he had no expectations because he had no information before the workshop. Another said he had come because we had invited him. This represents a lack of preparation which may have hindered the good development of the workshops.

These communication problems are linked to the testing phase with the extra intermediary, the student facilitator, and should not occur again in the same way. However it is important that the advisers-facilitators define objectives for each workshop together with farmers and inform them on the peculiar nature of the tool they are going to use, so that they can adapt their expectations. It is also useful to figure out when or not to use Forage Rummy. As the use of participatory methods needs to be optimized, their use has to be well reflected upon depending on the type of project, the stakeholders involved, the objectives and the context. It is not always beneficial to use one (Barreteau et al., 2010; Neef and Neubert, 2010).

3.2.3.2. Time management

Time management is crucial at three stages:

- Scheduling the workshops;
- Workshop preparation;
- Workshop duration.

The scheduling of the workshops was at the root of the organizational problems. At the beginning of the internship 7 workshops were planned (3 in Ardèche, 3 in Isère and 1 in Drôme). Only 4 took place before the end of the internship (2 in Ardèche, 1 in Isère, and 1 in Drôme). And only two of them occurred on the day they were planned in the first place (both in Ardèche).

Timetables of the advisers, the farmers, and the student were to take into account. The advisers set workshop dates suiting both them and the farmers, and the student had to accommodate. The problem being that the advisers and the farmers are two busy groups and the advisers postponed several times the workshops because the simulation modeling outputs did not satisfy them or because the farmers were not available because of the weather.

The time needed to prepare workshops is important. It is both necessary to take it to prepare accurate forage sticks (amongst other objects), and effective facilitation. It is assessed that normally 3 full days are necessary to prepare a workshop (identify participants and prepare supports adapted to local context) (Martin et al., 2012). This time is underestimated if simulation modelling problems occur.

Time management during the workshop itself was a major issue in the testing of forage rummy. All three advisers stated that there was not enough time in 2 to 3 hours of workshop to go through the two steps: designing the farm system and reflecting on adaptations possibilities. Thus more time was necessary to address the second step after the workshops and a use of the tool in two successive workshops with the same group of farmers was envisioned (use scenario dealt with in paragraph

3.3). Another solution could be to start the workshop with the farm system already designed to save time to work on the possible adaptations.

3.2.3.3. Role distribution during the workshops

During the preparation of the workshops, focus was on the simulation modeling outputs which left little space for the facilitation. For the first workshop little attention had been devoted to distributing the roles between the adviser-facilitator and the student-facilitator. Tasks were vaguely divided generating confusion during the workshop. In the next workshops, the roles of each were clarified and the workshops were better organized.

This issue occurred because of the testing phase but since advisers plan on facilitating workshops in pairs, they will have to be vigilant about role distribution. Indeed, they feel that they will not manage to facilitate a workshop alone and intend on being at least two for each workshop. They could organize as such: one person focusing on entering the data in the computerized support system and checking the accuracy of the results as well as communicating to the participants; and the other one, facilitating the communication in the group and the collective design of the systems.

3.2.3.4. Participation

There are three aspects of participation that will be dealt with in this paragraph: participation to the workshops (taking part in a workshop), and participation during the workshops (use of the forage rummy elements, and participation to the discussion).

3.2.3.4.1. Participation to a workshop

Forage rummy aims at "self-mobilization", defined as the most achieved participation type in which farmers take initiatives to change systems by developing contact with external institutions (Pretty, 1995). In principles, forage rummy is supposed to work this way: a group of farmers sharing a common need for change (or isolated farmers) contact their adviser. He/she groups them and help them define an objective which will be dealt with during a workshop.

In our case, farmers were contacted by advisers to test the adaptation of forage rummy. The definition of the issue treated in the workshop was thought of in advance according to farmers preoccupation in the area (adaptation to climate change and forage autonomy when faced with recurrent summer or spring drought). This was a starting point in the application of forage rummy in the Rhône-Alpes region, enabling advisers and farmers to familiarize with the tool. However, farmers' requests to work on specific issues are rare at the Chamber of Agriculture and so workshops based on self-mobilization will probably be also rare.

3.2.3.4.2. Participation during a workshop

Farmers can participate during the workshop in two ways: by physically using the elements of the game (placing the forage sticks, constructing the feeding for each period, writing on the board...) and by participating in the discussion triggered by the construction of the system and the resulting reflection to adaptation possibilities. Use of the elements of the game was a problem in 3 out of 4 workshops, meaning that some farmers did not touch the forage sticks, nor the feed cards nor the board. Reasons were that they either found the tool itself too complicated (2 out of 3) or that they found the elements unpractical (1 out of 3).

Participation in the discussion did not seem to be such an important problem as farmers are usually eager to share what they have on their mind. Although some may have been shadowed by more intent ones.

Participation depends on the attitude of the participants as they must have a specific attitude to begin with. They need to be driven by a will to learn, a self-questioning attitude defined as "reframing" (Aarts et Van Woerkum, 2012 in Morel, 2012), and to be open-minded, respect diversity and open to self critics to accept to consider points of view that are not theirs (Palh-Wostl et Hare, 2004, in Morel, 2012).

Besides, it is possible that the complexity of the tool intimidated some of the farmers who did not dare get into the game. It is the facilitator's role to make the participants feel at ease by explaining methodically and the most simply as possible the use of each element.

Participation also depends on the attitude of the facilitator. Prerequisite for forage rummy is a facilitating attitude from the adviser. It is acknowledged that the facilitator does not have the solution to all the problems but acts as an incubator of solution finding and valuation of knowledge held by each participant through the use of the forage rummy elements (Martin et al., 2012).

This attitude is different from the attitude that advisers adopt in their usual activity. Technicians of the Chamber of Agriculture are "advisers", which historically refers to individual technical counseling. This counseling is traditionally the materialization of a top-down process consisting in a person, the adviser, detaining knowledge and transferring it to the farmer. Although, in reality, exchange between the two parties is ever-present to formulate the counsel. What the forage rummy aims to develop is collective knowledge building. The facilitation is done for and with groups of farmers, thus favoring sharing of experience and knowledge, postulating that the group has a great part of the solutions each participant is looking for (Lusson, 2010).

The adoption of such attitude is difficult for advisers that are used to working differently as it calls for a change of mind-set. But it is not something that they are absolutely unfamiliar with as forage rummy is not the only tool demanding such flexibility.

It is also a challenge for farmers that ask for specific technical counseling from the advisers during the workshops. This kind of situation can be unsettling both for advisers and farmers. The adviser needs to adopt a position in between the facilitator and the classical adviser, facilitating the workshop as well as being able to answer technical questions when they occur. This can be achieved by facilitating the workshop in pairs: one person being the actual facilitator and the other serving as technical support, this scheme was tested in 3 workshops and seemed to reassure participants as well as facilitators and strengthen the group.

3.3. Future uses envisioned by advisers

3.3.1. Preferences towards existing farms as support

According to the designers of the tool, there are different possibilities to start the workshops and to choose the farm system that will serve as support.

There are two possibilities to start a workshop and facilitator and participants need to agree on one beforehand. Representation of the farm systems using forage rummy boundary objects can be done before the workshop, to focus the workshop on its adaptation. This is recommended when wanting to work on adaptation of existing farm systems or when time to devote to the workshop is limited. Otherwise, the farm system can be constructed during the workshop with the participants. This enables to understand the system and to asses the impact of specific farming practices. This can also help to understand the tool and its adaptation.

The farm system support needs to be chosen with the farmers. Farmers usually prefer working on existing farm systems rather than case studies. When working on existing farms, there are two possibilities: Working on a specific farm system, trying to be as close as possible to its reality, using farm diagnosis data (forage and animals) or working on an existing farm system but making it more general. Using its constraints and its strengths without the limits set by following exactly the farmer's practices. If the farmer whose farm serves as support is present during the workshop, it is essential that other farmers be present to discuss his practices and propose innovative solutions (Morel, 2012).

For all the workshops in Rhône-Alpes, advisers decided to work on an existing farm, whose owner would be one of the participants to the workshop and to reproduce the exact practices of the farmer.

Advisers preferred working on existing farms because typical farms are already optimized, and it is difficult to define an average farm that would be representative for a group of farmers. Working on an existing farm also allows verification of the performance of the system constructed by referring to the real farm. And doing it with the owner enables him to work on adapted solutions for his system. Advisers are convinced that finding solutions with farmers calls for precision, and that if the workshop stays too general, it won't produce anything.

However, participation of other farmers is required and these other farmers may feel frustrated or relieved that special attention is not given to their system. Specific indications on this kind of functioning must be given at the beginning of the workshop.

3.3.2. A combination of collective and individual use

Individual use was envisioned by two of the three advisers (two out of four workshops consisted of the farmer owning the farm system serving as support and other technicians or interns who worked with that farmer). This happened because the other farmers invited did not join. However, at least one of the advisers concerned doubts about the opportunity to organize collective workshops. According to him, this would strengthen the difficulties already encountered.

However, following the principles for using the game defined by its designers, a collective use (with more than one farmer) was recognized to favor discussion and comparison of farming practices between farmers by previous tests. This is found to be more conducive to change (in two of the four workshops), as it allows more innovative solutions to be proposed (Lusson, 2010; Morel, 2012). Thus advisers plan to ally individual use for advising about technical solutions, and collective use to engage farmers in the evolution of their practices which corresponds to a new orientation of the Chamber of agriculture (Esposito Fava and Naïtlho, 2013).

3.3.3. Use scenarios

The advisers concerned by the project envision differently the use of forage rummy and its integration in their activity. They are currently at different stages of reflection on the implementation of forage rummy in the near future. The three following scenarios described in table 3 are examples of possible scenarios ranked in order of achievement of definition.

Table 3: Modalities of envisioned forage rummy use scenarios

Issue	Adaptation to Climate Change		
Scenarios	Isère	Ardèche	Drôme
Question treated	Forage autonomy	Spring or summer drought	
Focus	Emphasis on the need for systemic view : matching feeding requirements to forage availability, setting cutting practices following the climate evolution...		Sensitization on impact of specific practices : grazing pressure (harvest height), fertilization.
Situation	Training on climate change (fall 2013).		
Steps	1) Individual description of the farm system of each intern ; 2) Synthesis in group to work on adaptations.	1) Workshop to construct the system and define adaptation hypothesis ; 2) Adviser work on consequences of hypothesis ; 3) Synthesis with the group.	
Individual/ Collective	Step 1 : Individual. Step 2 : Collective.	Collective.	Collective.
Farm system support	Existing farm. Owner is participant of the workshop.		
Use of forage rummy boundary objects	Step 1 : Use of only the computerized support system. Step 2 : Use of all boundary objects (board, sticks and computerized support system).	Use of all boundaries objects (board, sticks and computerized support system).	Use of all boundaries objects (board, sticks and computerized support system).
Facilitators	1 adviser and 1 dairy milk technician.		

3.4. General recommendations to use forage rummy in the Rhône-Alpes region

These recommendations are given in response to the problems which occurred. They are focusing on the simulation modelling, the format of the workshops and the constitution of the groups of participants according to the advisers' main preoccupations. The aim is to make the use of forage rummy possible and easier for them and the farmers they are working with.

3.4.1. About the simulations

Below are described three attitudes possible in order to overcome the simulation modelling inaccuracies. The first one acknowledges the problems encountered but aims for an immediate use of forage rummy, the two following options seek for a more durable solution.

3.4.1.1. Using the forage sticks already constructed

The forage sticks constructed could be used, even if some of the simulation modelling was inaccurate. Indeed, it is not unusual to modify the sticks during the workshops with farmers. This method holds the advantage of being ready to use. However, it can lead to unease both for farmers and advisers if the degree of precision expected is very high (if the workshop is done on an existing farm keeping its exact characteristics).

Forage sticks can be modified before the workshops, if facilitators already know what to expect. The limit of this method is that sticks based on expertise are created instead of simulation modelling based on climatic data, and so the impact of the climate on the system is not modelled anymore. This changes the whole principle of the tool.

3.4.1.2. Working on one simulation, for which all the parameters are known

The idea would be to work on one case for which all the values of the parameter can be known, in order to be able to use them in a simulation, and to compare the case with the simulation. The adviser of the chamber of agriculture would need to collect all the data needed, including making the measures of the missing data and then enter the data in the model. Comparison between observed yields and simulated yields would then be possible. And the parameters to enter would be settled. Ideally this should be done with the climatic data of several years if observed data is also available.

This method, contrary to the previous one, would help conclude on the accuracy of the simulation outputs and determine whether forage rummy can be used with the level of precision envisioned by the advisers. If that is not the case, it could help identify the improvements in the model to meet these expectations. Limits of this method is the collection of all the data and the control of all the parameters included in the model. To make this data collection process easier, advisers could set up a forage rummy workshop on an existing farm, with a group of farmers.

3.4.1.3. Comparing experimentations and simulations

Setting up a series of experiments with variables such as the type of vegetation, the fertilization, the height for harvest and the date of harvest would allow to control all those parameters and enter them exactly in the model. Measurements of experiment results could be compared with simulation outputs to determine their accuracy. These experiments could also be used to study the impact of the variables on the yield.

That option which aims at obtaining simulation outputs as close as possible to the potential of the area, would carry the same objectives as the previous one (assessing the simulations accuracy, concluding on their use, and identifying necessary improvements). Drawbacks of this method would be that experiments are also a kind of representation of the farmers' reality and not exactly what they experience themselves. This option would demand a great amount of work that would fall on the advisers' shoulders, unless they take an intern.

3.4.2. Intervention format depending on the use

The format of forage rummy could depend on the context of use. Following are two types of use (adaptation to change and design of a new system), and three possibilities to carry them out. These recommendations are a further development of the scenarios envisioned by advisers.

3.4.2.1. Working on adaptations of existing systems

This method is to work on adaptations to climate change like it was proposed during this internship or other kinds of adaptations like diversification, extension or new external production constraints, ect... Both working on setting up the system with forage rummy and working on adaptations will demand some time. There are two ways we can plan this kind of intervention: in one workshop or in two workshops.

3.4.2.1.1. In one workshop

The farm system is set up with forage rummy before the workshop, which enables to work on adaptations only during the workshop. The workshop in itself will last only 2 to 3 hours, but the preparation workload is heavier. Characteristics of the farm system must be discussed with farmers (or a reference farmer) before the workshop and entered in the computerized support system (in addition to the normal preparation work: construction of locally adapted objects). And adaptations hypothesis must be defined before the workshop to create the objects corresponding. In addition to saving time during the workshop, this method allows for a verification of the farm system representation with forage rummy prior to the workshop.

3.4.2.1.2. In two workshops

The first workshop is used to represent the system using forage rummy. It allows to understand its functioning and formulate adaptation hypothesis that will be dealt with during the second workshop. In between the two workshops, the facilitator constructs the boundary objects necessary to test the adaptations (forage sticks mainly), if some are missing. This method enables to deal with both representation and adaptation of the system in two steps and to readjust to the farmers' expectations in between workshops if needed. It demands twice as much time as the previous option, for the farmers to participate to two workshops of 2 to 3 hours each and extra preparation time linked for the facilitator.

Both formats use all of forage rummy's boundary objects and favor a collective approach to stimulate discussion on the adaptations tested during the workshop. It keeps to the principles of the tool invented by the designers.

3.4.2.2. Working on setting up new systems

To work on the setting up of a new system, one workshop of 2 to 3 hours should be sufficient. The workshop needs to focus on constructing and representing that system using forage rummy. Emphasis will be done on understanding the impact of each choice on the production but also on the other components of the system.

But the preparation of the workshop demands attention. Care should be taken that the forage sticks available cover the possibilities the farmer(s) wants to test, and that the composition of the group is relevant. The new farmer(s) should be accompanied by some more experienced farmers that will not necessarily benefit from the workshop, but who will give advice and references. This kind of use has been tested before in the Midi Pyrénées Region and was successful in guiding new farmers in their choices and reflection (Morel, 2012, Mathilde Piquet, 2013 personal communication).

3.4.3. Choosing the right participants to optimize the benefits for all

Forage rummy will give different outputs depending on the group of farmers participating. As explained above (in part 3.2.3.4.2), at least one of the farmers must adopt an attitude receptive to criticism that he/she will turn into learning. The main traits that the facilitator should look for in farmers is the acceptance to have his/her practices challenged by other points of view, and to have them drive changes in his own farm system.

Ideally, forage rummy should insert in a “reframing” dynamic (Aarts et Van Woerkum, 2012 in Morel, 2012). The farmers should already question an existing situation and have ideas of what changes to test. This situation is conducive to a positive attitude towards forage rummy (a new tool) and an active participation during the workshops.

Forage rummy will build on an already ongoing group dynamic. Workshop will go more smoothly in this case, as farmers will be used to interacting with each other. Otherwise, group dynamic can be worked on prior to a forage rummy workshop by holding reunion around other tools such as the Info'Prairie[1] for example. Identifying farmers' attitude as well as the issues they wish to work on during these, is an important step prior to forage rummy.

1 Info'Prairie is sent every week (during the growing season) by advisers to inform farmers on local temperature sums and grassland growth to help manage cutting and grazing. Meetings in farms, bringing together farmers, are organized to demonstrate the use of this method.

4. Livestock systems designed and climate change

4.1. The local climate

To study the effects of climate change and the possible adaptations of livestock systems, three typical years were chosen: an “average year”, a “summer drought year” and a “spring drought year”. For the purpose of this internship, drought years were defined according to the perception of the advisers when lack of water was limiting the grasslands' production. To strengthen these assumptions, we also looked at the amount and distribution of annual rainfall and the evolution of the water available in the soil as well as the average temperature, over several years.

Ardèche tends to be the dryer department of the three. Although there are differences, a general description can be made. The average years in the region are defined by a relatively wet spring and dry summer with a water storage capacity that tends to be half empty at the end of the summer. The years with driest summers are characterized by less annual rainfall (from 200 to 400 mm less) with a peak of drought in June and July resulting in the emptying of the water storage capacity. The dry spring years are characterized by more annual rainfall, as the dry spring (from mid March to mid May) is later compensated by a wet summer. The water storage capacity is entirely empty by the end of March in Ardèche, while it becomes half empty by the end of May for the two other departments.

The years chosen for each workshop are described with details in appendix 7. A summary is given in table 4.

Table 4: Comparison of years chosen to represent average, summer drought and spring drought for each department

		Ardèche	Isère	Drôme
Average year	Year chosen	2009	2010	2007
	Total Rainfall (mm)	843	1094	1412
	Rainfall distribution	Regular over spring and summer (~50mm/period).	Wet spring (~100-150mm/period mid March-mid June), dryer summer (~50mm/period mid June-mid August).	Wet spring and begining of summer (~150-200mm/periodexcept P4 : 29mm), dryer end of summer (P8, 9~80 mm).

	State of water storage capacity	Temporarily empty end of May and beginning of August.	50 % empty from mid July to mid September.	60 % empty mid July
Summer drought	Year chosen	2005	2009	2009
	Total Rainfall (mm)	596	804	1030
	Rainfall distribution	Dry from mid May to mid July (P6:33mm, P7:8.8mm).	Dry from January to October (~50mm/period, with P7:9.4mm)	Dry spring and summer (P4,5 ~50mm, P7:27mm, except P6 : 130mm).
	State of water storage capacity	Empty from the end of May to the end of July.	Empty end of July and August.	Empty from mid July to end of September in 4 successive episodes.
Spring drought	Year chosen	2011	2011	2011
	Total Rainfall (mm)	761	1132	1175
	Rainfall distribution	Dry from mid March to mid May (P4:21mm, P5:24.4mm).	Dry from mid March to mid May (P4:35mm, P5:42mm).	Dry spring (P4,5~35mm) and wet summer (~100-150mm).
	State of water storage capacity	Temporarily empty at the end of April and at the end of July and end of August.	50%empty at the end of May and mid June.	50 % empty mid May.

The forage rummy periods of interest are spring periods: 3 (26/02-25/03), 4 (26/03-22/04) and 5 (23/04-20/05) and summer periods 6 (21/05-17/06), 7 (18/06-15/07) and 8 (16/07-12/08).

4.2. Farm systems designed and impact of climate change

Four workshops were held in the Rhône-Alpes region: 2 in Ardèche's high plateaux, 1 in Isère in the Vercors mountains and 1 in Drôme in the Vercors mountains as well (see map in appendix 6). The systems covered were one dairy goats with suckling cows as secondary herd and three dairy cows, including one organic. The two Ardèche systems will be called Ardèche system 1, for the dairy goat farm, and system 2 for the dairy cows farm.

4.2.1. The farm systems' mains characteristics

The four farm systems are three dairy cows, and one dairy goats (with suckling cows as secondary herd). Their description is summarized in table 5 below.

The Ardèche 1 and Isère systems are relatively extensive regarding the area distribution, with an important part of permanent grassland (more than 80%), and the production per animal (600L/goat/year and 6000L/cow/year). These systems are rather representative of their area as references for Isère Vercors are 70% of permament grasslands and 5200L/cow/year (Cas type BLRA 1, (Réseaux d'élevages Rhone-Alpes, n.d.) (see references for Ardèche below).

The Drôme system is organic and has a low production per animal (5000L/cow/year) but the area distribution is more intensive with more temporary grasslands and cereal crops (48% of permanent grasslands and 12% of cereals). In this area the production per animal is generally slightly higher (6200L/cow/year) but the area distribution is similar (permanent grassland: 54% and cereal crops: 15%, (Cas type BLRA 1, Réseaux d'élevages Rhone-Alpes, n.d.).

The Ardèche 2 system is rather intensive with a high production per animal (9000L/cow/year) which are calving early (first calving at 24 months) and with a high turnover rate (40%). This system is not very representative of the department as references for Ardèche's high plateaux are 5500L/cow/year with a turnover rate of 20% and 67% of permament grasslands (Cas type BL Haut Vivarais, Réseaux d'élevages Rhone-Alpes, n.d.).

Table 5: The farm systems' main characteristics

		Ardèche 1	Ardèche 2	Isère	Drôme
Total Area (ha)		72	62	88	62.5
Permanent grasslands (ha)		61	27	78	30
Temporary grasslands (ha)		7.2	22	10	25
Other Crops (ha)			13		7.5
Animal Herd 1	Number and Type	125 Dairy goats	39 Dairy cows	50 Dairy cows	38 Dairy, cows (organic)
	Production	600 L	9000 L	6000 L	5000L
	Birthing	week 5*	spaced calving	autumn calving	autumn calving
Animal Herd 2	Number and Type	20 Suckling cows with calves under the mother	15 Heifers /generation	15 Heifers /generation	8 Heifers /generation
	Birthing	spaced calving	calving at 24 months	calving at 36 months in autumn	calving at 36 months in autumn

Animal Herd 3	Number and Type	2 Heifers			
	Birthing	calving at 24 months in autumn			
Others animals		-35 young goats -5 male goats			

*Week 5= 1st week of February

Forage sticks chosen for each workshop and their description can be found in Appendix 8.

4.2.2. Forage balance and impact of climate change

No system was fully designed during the Drôme workshop, that is why it will not be dealt with in this chapter (reasons can be found in part 3).

4.2.2.1. Forage balance for the average years

During an average year, there is enough pasture for all the animals in all the systems (refer to appendix 9 for pasture available for all systems for the different years). The hay and silage/wrapping are produced in enough quantity to replenish the stocks and to have extra stocks for an unfavorable year.

The Ardèche 1 system produces hay only while Ardèche 2 and Isère systems produce grass wrap or silage. And Ardèche 2 system produces legume wrap also.

Cereals are also produced in both Ardèche systems. It is important to note that the production of the crops other than grasslands is not simulated. The values come from discussion between the farmers and the advisers. Not enough cereals are produced to replenish the stocks. The systems are not autonomous in concentrates. Nor is the Isère system that buys all his cereals.

4.2.2.2. Impact of the dry summer years

In Ardèche, the dry summers affected the pasture production resulting in lack of pasture for two of the three herds of system 1 at two different periods. During period 4 (March 26th-April 22nd) 50% of the suckling cows' pasture daily intake is lacking and 100% for the heifers. During period 7 (June 18th-July 15th), respectively 84% and 100% lacking. It also affected system 2 during period 7 (June 18th-July 15th): 100% of the heifers' daily pasture intake is missing.

In Isère, the pasture available was also reduced during period 7 (June 18th-July 15th) 25% of the dairy cows' pasture was missing and 100% of the heifers'.

However, in Ardèche this year did not affect the hay yields negatively compared to the average year chosen. This is because there was a rainfall peak in the spring that did not occur during the average year (140 mm in 2005 compared 55mm in 2009 for period 4- March 26th to April 22nd). And the hay harvest was done after this rainfall, when the plants had had time to benefit from it. Whereas the grass and leguminous silage did not benefit from that rainfall and suffered loss of 34% for the grass and 24% for the leguminous (system 2).

In Isère, the dry summer affected negatively both the hay and the silage yields (-15% for the hay and -9% for the silage).

The cereal yield losses for a dry summer year were estimated at 40% for both Ardèche systems, and 30% for the Isère system.

4.2.2.3. Impact of the dry spring years

The dry spring year has less impact on the pasture available for the animals than the dry summer except for Ardèche 2 system. For the Ardèche 1 system lack of pasture occurs in November. There is a lack of total pasture available in May (period 5) but it is compensated by excess pasture growth during the two preceding periods and so the animals don't lack any pasture in the spring.

For the two other systems, pasture is missing during the spring (May and june). In the Ardèche 2 system, 80% of the dairy cows pasture is unavailable during period 5 and 57% during period 6, as well as 100% of the heifers' pasture both in period 5 and 6. In the Isère system, 64% of the heifers' pasture comes to be missing during period 6 (May 21-June 17).

The dry spring years have a greater impact on the systems. The yield losses on hay production are of about 50% for Ardèche 1 and 30% for Ardèche 2 and Isère. Grass wrapping production of the Isère system also suffered a 20% loss. The other productions of Ardèche 2 system (grass and leguminous wrapping) did not suffer any losses.

The cereal yield losses were estimated to be the same than for a dry summer year, 40% for both Ardèche systems, and 30% for the Isère system.

Table 6 describes the production of each system for each type of forage and depending on the years.

Table 6: Forage balance for each system depending on the year

		Ardèche 1			Ardèche 2			Isère		
Harvest Type	Year / Criteria	Av	Dry Su	Dry Sp	Av	Dry Su	Dry Sp	Av	Dry Su	Dry Sp
Pasture (kgDM/al/day)	Lack of pasture	none	-46.6	-8.1	none	-16	-44.5	none	-24.9	-12
Hay (tDM)	Production	110	+ 8 %	-47 %	66	+27%	-33 %	144	-15 %	-26 %
	FS-BS	43	52	-10	20	39	-1	8	-35	-35
Grass Silage/ Wrap (tDM)	Production				101	-34 %	+1 %	100	-9 %	-20 %
	FS-BS				15	-20	22	11	1	-9
Legume Forage (tDM)	Production				34	-24 %	+3 %			
	FS-BS				16	7	16			
Cereals (qx)	Production	158	-43 %	-43 %	234	-33 %	-33 %			
	FS	-164	-232	-232	-680	-758	-758			

FS= Final Stock, BS= Begining Stock, Av= Average year, Dry Su= Dry Summer, Dry Sp= Dry Spring. The production of forage for the dry years are in percentage of the quantities for the average year.

4.3.Evaluation of the farm systems

4.3.1. State of the farm systems represented with forage rummy

One of the objectives of forage rummy adaptation to the Rhône-Alpes region was to reflect on adaptations to climate change. To give meaning to the evaluation of the farm systems represented with forage rummy, we proposed to look at agroecological indicators to measure three characteristics of the farm systems: autonomy, diversity and environmental impact. And to lead to adaptation possibilities that would strengthen the farm systems in the face of climate change.

Table 7 gives the values of the indicators for the three systems in an average year. Economic and social aspects were also included for information. Details on the calculation of all the indicators are available in appendices 10 and 11.

Table 7: Values of indicators for the three systems for an average year

	Ardèche 1	Ardèche 2	Isère
Economy			
Cost of food (euros/1000 L)	256	145	148
Social			
Workload (ha to harvest/period)	39.8/4.5	22 / 5/27/22.7/7.5/5	60/15/10
Autonomy			
Percentage of concentrate produced on farm	45	18	0
forage autonomy index	autonomous	autonomous	autonomous
Diversity			
Number of animal species	2	1	1
Percentage of permanent grasslands	85	43	89
Environmental impact			
N, P, K balance (kg/ha SAU)	7 / 0/ 2	67 / 3 / 10	-17 / -2 / 1
GHG emissions (t Ceq/ year)	60.4	77.3	91
Milk density (L/ha)	1 042	5 661	2 659

4.3.1.1. Economy

The cost of the food is of 256 euros/1000L for Ardèche 1, 145 euros/100L for Ardèche 2 and 148 euros/1000L for Isère.

It is important to note that the Ardèche 1 system cannot be compared with the two others using this criteria, since it is a dairy goat system. The goat milk is more expensive to produce but is sold at a higher price. Especially since this farm system produces milk for an AOC cheese making.

The Ardèche 2 system would be expected to have a more expensive food compared to the Isère system, since the system uses a lot of concentrates produced outside the system (VL 3L: 51t, Potatoes: 18t, nitrogen corrector: 11t, dried distiller grains: 27t, cereals: 11t, soja: 14t), while the Isère system only buys cereals (532 qx) and dehydrated alfalfa (233 qx). Indeed the concentrate cost for the Ardèche 2 system is 1.7 times more than the Isère system (32 vs 19 thousand euros). But this important concentrate cost is compensated by a lower forage cost and a higher milk production than the Isère system.

Both systems are viable according to the farmers but this indicator does not attest of it on its own. It needs to be compared to the price of the milk for example. Another limit is that in this method the production costs include the operational expenses only, they are the variable expenses directly linked to the production level. The structural expenses are not included.

4.3.1.2. Social

The workload was evaluated using the number of hectares to harvest per period. The Isère system has up to 60 ha to harvest in one period and the Ardèche system 1 has up to 40 ha to harvest in one period while the Ardèche system 2 reaches only 27 ha to harvest in one period but repeated over 3 periods.

The quantity of work per hectare to harvest can differ with the nature of the harvest, silage or wrapping will take more time than hay making. The working time is probably lesser for the Ardèche 1 system since there is no silage/wrap.

4.3.1.3. Autonomy

The three systems are considered capable of forage autonomy according to the autonomy index. But as explained in part 3.2.2., during dry years, yield losses result in lack of pasture and cut forage available. Thus the systems tend to rely on purchased forage.

Besides they are not autonomous in concentrates. The percentages of concentrates produced on the farms are of 45% for Ardèche 1, 18% for Ardèche 2 and 0% for Isère.

4.3.1.4. Diversity

The animal diversity is low in the three systems, Ardèche 1 system has a higher diversity with two animal species (dairy goats and suckling cows) . While the others have only one (dairy cows).

Percentage of permanent grassland gives an idea of the plant diversity of the system since they are the most diverse soil cover (compared to the temporary grasslands and cereals cropped). Calculation of this percentage shows the Isère system in front with 89% of permanent grasslands, then the Ardèche 1 system counts 85 % and the Ardèche 2 system 43%.

For the farm system studied, the exact composition of the grasslands are not known. The grass composition of the permanent grassland is given in plant functional types for the purpose of forage rummy. Permanent grasslands are composed of a great number of different species (10 to 100) even if the biomass production is generally supported by 2 to 4 species only (Guo, 2007 cited in Farruggia et al., 2008). Fertility (natural and fertilized) and defoliation rate are the main factors that influence the botanical diversity (Cruz et al, 2002 cited in Farruggia et al., 2008).

Intensive management favors highly competitive species with a nutrient capture strategy resulting in a diminution of the botanical diversity. This strategy corresponds to funcional types A and B. While extensive management favor less competitive species with a nutrient preservation strategy resulting in a high botanical diversity (> 40 species). This strategy corresponds to functional types b and C (Cruz et al, 2002 cited in Farruggia et al., 2008).

The analysis of the functional types also shows the Ardèche system 1 to be the most diverse with permanent grasslands composed of type b (18 ha) and C (29 ha), the Isère system in second position with type C grasslands (11 ha) and the Ardèche 2 as less diverse with only type A and B grasslands.

4.3.1.5. Environmental impact

4.3.1.5.1. N, P, K balance

The N, P, K balance was calculated for the three systems and gave the following results. The Ardèche 1 system is the most balanced system with little excess of the three elements 7 kg of N/ha, 0 kg of P/ha and 2 kg of K /ha.

The Isère system is equally almost balanced but with some deficit in two out of three elements: -17 kg N/ha, -2 kg P/ha, and 1 kg K/ha. There is mainly a lack of nitrogen in the system, that could be reintroduced by cropping more legumes or by increasing the concentrates inputs. But this latter option would decrease the autonomy of the farm system and increase costs.

The Ardèche 2 system suffers excessive inputs of nitrogen especially with 67 kg N/ha, 3 kg P/ha and 10 kg K/ha. This is due to the quantity of concentrates used. More concentrates need to be produced on the farm or less concentrates need to be used. The excess of nitrogen can cause nitrate pollution (soil and water) as well as contribute to N2O green house gases emissions (Arrouays, 2002).

4.3.1.5.2. Carbon balance

Agriculture is responsible for 19 % of the total ghg emissions in France. The principal emissions are methane (CH4) and nitrate protoxyde (N20). The ruminant are responsible of 98% of the emissions of livestock enteric methane (Dollé et al., 2013). Ghg emissions therefore play an important role in the environmental impact of livestock systems.

Ghg emissions were calculated for each system in in CO2 equivalent (CO2 eq). According to this method, the most "polluting" system seems to be the Isère system with the emission of 91 t Ceq/year, followed by the Ardèche 2 system with 77.3 t Ceq/year and the Ardèche 1 system with

60.4 t Ceq/year. The transport for the food not produced on the farms is not included in the calculations and some of the food not produced on the farm were not included as the hectares necessary to produce them is unknown or because the CO2 eq value for the crop is not given by the method.

However, livestock systems are also carbon sinks as they rely on grasslands that compensate in part the ghg emissions of the livestock. Indeed livestock systems are able to compensate up to 28% of France's ghg emissions: with grasslands and agroecological infrastructures like hedges and bushes (Dollé et al., 2013).

The impact on carbon sequestration induced by changes in forage management systems were measured (Dollé et al., 2013), but their stability in time is less certain (Arrouays, 2002). Conversion of a cropped area into a grassland results in carbon sequestration of 490 kg C/ha/yr, while conversion of a grassland into a crop generates a loss of 950 kg C/ha/yr. The conversion of a permanent grassland into a temporary grassland can either induce a loss of carbon (100-200 kg C/ha/yr) or carbon sequestration (100-200 kg C/ha/yr) if the temporary grassland is more intensified but the degree of intensification is not clearly defined (Dollé et al., 2013).

In stable situations permanent grasslands are known to sequestrate variable quantities of carbon depending on factors such as climate (humidity increases carbon sequestration), fertilization (moderated nitrogen fertilization favors carbon sequestration while excess or lacks of nitrogen can liberate carbon), the presence of legumes (auto-regulation of nitrogen favoring carbon sequestration), grazing vs cutting (grazing favors carbon sequestration with direct OM inputs and by leaving more soil cover) and the grazing intensity (overgrazing tends to degrade the soil cover and provoke loss of carbon) (Dollé et al., 2013).

Concerning management the most favorable conditions are the combination of grazing only (without degradation of the soil cover), or cut and grazed with a medium fertilization level: 40-90 kg N/ha. This situation is known to sequestrate 250-1200 kg C/ha/yr (Dollé et al., 2013).

Agroecological practices such as hedges rows and bushes allow carbon sequestration of 100 kg C/ha (on a basis of 100 linear m/ha) ,as well as green manure (160 kg C/ha/yr) and no tillage (200 kg C/ha/yr. These practices allow other positive environmental effects such as limiting erosion and nitrate leaching (Arrouays, 2002).

Concentrates produced on the farm generate a loss of 155 kg C/ha/yr (Dollé et al., 2013).

Table 8 gives more details on the forage management to give an idea of the potential carbon sequestration of each system.

Table 8: Percentages of different management practices over the total area

	Ardèche 1	Ardèche 2	Isère
% PG	85	43	89
% PG grazed only or cut and grazed with 40-90 kg N/ha	85	8	89
% concentrates	5	21	0

Ardèche 1 system combines a high percentage of permanent grassland (85%) all combining grazed only or cut and grazed management with medium fertilization and only 5 % of concentrates, which are all factors influencing positively carbon sequestration. The Isère system is similar to this, although it presents no concentrates. The carbon sequestration potential of both farm systems is high.

Ardèche 2 system combines a low proportion of permanent grassland in the total area, with a low percentage of the area combining the management practices favorable to carbon sequestration (8%) in favor of a relatively large area devoted to crops. The combination of all these factors, as well as the excess nitrogen found in the N, P, K balance, suggests a low carbon sequestration potential for this system.

4.3.1.5.3. The milk density

The milk density is high for the Ardèche 2 system with 5 661 L/ha, the Isère system has a milk density of half as much (2 659).

The Ardèche 1 system has milk density of 1 042 but it cannot be compared to the two preceding systems as it is a goat milk production.

4.3.2. Opportunities

The SWOT analysis enables to summarize the information given by the indicators (as Strenght, Weaknesses, and Threats to the farm systems), and to present the adaptations of the farm systems as Opportunities.

4.3.2.1. Ardèche 1

Table 9 gives the result of the SWOT analysis for Ardèche system 1.

Table 9: Ardèche 1 system SWOT analysis

Strenght	Weaknesses
-autonomy (45 % of concentrates produced on farm ans atonomous index) -diversity (2 animal productions and 85 % of PG) -N, P, K balance close to 0 -High potential for carbon sequestration (85 % of PG, 85% favorable area, 5 % of concentrates over total area)	-no protein autonomy -high ghg emissions : 60.4 t Ceq/yr
Opportunities	**Threats**
-intensify on the animals : decrease the goat number, increase the production per goat or extensify : increase goat number, decrease production per goat ? -cut grass earlier (silage/wrap)*	-loss of forage autonomy and pasture available during dry years

*discussed during workshop with other farmers but prohibited for this specific farm system by the constraints of the AOC Picodon

Reflection on the number of goat and their level of production was initiated during the workshop. This would be a proposition to adapt to the lack of pasture available and forage produced during dry years (yield losses on 1st cut from 20 to 50% according to forage sticks).

Two systems were designed using forage rummy. One with 150 goats producing each 500 L of milk per year and one with 94 goats producing 800 L of milk per year. Table 10 shows that the consumption of food is more important for the hypothesis of 150 goats, even if the production is lowered. Table 11 shows that the cost of the food is also higher for this system. This hypothesis does not address the issue. It would seem that increasing the production per goat and decreasing the goat number would be the most adapted solution to face the pasture and cut forage deficit.

However, the increase of milk production per goat is done using more rape oil cake concentrate, which would not be a sustainable solution for this system. Indeed, using more concentrate would decrease the farm autonomy (if it is not produced on the farm). And it would not be an innovative adaptation as it would return to depending on external productions to face yield losses linked to climatic variations. Producing the concentrate on the farm would decrease the farm biodiversity, could potentially decrease the carbon sequestration and increase the N, P, K balance.

A more sustainable alternative would be to increase the production per goat based on the dehydrated alfalfa concentrate. As it could be produced on the farm with less negative effects on the indicators than the rape oil cake by converting permanent grassland in temporary grassland which is less destructive than converting permanent grasslands in a monoculture crop. However, producing this kind of concentrate would probably demand technical means unavailable.

Table 10: Quantities of food consumed depending on the hypothesis and the year

	Quantities consumed (tDM)								
Year	Average			Dry Summer			Dry Spring		
Hypothesis (L)	500	600	800	500	600	800	500	600	800
Pasture	111	105	95	97	94	90	108	104	94
Hay	77	68	65	77	68	65	77	68	65
Cereals (qtx)	303	322	243	303	322	243	303	322	243
Dehydrated alfalfa	12	14	11	12	14	11	12	14	11
Rape oil cake	47	30	53	47	30	53	47	30	53

Table 11: Cost of food (including production costs and buying costs) for each hypothesis and depending on the year

	Costs (euros/1000L)								
Year	Average			Dry Summer			Dry Spring		
Hypothesis (L)	500L	600L	800L	500L	600L	800L	500L	600L	800L
Forage (including dehydrated alfalfa)	160	166	151	161	168	156	175	155	133
Concentrate	92	91	75	105	120	87	105	103	87
Total Feeding	252	256	226	266	288	243	280	258	220

Another possibility discussed by the farmers during the workshop was to harvest forage earlier, before the drought, and to make silage or wrap to increase the quality of the forage. Indeed, late harvest suffers more loss during dry years than early harvest (yield loss of 30% for late harvest at 1000°Cdays for stick 1 vs 50% yield loss for late harvest at 1200°Cdays for stick 4). Proposition to make silage or wrap would mean harvesting at around 750 to 900°Cdays. This could also favor pasture growth after cut (since late cutting penalizes regrowth and pasture valorization). However, silage or wrap making is prohibited by the constraints of the AOC Picodon and so impossible for this specific farm, but still an opportunity for similar farm systems.

4.3.2.2. Ardèche 2

Table 12 gives the results of the SWOT analysis for Ardèche 2 system.

Table 12: Ardèche 2 system SWOT analysis

Strenght	Weaknesses
-high milk production (good genetics of cows) with relatively low costs (economy of scale)	-no concentrate autonomy (18 % produced on farm) generating high food costs - low diversity (1 animal species, 43 % of PG) -Positive N, P, K balance (67, 3, 10 kg/ha) excessive nutrient inputs -high ghg emissions (77.3 t Ceq/yr) -low carbon sequestration potential (53 % PG, 8 % favorable area, 21 % area for concentrates, excess N)
Opportunities	Threats
-decrease milk production per cow to decrease external inputs, increase farm system autonomy and restore balance to nutrient fluxes*	-loss of forage autonomy and pasture available during dry years -increasing environmental impact (pollution linked to Nitrogen and Carbon liberation) -increasing external dependance and reaching the limits of the ressources of the system with plans of increasing the milk production per cow by using more concentrates

* This strategy is in opposition with the farmer's plans.

This system appears quite unsustainable with a number of threats and weaknesses that would be enhanced by an increase of the production per cow based on concentrates, wished by the farmer. No adaptation to climate variation was developed during the workshop, when strengthening the overall system should be the center of focus. This is why the opportunity explained below aims exactly at the opposite of the farmers' wishes.

The high milk production of this system is sustained by reliance on a high and varied amount of concentrates acquired externally of the farm system. The farm system uses 3 248 kg of concentrates per dairy cows per year (not counting the heifers). Only cereals are produced on the farm and they don't account for the cereal intake of the dairy cows (30 kg missing per dairy cow).

Proposition to lower milk production per animal, would be justified by the resulting increase of food autonomy and decrease of nutrient inputs. The milk production could be supported by less concentrate preferably produced on the farm. However the PG percentage being already low, it would be difficult to produce concentrates on the farm without compromising biodiversity and carbon balance.

Another justification for lowering the production per cow would be regarding concerns about animal welfare. To support a high production, the renewing rate is especially high (more than 40% of the cows are renewed each year).

Concerning the economical profit, it is supposed that a compromise between production amount and cost could be found to generate as much income in the end by not spending so much on concentrates.

4.3.2.3. Isère

Table 13 gives the results of Isère's system SWOT analysis.

Table 13: Isère system SWOT analysis

Strenght	Weaknesses
-low concentrate cost (economy of use) -forage autonomy (normal years) -vegetal diversity (89 % of PG) -high potential for C sequestration (89 % of PG, 89 % favorable area, no concentrates)	-no concentrate produced on farm -negative N,P,K balance (-17, -2, 1 kg/ha) -high ghg emissions : 91 t Ceq/yr -high workload in short periods of time
Opportunities	**Threats**
-move calving to the spring to make feeding requirements stick to the late grass production of dry years (dry springs) -introduce more legumes in the system -produce own concentrates	-loss of forage autonomy and pasture available during dry years -depleation of the system's ressources (outputs>inputs)

Moving calving period from autumn to spring would hold the advantage of making high feeding requirements stick to the later grass production of the dry years. Figure 13 shows the pasture available in the system for a dry year and the ingestive capacity of the herd with autumn calving at the top and spring calving at the bottom.

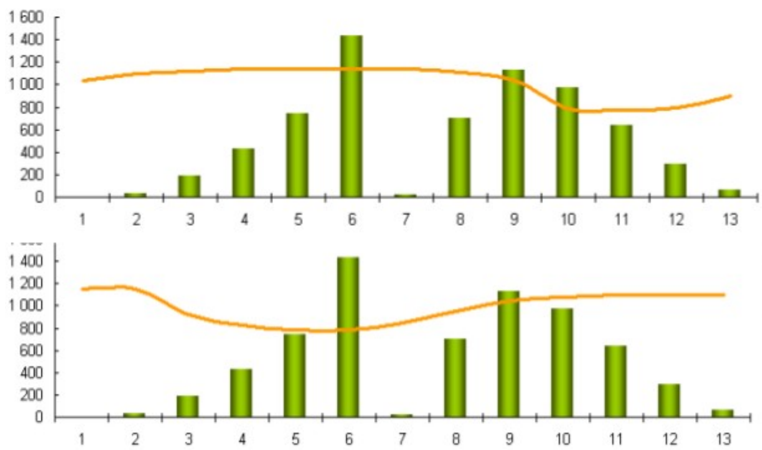

Figure 6: Pasture available and ingestive capacity for autumn (top) and spring (bottom) calving (Isère, dry year)

With spring calving, the excess pasture available just before the summer "hole" compensates for that lack of pasture and the pasture available increases again after the summer together with the ingestive capacity increase. Since more pasture is available less hay is consumed resulting in lower deficit in the forage balance.

This adaptation possibility was thought of during the workshop and the farmer reckoned it was an interesting opportunity for his system.

Introducing more legumes in the system is a proposition resulting from the negative N, P, K balance showing a lack of nitrogen of 17 kg N/ha. This solution would increase the nitrogen inputs in the system but could have other impacts. Sowing legumes would mean transforming a permanent grassland into a temporary grassland. This could have negative effects on both biodiversity and carbon sequestration.

To minimize the impact on biodiversity, it would be to sow a mixture of a number of legumes and grass species.

Regarding carbon sequestration, the impact is more difficult to control. It would be possible to limit carbon liberation or to induce carbon sequestration by converting a poor permanent grassland of the system into a more intensified temporary grassland. But the differences in intensification levels are not specified in the studies made which makes decision difficult on the grassland choice (refer to part 4.3.1). Another factor being the use (grazing vs cutting), the choice of the permanent grassland to convert should be oriented towards one that was already cut in the past (since the leguminous grassland is probably going to be cut).

The transformation of a permanent grassland into a temporary grassland could decrease yield losses linked to climate change in the farm system. Indeed the comparison between forage sticks resulting from simulations showed that yield losses on 1st cut for TG were lower than for PG (20% vs 30% for the dry summer year and 40% vs 50% for the dry spring year when comparing forage sticks 16 and 5).

Another advantage of producing more legumes would be to replace the dehydrate alfalfa purchased. This would increase the protein autonomy and decrease the food costs (but they are already relatively low in this system).

Producing the cereal on the farm would have similar autonomy increase effects. It could also increase the nutrient inputs depending on the fertilization practices of the crop, with pending negative effects on ghg emissions linked to fertilizers, on carbon sequestration and on biodiversity. These could be compensated by the introduction of a green manure in sequence with the cereal crop. To increase the nutrient balance more concentrates could be purchased but this could have negative impacts on the farm system autonomy, on the ghg emissions (production and transport of cereals) and on biodiversity.

5. Conclusion

The development of forage rummy in the Rhône Alpes region showed that it was perceived positively by advisers. It was found to be a unique tool enabling to visualize the impact of climate change on the farm system, giving new insights on the forage balance, and opening dialogue on multiple issues.

However, restraining problems occurred, being technical, knowledge related and organizational, leading to the formulation of recommendations for its use. Advisers need to define the issue to address together with farmers and the format of the intervention will need to be adapted to the objectives of the workshop(s). Participants must be aware of the characteristics of the tool requiring specific attitudes from both farmers and facilitators and what to expect out of this kind of exercise. If a participatory approach like forage rummy does not seem adapted, other tools should be taken in consideration. During the preparation of the workshops, special care needs to be taken regarding the simulation of the forage production and the choice of the climatic data.

Description of the farm systems using forage rummy showed that the occurrence of dry springs and dry summers have a negative impact on grassland and forage crops production. The dry summers tend to have a greater impact on the annual pasture available and the hay production while dry springs affect silage/wrap yields.

Adaptations to the changing grass production induced by climate change is possible through the rethinking of management practices both concerning the forage production itself and the animals. The three examples explored based on the workshops held in Rhône-Alpes region showed adaptations to the quantity and quality of forage produced and adaptation to the timing of the production.

Concerning adaptation to quantity and quality of forage produced, analysis using agroecological indicators showed that optimizing the production per animal to control the herd size and so the consumption was essential. The aim being to make an effective use of the resources taking in consideration the impact of the climate, to maintain the balance with the environment while generating a sustainable economic income.

Concerning the timing of the production, making early harvests could help secure the forage production in case of dry summers, and favor more regrowth after the cut if the summer is not too dry. However this could lead to intensification, focusing on the precocity of the grasslands and thus favoring a certain type of vegetation, and needs to be planned carefully. The level of intensification has to be a compromise between the productivity and minimizing the environmental impact in order to give strength to the system and not weaken its relationship with the environment. Moving calving dates to correspond to the early grass production was also discussed, to optimize the use of the pasture when it is available.

An effective use of forage rummy can help think about farm systems in a way conducive to developing adaptations in accordance with agroecological principles as well as strengthening these systems threatened by climate change. However, forage rummy remains a tool and it can be used independently from the intentions of its designers or the agroecological worldview.

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7. Appendices

Appendix 1: Description of forage rummy components

(Adapted and translated from Morel, 2012)

The game is played on a **board** that serves as physical support to the game. It is around the board that the participants will exchange and discuss the design of the system and its possible modifications. The board is divided horizontally in two main parts (figure 1): The upper part represents the distribution of crops and pastures on the farmland through forage sticks describing plant production; the lower parts is reserved for the herd. It is described as a set of herd batches and their feeding can be specified using the animal and feed cards. The representation of the farm system is done for a year, divided in 13 periods of 4 weeks each (described in table 1). And so the board is divided vertically in 13 and the calendar dates are written in each period to help visualize the division of the year in 13 periods instead of 12 months.

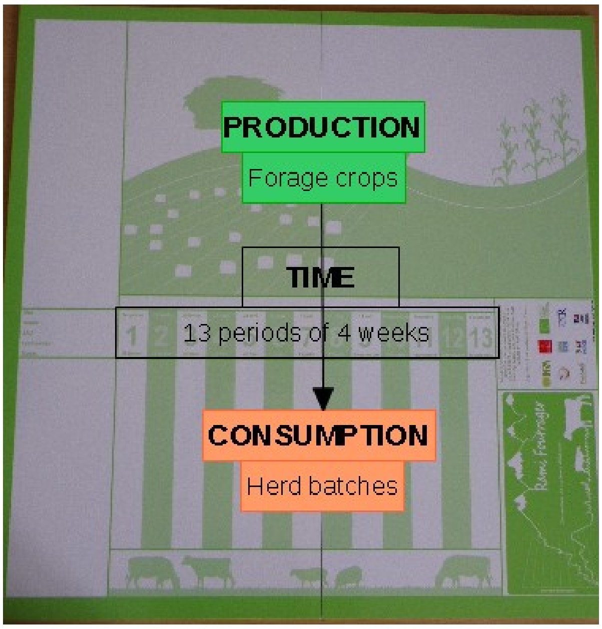


Figure 1: Representation of Production and Consumption over time on the forrage rummy board

Table 1: Delimitation of forage rummy periods

Period	1	2	3	4	5	6	7	8	9	10	11	12	13
Date	01/01 28/01	29/01 25/02	26/02 25/03	26/03 22/04	23/04 20/05	21/05 17/06	18/06 15/07	16/07 12/08	13/08 09/09	10/09 07/10	08/10 04/11	05/11 02/12	03/12 31/12

On the left hand side, a box is provided to write down key characteristics of the system (Figure 2):

- site and year
- total cultivated area (SAU)
- constraints: shallow soils area, plowable area
- stocks in advance

Figure 2: Characteristics of system written on the board

<u>The production</u>

-The **forage sticks** describe the forage production for each combination of a forage crop and its management in a given natural environment (soil and climate). Forage sticks display the available forage yield in kilograms per hectare and per day for each of the 13 periods when the pasture is grazed (Figure 3) and a yield in tons of dry matter per hectare for the period when the pasture is cut (Figure 4).

Figure 3: An example of a forage stick for a grazed permanent pasture

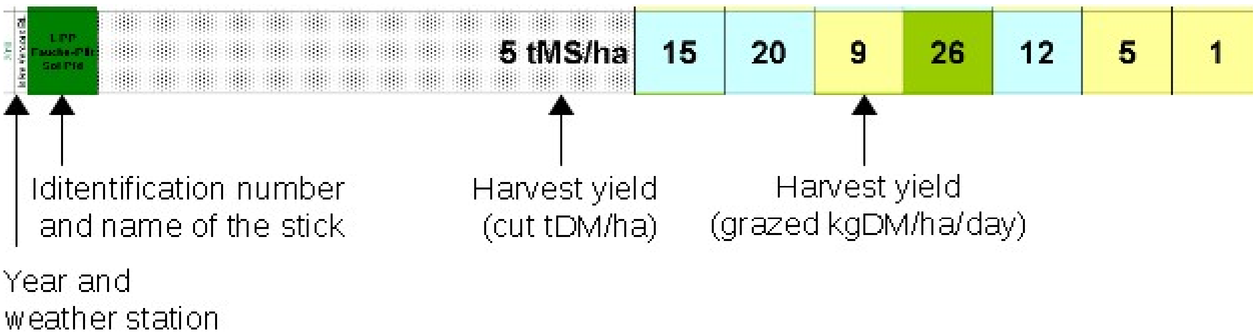


Figure 4: An example of a forage stick for a cut then grazed permanent pasture

Forage sticks are used to describe temporary and permanent pasture as well as other forage crops (cereals, silage, …). The sticks are prepared beforehand to give a large range of possibilities to the players during the worshops. To fit the local conditions, the grasslands' productions are modelled using Herb'sim, a model developed at INRA of Toulouse. For the other crops, yields are given by local experts for each year.

During the workshop, forage sticks are arranged by the participants on the upper part of the board to describe the composition of the total cultivated area (SAU) of the system represented. The area (in hectares) affected to each kind of crop is written beside each stick (Figure 5).

Figure 5: Forage sticks placed on the board with area affected to each

<u>The consumption:</u>

-**Animal cards** define animals representative of a specific herd batch (the "average animal" of the batch). They enable to specify the kind of animal, its production level and other characteristics of its production cycle (calving date, grouped calving, age at first calving,...). These cards are placed on the left-hand side of the bottom part of the board and the number of animals is written directly on the board (Figure 6). For now, forage rummy was tested with dairy and suckling cows, goats and sheep. There is a maximum of three batches per system accepted by the computerized support system.

Figure 6: Examples of animal cards. (Top: 50 Dairy cows, producing 6 000 L, calving in autumn; Bottom: 15 Dairy heifers)

-The **feed cards** enable to describe the year-round diet of the herd batches. Each card represents a type of feed and its nutritional characteristics. They are placed under each period number to describe the combination of feed given per period.

There are forage cards (Figure 7):

- good/ medium/ poor quality hay
- straw
- grass silage, grass wrap, maïs silage
- pasture
- leguminous forage …

Figure 8: An example of a concentrate card (cereals)

Figure 7: Forage cards disposed on the board for periods 1 to 7

And concentrate cards (Figure 8):

- soya / rape oil cake
- cereals
- deshydrated alfalfa, …

<u>The climate sticks</u>

The climate stick gives an overview of the climatic conditions of the year chosen. It is a diagram presenting the evolution of the water available in the soil for two different soil depths throughout the year as well as the average temperature (Figure 9). It can be complemented by a rainfall diagram (Figure 10). They are created beforehand using the local weather data. They are presented at the beginning of the workshop and can be left above the board to serve as point of reference.

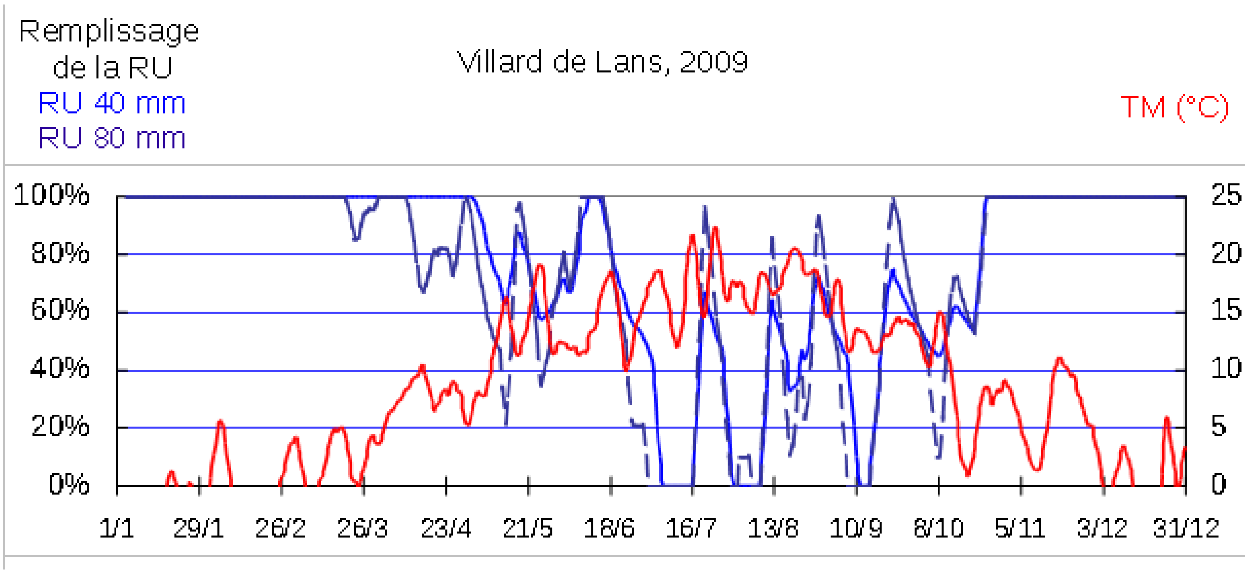


Figure 9: Climate stick: Soil water available and average temperature evolution for Villard de Lans,2009

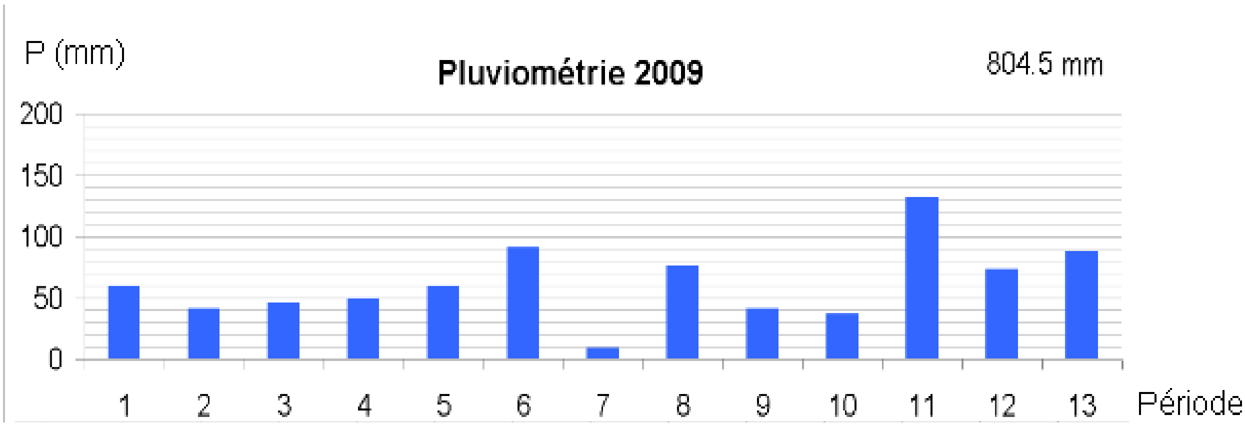


Figure 10: Rainfall diagram, Villard de Lans, 2009

The computerized support system

The computerized support system integrates the input information: key characteristics of the system (forage production, animals and their diet, …) and allows to assess instantly the adequacy between the feeding requirements of the herd batches and the forage production selected. It also gives material for discussion through a forage balance including economic, agronomic and social aspects.

It is an excel document composed of several sheets. The main sheet is an interface to present the results to the participants (the others enable the calculation).

The top part (Figure 11) is dedicated to the system characteristics and constraints, the forage crops selected and the resulting available pasture and stock evolution.

The middle part enables to enter the herd batches and select their food for each period. It gives the composition of the diet over each period and compares it to the quantity to ingest. Finally it makes an assessment of the satisfaction of the energetic and protein animal needs per period (Figure 12).

The bottom part of the interface analyzes the farm system. It gives global indicators such as the carrying capacity and forage autonomy as well as a workload indicator. The main feature is a balance showing the yearly evolution of the pasture and of forage crops and straw stocks. Economic indicators are also included (Figure 13).

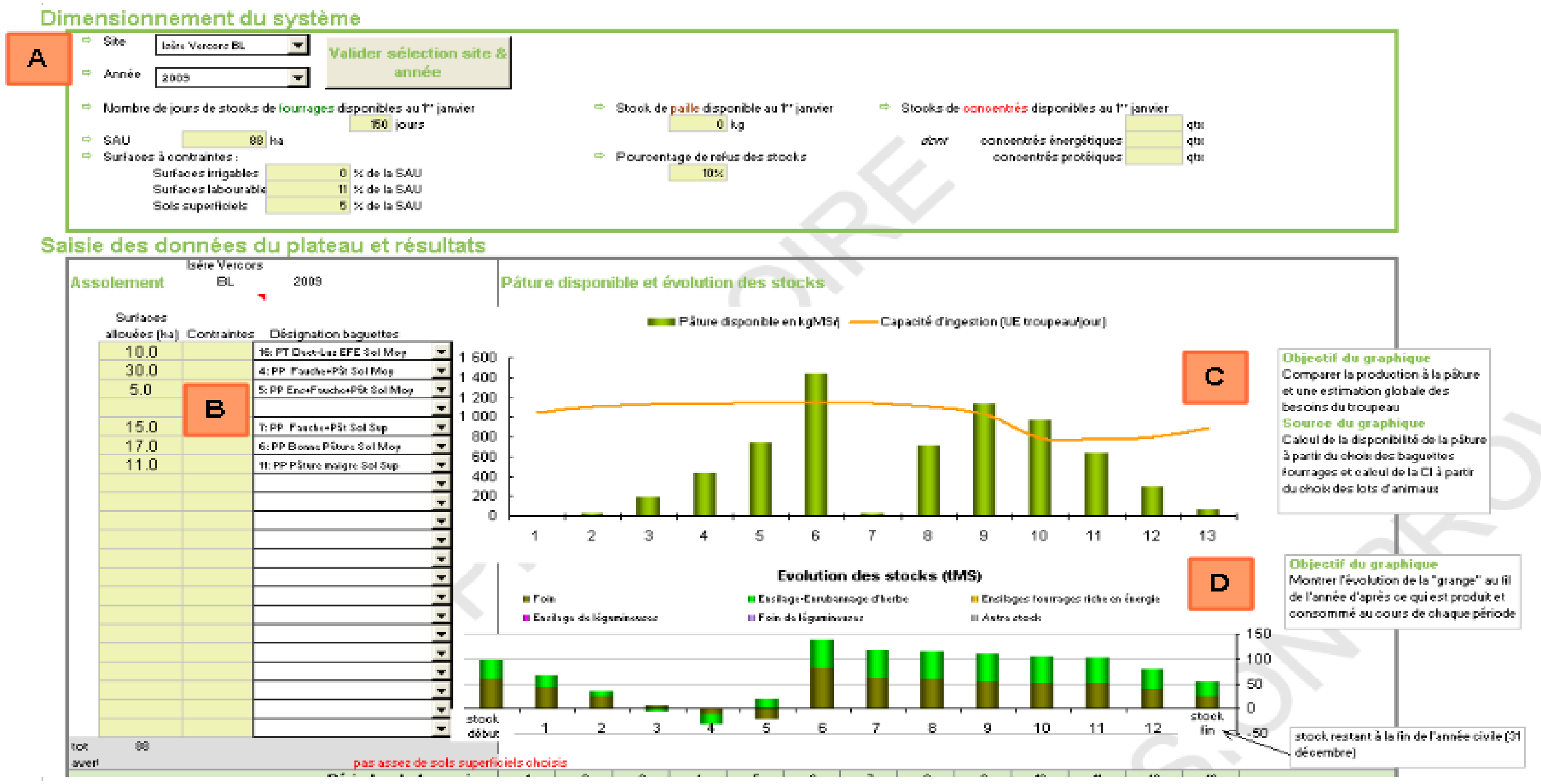


Figure 11: Top part of the interface : system dimensions and constraints, forage crops selected and resulting available pasture and stock evolution

A: System dimensions: site, year, total cultivated area (SAU) and constraints (irrigable areas, plowable areas, shallow soils area), stocks in advance: forage, straw, concentrates

B: Forage sticks selected and area affected to each

C: Graph representing in orange the ingestion capacity of the herd batches and in green the available pasture (kgDM/day) for each period.

D: Graph showing the evolution of forage stocks throughout the year depending on initial stocks, production and consumption.

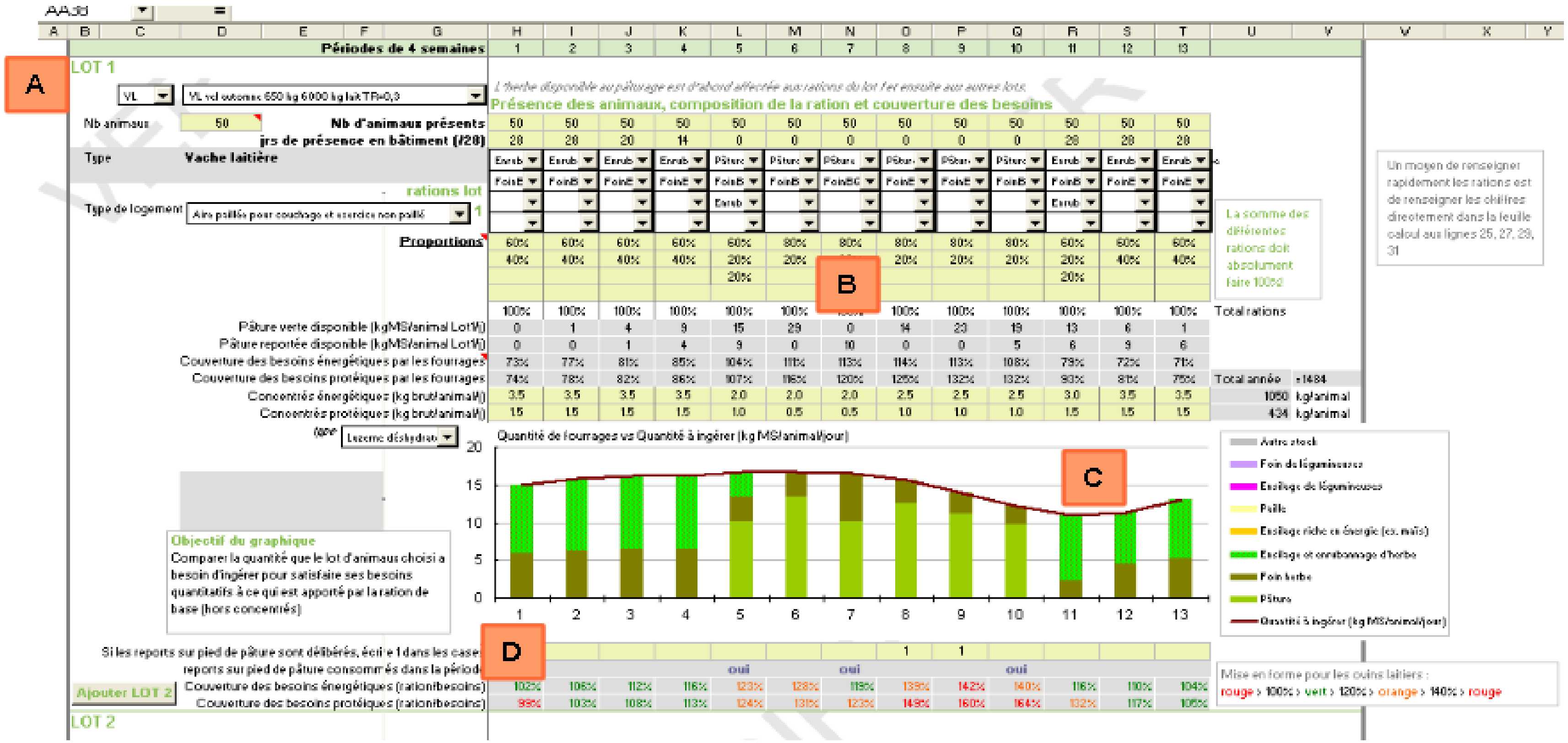


Figure 12: Management of an herd batch: characteristics, feed and covering its needs

A: Herd batch characteristics: type of animals, calving date, production level, lodging type...

B: Animal intake of each feed for each period (%). Satisfaction of needs covered by forage (%) and possibilities to add concentrates.

C: Graph showing the quantity to ingest (kgDM/aniaml/day) and the proportion of intake of each feed (pasture and forage stocks) per period.

D: Indicator of satisfaction of energetic and protein animal needs (%) per period.

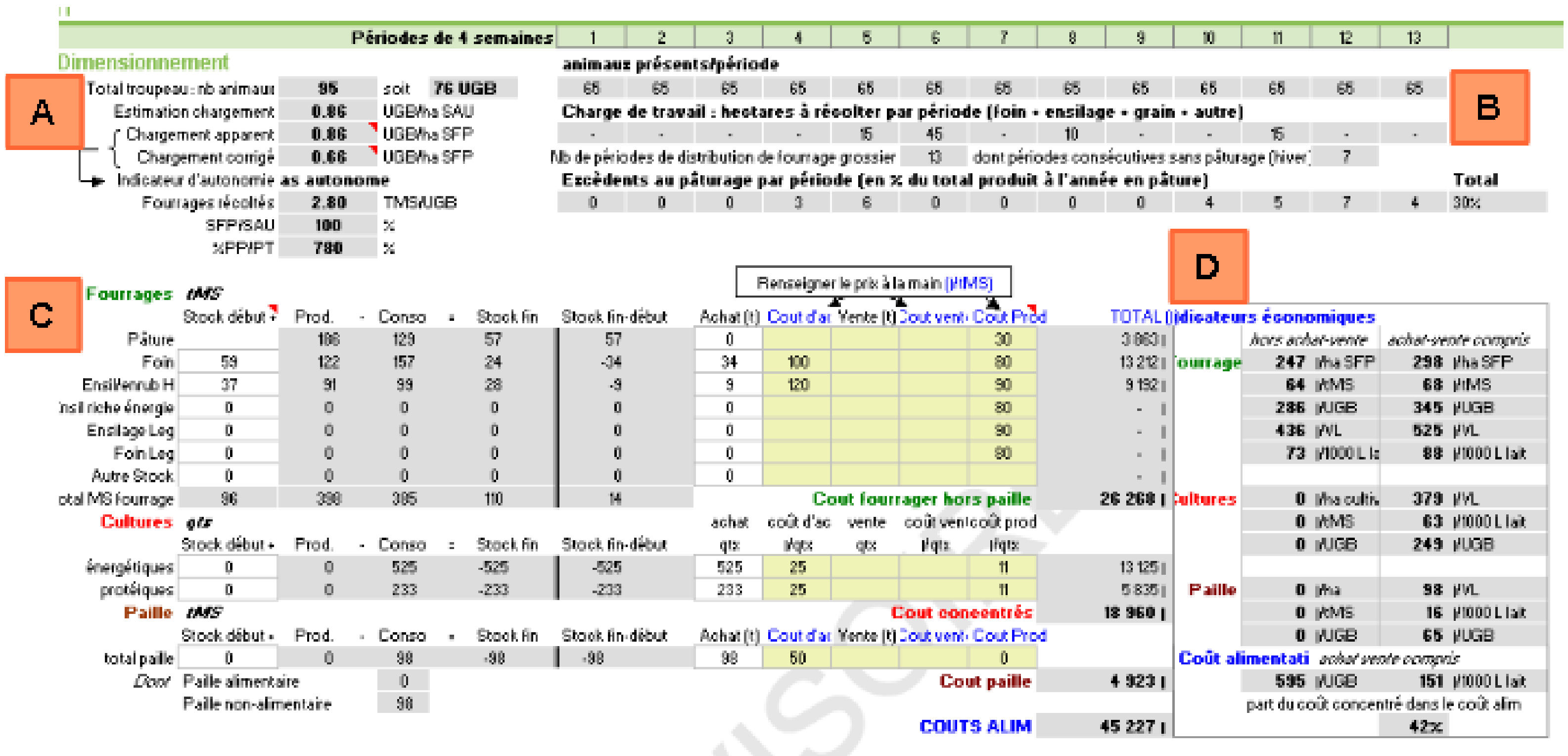


Figure 13: Forage balance

A: Global indicators of the farm system (e.g: carrying capacity, autonomy).
B: Workload indicators and excess pasture .
C: Pasture, forage, crops and straw stocks balance (initial stock, production, consumption, final stocks). Costs entries (buying, selling, and production costs). Cost of the feeding.
D: Indicators for feeding costs (e.g: per liter of milk produced).

Playing the game

Forage rummy workshops are held for a small group of people including farmers, advisers and facilitators. They are set to create space for reflection and discussion around themes dealing with change such as climate change, forage, protein or straw autonomy, respecting new production constraints... It is important to focus each workshop on an issue that concerns all the participants for a better outcome. Usually workshops last 2 hours and progress as follows:

1. Expectations and opinions on the issue asked to each participant (10'),
2. Information on the problem addressed (5'),
3. Presentation of the principles, components and use of the game (10'),
4. Presentation of the local context (climatic data) (5'),
5. Playing round (1h20),
6. Discussion on possible adaptations for the farm system studied (10').

After the workshop, analysis is conducted on its format and content, and synthesis documents should be returned to farmers and advisers.

Appendix 2:

Eléments nécessaires à la préparation des ateliers

Thématique à traiter

- Liste non exhaustive de propositions : autonomie fourragère, autonomie protéique, autonomie en paille, arrêt des aliments fermentés, passage à un système plus herbager, adaptation du système à un cahier des charges, agrandissement de l'exploitation, adaptation aux aléas climatiques, élaboration d'un système standard dans un but de formation.

Paramètres géographiques et climatiques

- Station météo susceptible de fournir les données quotidiennes suivantes : précipitations, évapotranspiration, rayonnement global, température minimale et température maximale.
- Différence d'altitude entre la station météo et la zone sur laquelle sera simulée d'exploitation du jeu.
- Exemple d'année moyenne, d'année sèche au printemps, d'année sèche en été, d'année globalement sèche, d'année humide ?

Contexte agricole

- Taille des exploitations
- Importance des surfaces fourragères dans la SAU
- Présence de contraintes particulières dans la zone

Description des prairies rencontrées dans la zone

Pour chaque grand type de prairie temporaire ou permanente :

- Renseigner le pourcentage des espèces présentes dans le couvert.
- Dates de mise au pâturage et de fauches en année moyenne (pour caler la précocité des espèces).
Rendement des fauches (foin et ensilage) à chaque date en année moyenne.
- Pratique du déprimage ? Si oui, à partir de quelle date en année moyenne ?
- Quel type de pâturage : tournant, continu. Vitesse de rotation entre les prairies pâturées ? Hauteur de sortie d'herbe en fin de pâturage ?
- Pratiques de fertilisation

Autres cultures fourragères ou non fourragères (non simulées par Herb'sim)

- Espèces rencontrées dans la zone et/ou que l'on veut présenter aux joueurs.
- Dates d'implantation et de récolte de la culture en année moyenne. Dérobées ?
- Rendement en année moyenne, en année favorable et en année difficile.
- Mode de valorisation de la culture : pâturage, fauche, ensilage, grain, vente.

Animaux

- Races des animaux et niveaux de production que l'on souhaite présenter
- Organisation du cycle zootechnique (dates de mises-bas, mises-bas groupées, intervalle entre mises-bas, périodes de tarissement)
- Age et poids des mères à la première mise-bas, poids de la portée
- Autres détails qui permettent de renseigner la feuille de calcul des besoins animaux.

Contexte pédologique

- Profondeur des sols moyens de la zone ? Présence de sols superficiels et séchants ? Présence de sols hydromorphes ? Sols irrigués ?
- Fertilité des sols (idéalement indice de nutrition azotée et indice de nutrition phosphatée, sinon on se base sur les rendements en année moyenne pour caler le modèle)

Coûts de production

Quels coûts de production veut-on considérer (implantation, entretien, récolte, conservation, distribution, fermage ? Trouver des références de coûts adaptées (en euros par tonne de matière sèche) pour :

- Herbe pâturée
- Foin
- Ensilage/enrubannage d’herbe
- Ensilage de maïs
- Fourrage de légumineuses
- Autre fourrage considéré (betterave, chou, colza)
- Céréales considérées
- Protéagineux considérés

Réfléchir également au coût d’achat et de vente. Ils peuvent être saisis directement par les agriculteurs lors de l’atelier. Mais s’il est question d’un public d’étudiants ou autre (non susceptible d’avoir ses prix en tête), il est préférable d’avoir déjà défini des valeurs.

Appendix 3: Documents to collect data during the workshops for workshops analysis

(Translated from Mathile Piquet)

- Collective questions to ask at the beginning and at the end of each workshop
- Observation grid
- Questionnaire for participants (focused on farmers)

Collective questions to ask at the beginning and at the end of each workshop:

Ice breaker

- presentation (name, activity)
- why do you participate to this workshop ?
- Do you feel concerned by the issue addressed ?

Questions to ask at the end of the workshop

- What is your state of mind after this workshop? (the idea is to see if some participant regret the time spent for the workshop or if they felt it was useful, nice...)
- What are the principal advantages and drawbacks of this exercise?

Deux temps de questions à poser au groupe :

Questions à poser pour le tour de table

- se présenter (nom, prénom, métier)
- pour quelles raisons participez-vous à cet atelier?
- vous sentez-vous concerné par le problème traité lors de cet atelier?

Questions en fin d'atelier :

- quel est votre état d'esprit après cette séance de Rami ? (l'idée est de voir s'ils regrettent le temps passé ou ont plutôt vécu un moment utile, agréable ...)
- quels sont les principaux points forts / points faibles de cet exercice ?

Grille d'observation Rami fourrager

Le but de cette grille est de recueillir des éléments pour décrire le fonctionnement qu'a eu un atelier RAMI. L'idée est de repérer des mécanismes qui favorisent ou brident la séquence de jeu, les apprentissages et les échanges (entre éleveurs ou éleveurs / animateurs) qu'on en attend. La valorisation finale des fiches bilan pourra se faire en termes de recommandations pour la mise en oeuvre d'ateliers RAMI.

ouverture de séance	date et lieu de la séance	
	heure de début d'atelier	
	Points remarquables de la phase d'explication / introduction (consignes de jeu, choix du scénario ...) = questions ou remarques originales, utiles comme exemples dans un futur document de prise en main du RAMI; difficultés de compréhension qu'il sera utile d'anticiper pour une prochaine fois ...	
	heure de début du jeu de plateau entre participants	
construction du système	Stratégie choisie par les participants : que définissent-ils successivement pour construire le système ? Comment s'y prennent-ils ? (et cela fonctionne-t-il bien !)	
	Le groupe a t-il eu un ou des leaders ? Si oui comment s'est faite la "désignation" ? Quel a été son rôle ?	
	y a t-il eu des moments de blocage pour construire le système ? Qu'est-ce qui posait problème pour avancer ? Comment-ont ils été dépassés ? (appel à l'animateur ou au conseiller, retour en arrière sur une hypothèse de base, "putsch" d'un des participants ...)	
simulations	A quelle heure fait-on la 1ère simulation ? Quels résultats (mémoriser les différentes simulations pendant le jeu ?)	
	Réaction des participants à la simulation (compréhension, étonnement, protestation, demande d'en savoir plus sur les règles et hypothèses de calcul ...)	
	Comment les modifications pour parvenir à l'équilibre ont elles ensuite été élaborées ? (avec ou sans aide des animateurs, petits ajustements successifs (plutôt sur quoi) ? Changement des hypothèses de départ ?)	
	Combien de simulations ont été nécessaires pour parvenir à un système équilibré ?	
bilan global de l'exercice	Avis exprimés sur le système final	
	Tonalité globale de la séance (dynamique, laborieuse, enthousiaste, gaie ...) : 3 adjectifs SVP !	
	Aspects matériels : des manques, des difficultés, des accidents de manipulation, des bugs repérés par les participants ?	
rôle du conseiller	Quelle place le conseiller/observateur a t-il occupé pendant le jeu (retrait volontaire ? Immersion active parmi les participants ? Intervention ponctuelle sur demande des joueurs ? ...) Etait-ce un choix initial ?	
	Y aurait-il eu avantage à faire différemment ? (expliciter)	
	Des apports "théoriques" / références préparés à l'avance auraient-ils été utiles à un moment ou à un autre du jeu ? (lesquels)	
participation des éleveurs	Selon la connaissance que le conseiller a des participants, pour chaque participant : - a t-il "exploré" des cultures, itinéraires, conduites de troupeaux différents des siennes ? - a t-il été amené à envisager ses pratiques/résultats actuels avec un autre regard ? - semble-t-il avoir été intéressé à réfléchir à de nouvelles pistes pour chez lui ?	
	Si un ou des participants ont peu participé, aurait-on pu / du les solliciter plus ?	
	La composition du groupe était-elle adaptée ? En quoi a t-elle aidé ou limité les échanges ?	
	Faut-il réfléchir à l'avance au rôle du leader de groupe ?	
bilans et enseignements de la séance	Etait-ce au final une bonne séance ? (intéressante, utile ? Conviviale ? ...) Sur quelles bases ce sentiment se fonde-t-il ?	
	Cette séance, avec ces éleveurs avait-elle des objectifs précis ? Ont-ils été atteints ?	
	En quoi cette séance pourrait-elle modifier le travail futur du conseiller avec les différents participants ? (des choses apprises sur les logiques de choix en matière fourragère, une relation interpersonnelle différente, des rendez-vous pris pour une suite ... ?)	
	De la même façon, cette séance a-t-elle contribué à former / souder le groupe ?	
	Les 3 enseignements clés de cette séance pour un prochain atelier	

Bilan à chaud - côté éleveur - d'une séance Rami

nom prénom de l'éleveur : date et lieu de la séquence de jeu :

tél éleveur :

Quelles étaient vos attentes en venant à cette séance ?

Ont-elles été satisfaites ? non plutôt non plutôt oui tout à fait

Expliciter les causes de satisfaction / insatisfaction

Les explications pour la mise en route vous ont-elles paru : très claires / plutôt claires / plutôt peu claires / pas du tout
bien calibrées / trop longues / trop courtes

commentaires libres sur la mise en route :

Le démarrage du jeu (établissement des surfaces et itinéraires, lots d'animaux, ration …) vous a-t-il semblé :

difficile / plutôt difficile / plutôt facile / facile
trop long / plutôt long / normal / trop court

commentaires libres sur la phase de démarrage de la partie :

Les résultats de simulation vous ont-ils semblé : très cohérents plutôt cohérents peu cohérents incohérents

Y a-t-il des manques, des approximations, des anomalies gênantes ?

Qu'avez-vous pensé de l'implication et du rôle des animateurs / conseillers dans la séance ?

Auriez-vous souhaité qu'ils interviennent différemment ? (plus, moins, avec d'autres supports …)

Le temps de la séance de jeu vous a paru : trop long plutôt long normal plutôt court trop court

**Le scénario et les hypothèses de travail (type d'exploitation, données climatiques, fourrages exploitables …)
vous ont-elles parues adaptées à vos besoins / à votre réflexion ?**
pas du tout plutôt non plutôt oui oui tout à fait

expliciter

Au final qu'est-ce qui dans cet exercice vous a particulièrement intéressé ou plu ?

Au final qu'est-ce qui dans cet exercice vous a plutôt déplu ou gêné ?

Que vous ont apporté les échanges durant l'atelier ? (merci de préciser votre réponse par quelques exemples !)

Cette séquence vous donne-t-elle envie de creuser certaines pistes pour votre exploitation ? Comment ?

Etes vous partant pour une nouvelle séance ? Si oui avec quelles envies de scénario, données de contexte à tester ?

Au final comment qualifieriez -vous ce moment de jeu ? (comment le décririez-vous à un voisin éleveur ?)

Appendix 4: Interview guides for post workshop data collection

Questions asked for the individual phone interviews by the forage rummy developer to the advisers:

- What interests did you find in the use of the forage rummy ?
- What problems did you identify ?
- How do you plan to use forage rummy in the future ?

Questions asked during the collective reunion (after making a synthesis of the individual interviews):

- Are there more interests and problems that we did not mention previously ?
- Can you define more precisely in which situations and how you would use forage rummy in the future ?

Appendix 5: Workshop material checklist

Liste du matériel à prévoir pour les ateliers du rami fourrager

Matériels

Descriptif	A réserver	Réservé	Nb	Emmené
2 plateaux de jeu				
Cartes animaux et rations				
Stylos feutres effaçables				
2nd écran	X			
Caméra	X			
Appareil photo	X			
Enregistreur audio	X			
PC portable avec la copie des supports informatiques	X			
Clé USB avec les supports informatiques				
Itinéraires et/ou GPS	-/X			
1 multiprise				
Numéros de téléphones des participants				
Stylos et feuille de notes				
Voiture et documents de la voiture	X			
Ordre de mission	X			
Autorisation de conduire	X			

Supports informatifs et interactifs physiques

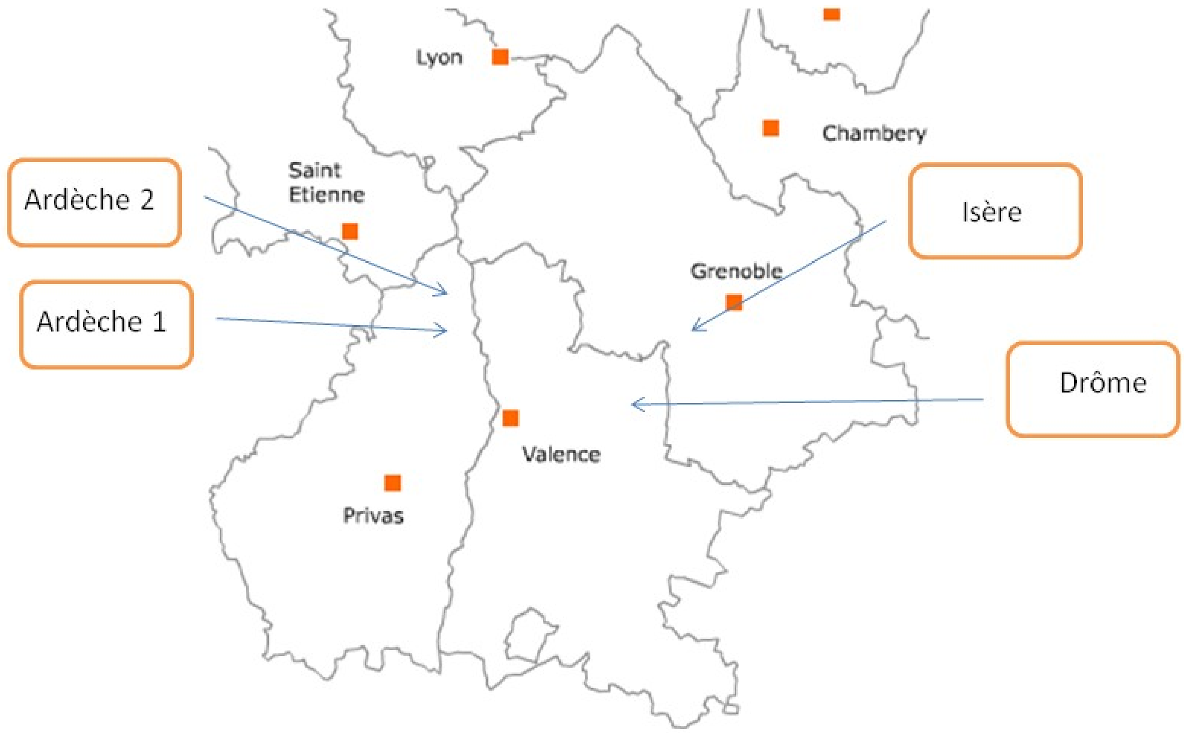
Descriptif	Nombre	Emmené
Diaporama de présentation imprimé en nb d'exemplaires suffisant		
Baguettes fourrages imprimées pour la / les années étudiées		
Questionnaires de retours observateur + joueurs		
Descriptifs des baguettes		
Frise(s) climat (autant qu'il y a d'années étudiées) + Pluvio/période		

Supports informatifs et interactifs informatiques

Descriptif	Format fichier	Emmené
Diaporama de présentation de / des ateliers (contexte, objectifs, ordre du jour, présentation des années étudiées, du cadre de conception, explication des règles du jeu, etc.)	Power point	
Module d'évaluation (1 ou plusieurs selon les études)	Excel avec macros	
Fichiers de justification de choix des années, de couverts, …		
Fichier de calcul des baguettes	Excel	
Frises climat	Power point + Excel	
Module de calcul des besoins des animaux	Excel	
Questionnaires de retours observateurs et joueurs	Excel	
Les fichiers de/des ateliers précédents (si plusieurs ateliers dans la zone ou avec le même groupe)	Power point, Excel, …	

Source: Personal communication, Mathilde Piquet

Appendix 6: Map of workshops location



Appendix 7: Local Climate description for the four workshops

The local climate is roughly described using two indicators: rainfall for each four weeks long periods, and the year-round filling/emptying of the water storage capacity (representing the water available for the plants) compared to the evolution of the average temperature.

<u>In Ardèche</u>

In 2009, our "average year", annual rainfall reached 843 mm with a regular distribution over spring and summer: around 50 mm per four week period from February to August (fig 1). The water storage capacity was temporarily empty at the end of May and at the beginning of August for both deep and shallow soils (fig 4).
In 2005, our "summer drought", annual rainfall was of 596 mm. The dry period extended from mid May to mid July: 33 mm for period 6 (mid May to mid June) and 8.8 mm only for period 7 (mid June to mid July) (fig 2). The water storage capacity was empty from the end of May to the end of July for both soil types (fig 5).
In 2011, our "spring drought" year, annual rainfall went up to 761 mm. The water deficit observed in spring, from mid March to mid May: 21 mm only for period 4 and 24 mm for period 5, was compensated later in the year (fig 3). The water storage capacity emptied temporarily at the end of April for both soil types. Two other temporary deficits occurred at the end of July and August (fig 6).

Rainfall diagrams:

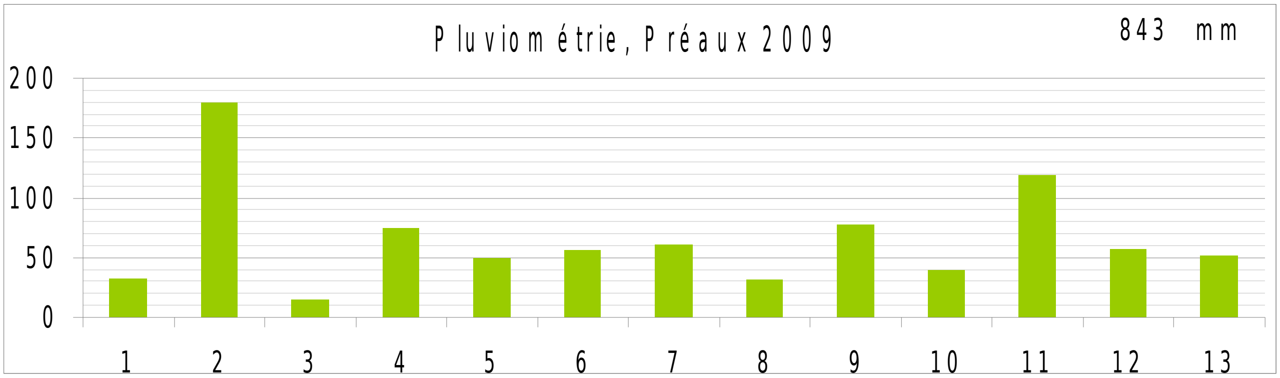


Fig 1:

Rainfall, Préaux, 2009 (average year)

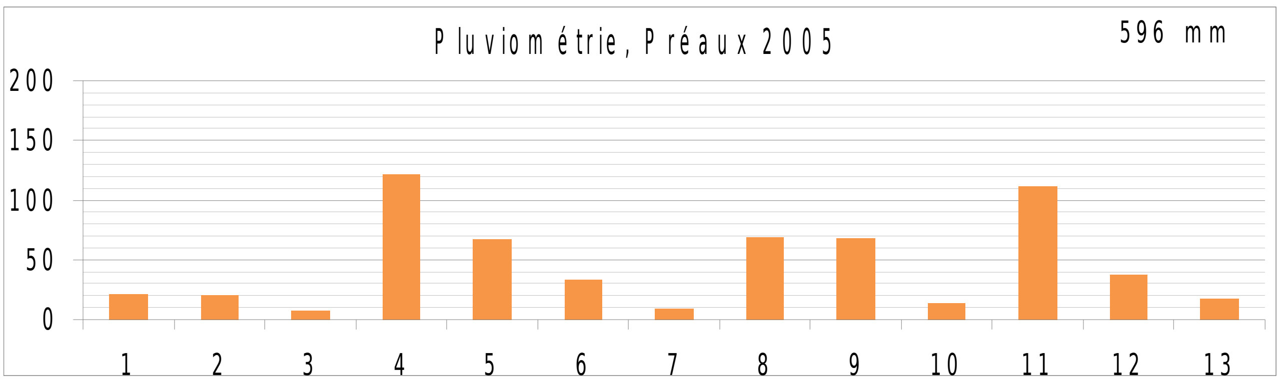


Fig 2:

Rainfall, Préaux, 2005 (summer drought)

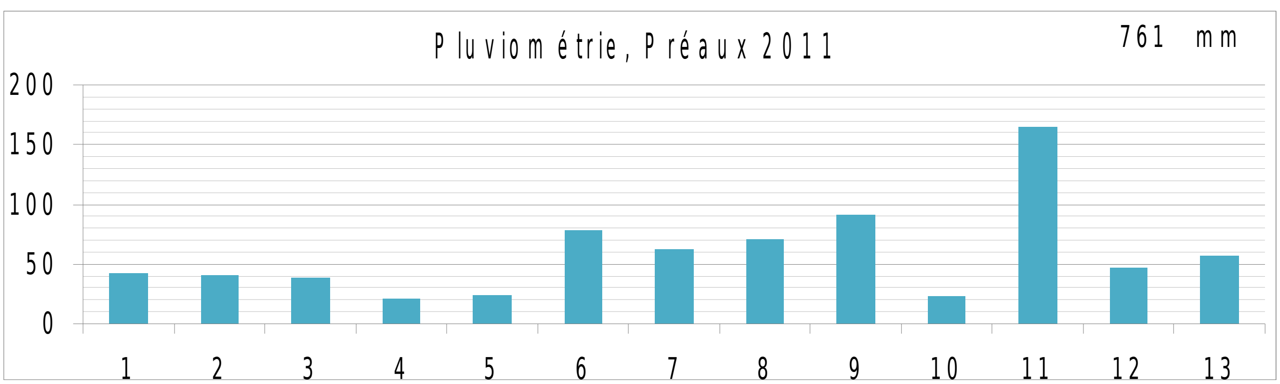


Fig 3:

Rainfall, Préaux, 2011 (spring drought)

Water storage capacity and average temperature diagrams:

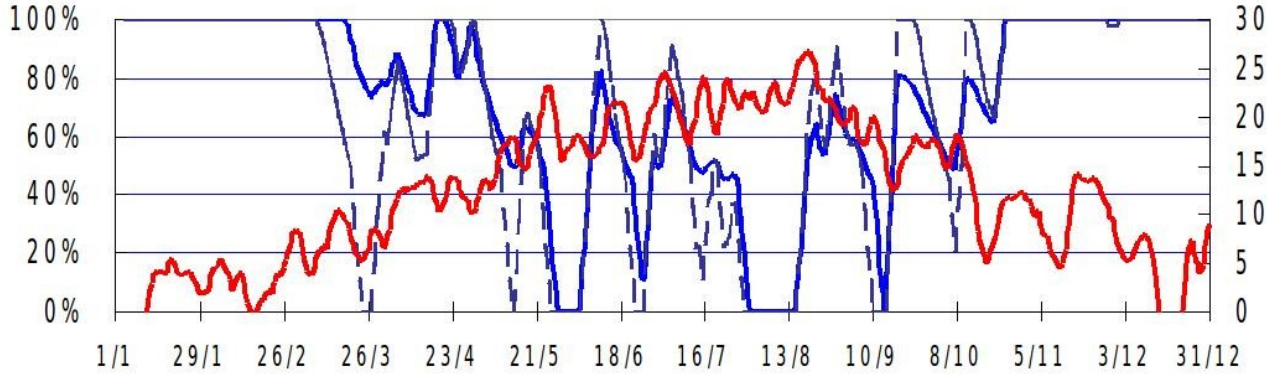


Fig. 4: Water storage capacity and average temperature, Préaux, 2009 (average year)

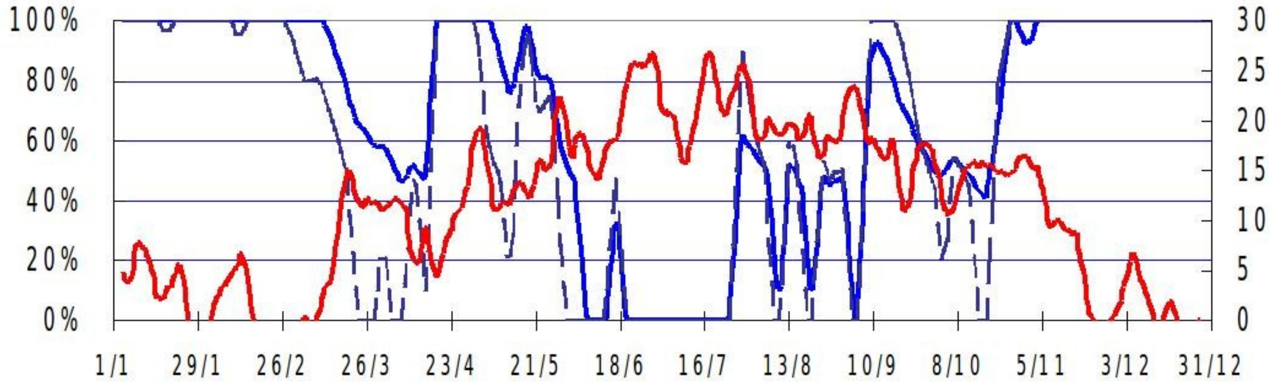


Fig. 5: Water storage capacity and average temperature, Préaux, 2005 (dry summer)

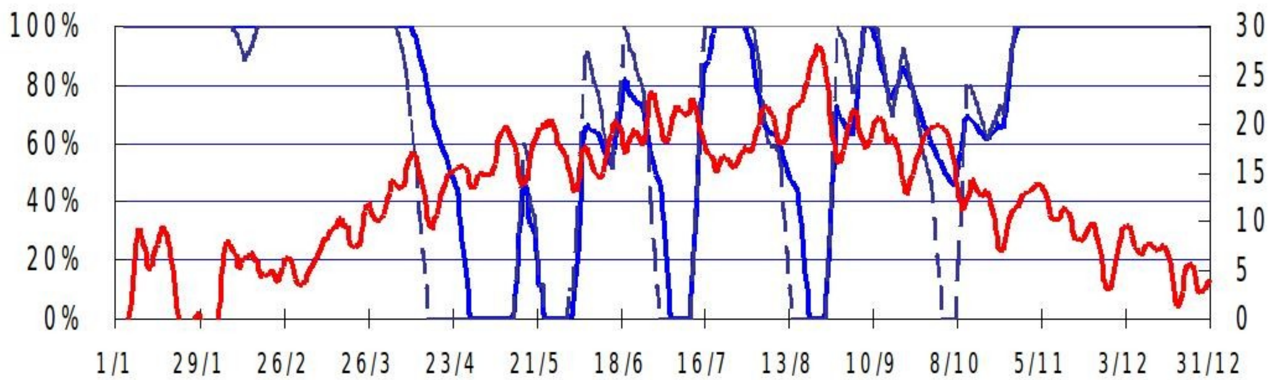


Fig. 6: Water storage capacity and average temperature, Préaux, 2011 (dry spring)

Legend :

- average temperature
- filling/emptying of the Water Storage Capacity for a 80 cm depth soil
- filling/emptying of the Water Storage Capacity for a 40 cm depth soil

Weather data from Meteo France, for the stations of Préaux (rainfall and minimum and maximum temperatures) and Collombier le Jeune (solar radiation and ETP). The same weather data was used both for Workshop 1: North Ardèche, dairy goats and suckling cows and Workshop 2: North Ardèche, dairy cows.

In Isère

In 2010, our "average year", annual rainfall reached 1094 mm with important rainfall in spring and summer: between 100-150 mm per four week period from the end of March to mid June. These wet periods were followed by dryer summer periods: around 50 mm for each four-weeks periods from mid June to mid August (fig 7). The water storage capacity was half empty from mid July to mid September for deep soils (fig 10).
In 2009, our "summer drought", annual rainfall was of 804 mm. The dry period extended from January to October around 50 mm for each period except for period 7 (mid June to mid July) which received only 9.4 mm (fig 8). The water storage capacity was empty by the end of July and in August for both soil types (fig 11).
In 2011, our "spring drought" year, annual rainfall went up to 1132 mm. The water deficit observed in spring, from mid March to mid May: 35 mm for period 4 and 42 mm for period 5, was compensated later in the year (fig 9). The water storage capacity was up to 50% empty at the end of May and mid June for deep soils (fig 12).

Rainfall diagrams:

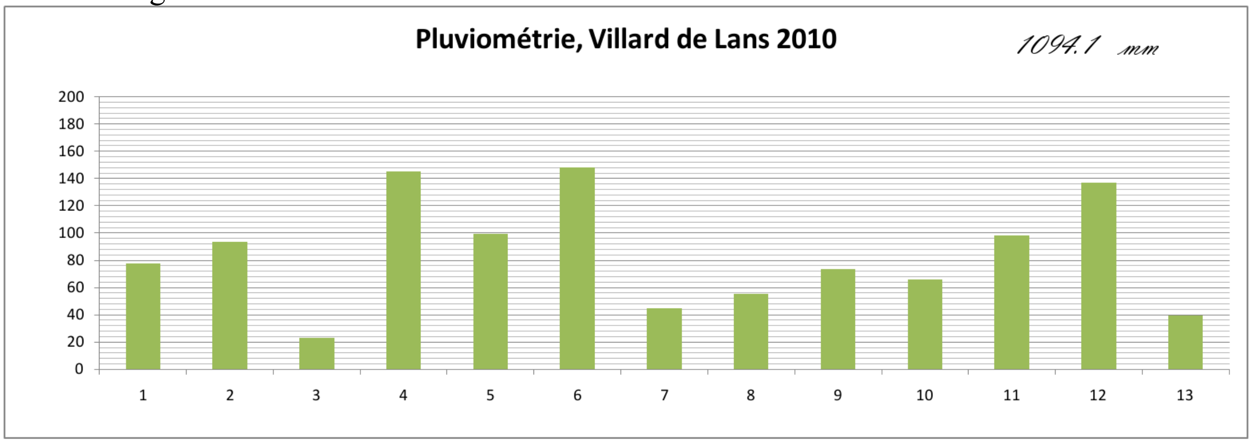


Fig 7: Rainfall, Villard de Lans, 2010 (average year)

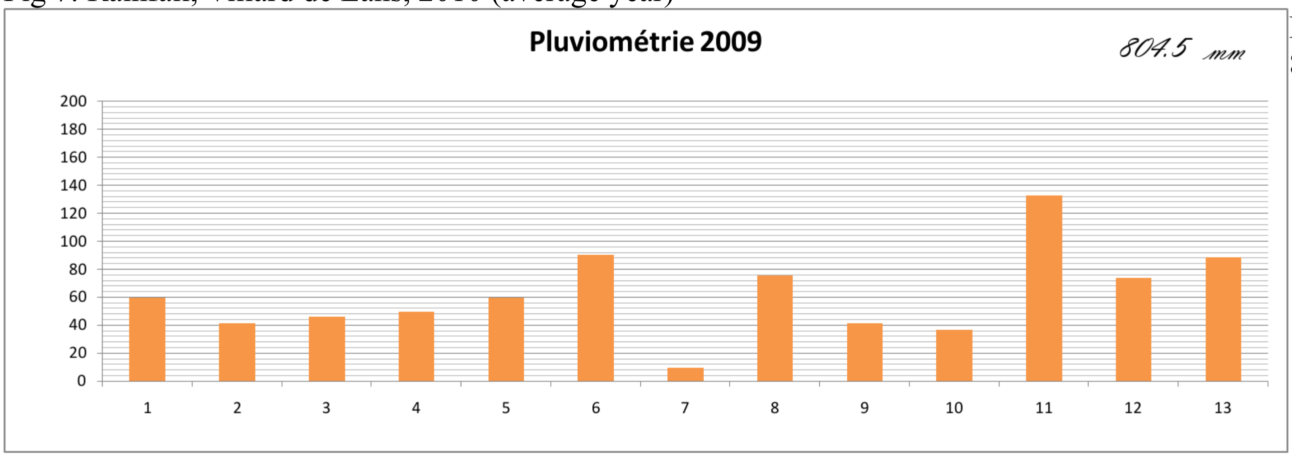


Fig 8: Rainfall, Villard de Lans, 2009 (summer drought)

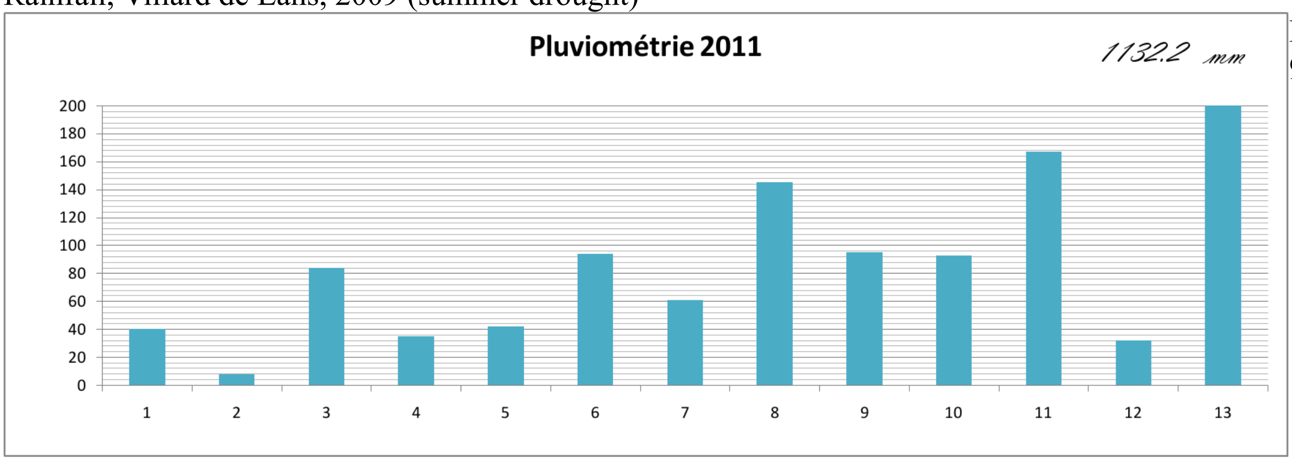


Fig 9: Rainfall, Villard de Lans, 2011 (spring drought)

Water storage capacity and average temperature diagrams:

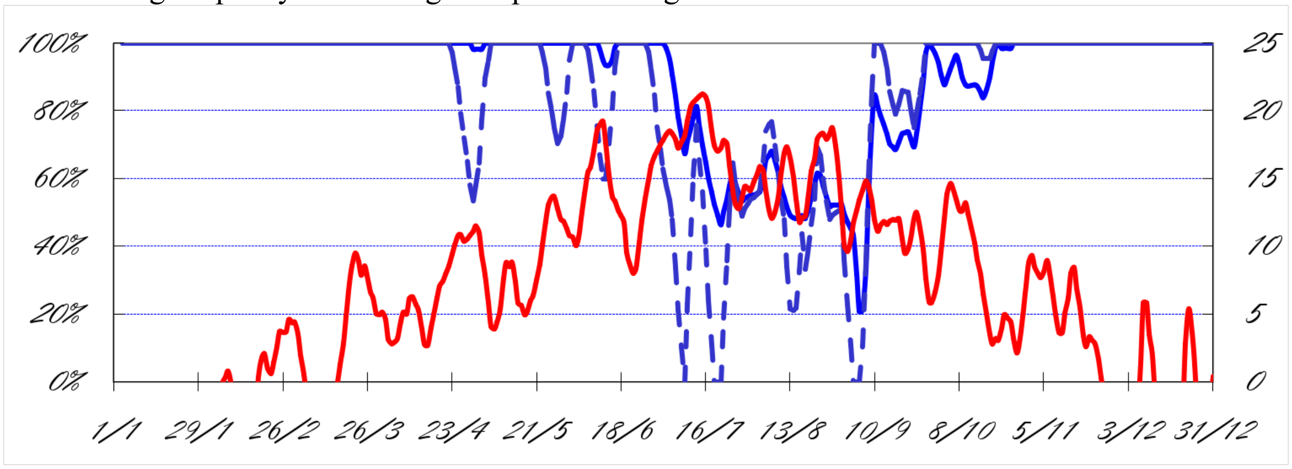


Fig. 10: Water storage capacity and average temperature, Villard de Lans, 2010 (average year)

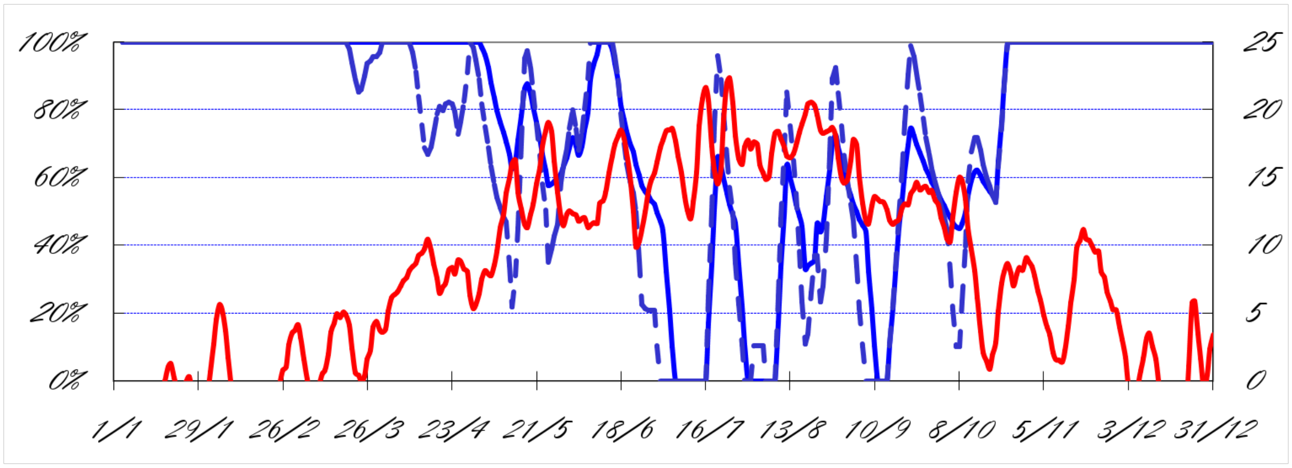


Fig. 11: Water storage capacity and average temperature, Villard de Lans, 2009 (dry summer)

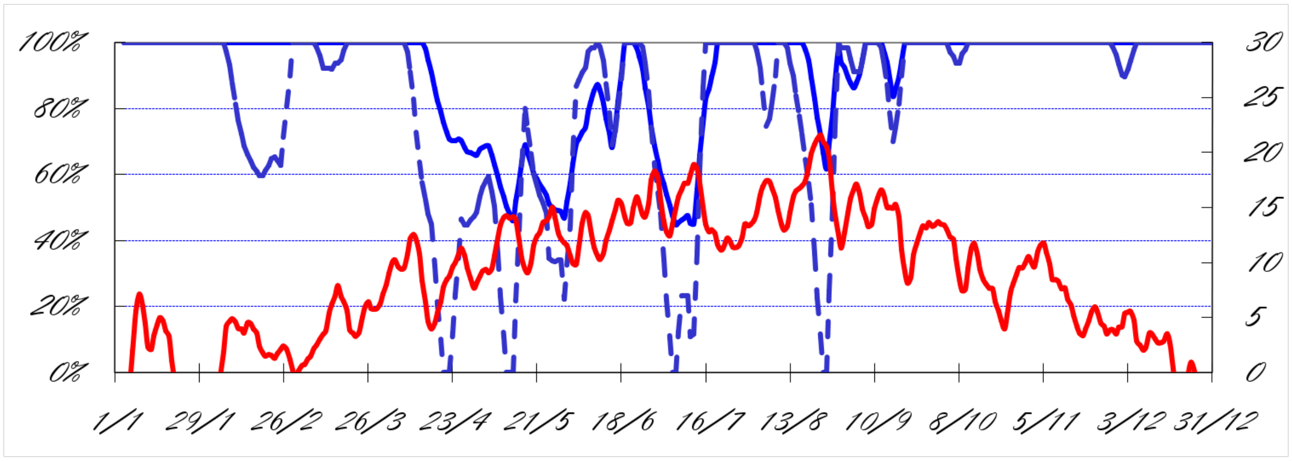


Fig. 12: Water storage capacity and average temperature, Villard de Lans, 2011 (dry spring)

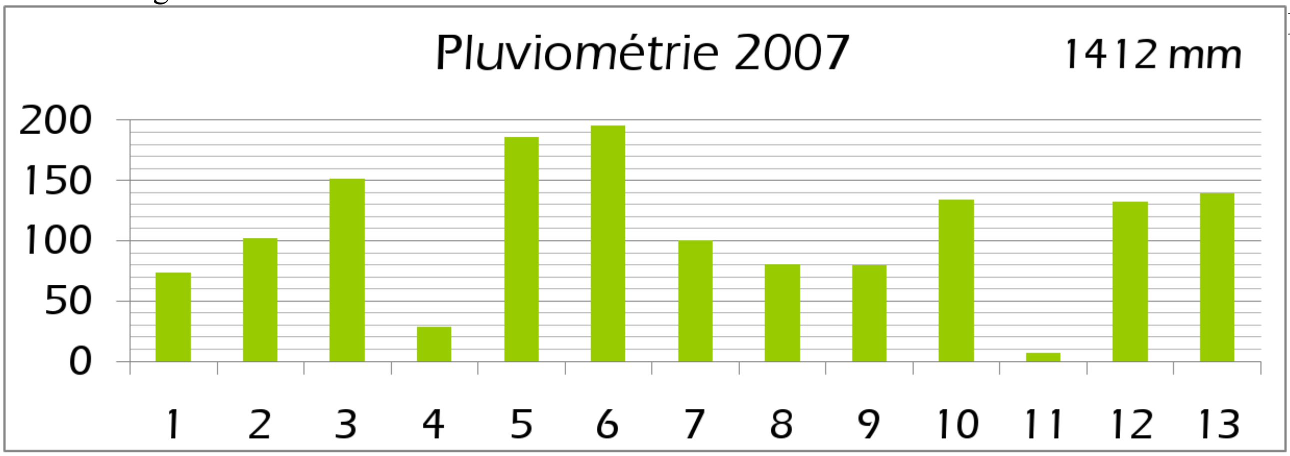
Weather data from Meteo France, for the stations of Villard de Lans (rainfall and minimum and maximum temperatures) and Lus la Croix haute (solar radiation and ETP).

In Drôme

In 2007, our “average year”, annual rainfall reached 1412 mm with a wet spring and beginning of summer: between 150 and 200 mm per four week period from February to June, except for period 4 (April) which received 29 mm only (fig 13). The end of the summer was dryer with around 80 mm per period from mid August to mid September. The water storage capacity was temporarily empty mid July (for deep soils) (fig 16).
In 2009, our “summer drought”, annual rainfall was of 1030 mm, with a dry period in spring from end of March to mid May : around 50 mm for each period. And another dry period in summer: 27 mm for period 7, mid June to mid July (while period 6 received 130 mm of water)(fig 14). The water storage capacity was empty from the end of May to the end of July (fig 17).
In 2011, our “spring drought” year, annual rainfall went up to 1175 mm. The water deficit observed in spring, from mid March to mid May: 30 mm for each period, was compensated later in the year with 100 to 150 mm for the next five periods (fig 3). The water storage capacity emptied up to 50% mid May for deep soils (fig 6).

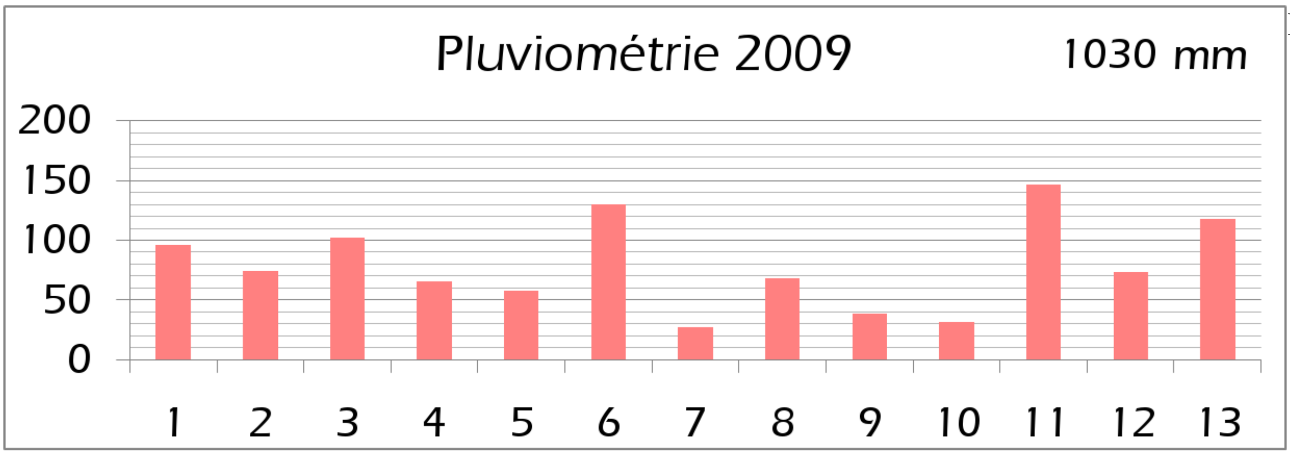
Rainfall diagrams:

Fig 13:



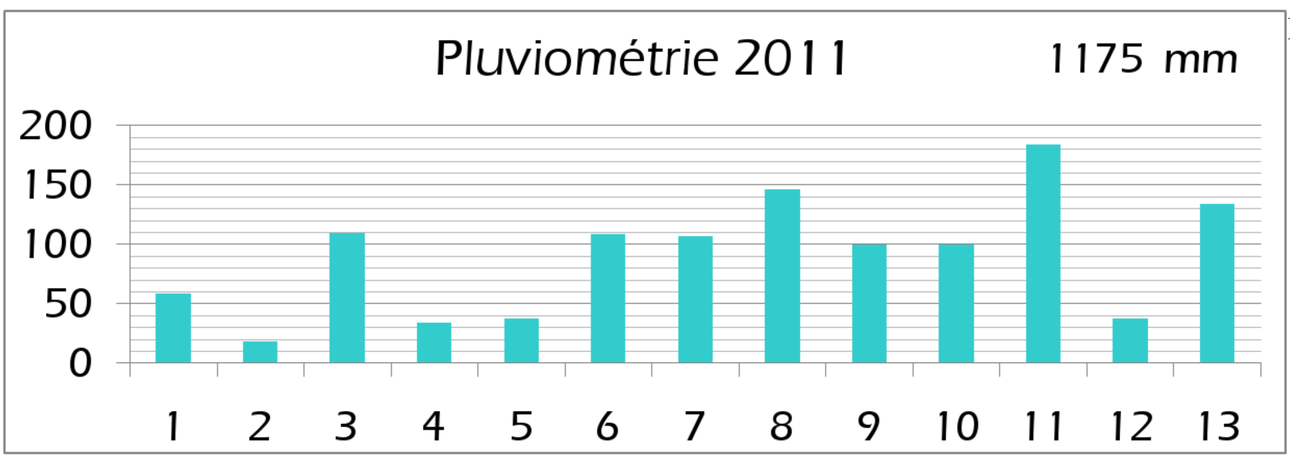
Rainfall, La Chapelle en Vercors, 2007 (average year)

Fig 14:



Rainfall, La Chapelle en Vercors, 2009 (summer dry)

Fig 15:



Rainfall, La Chapelle en Vercors, 2011 (spring dry)

Water storage capacity and average temperature diagrams:

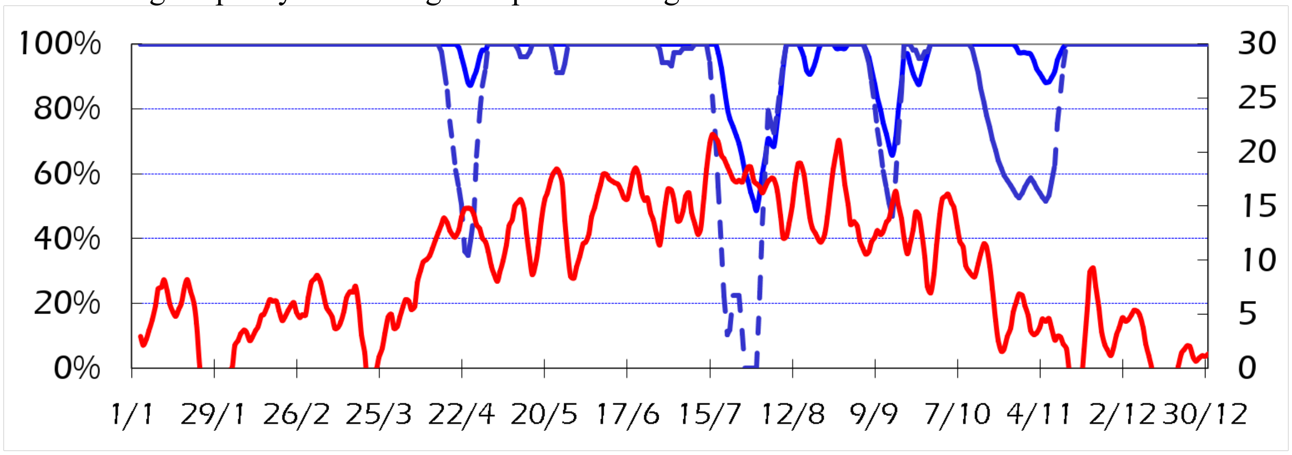


Fig. 16: Water storage capacity and average temperature, La Chapelles en Vercors, 2007 (average year)

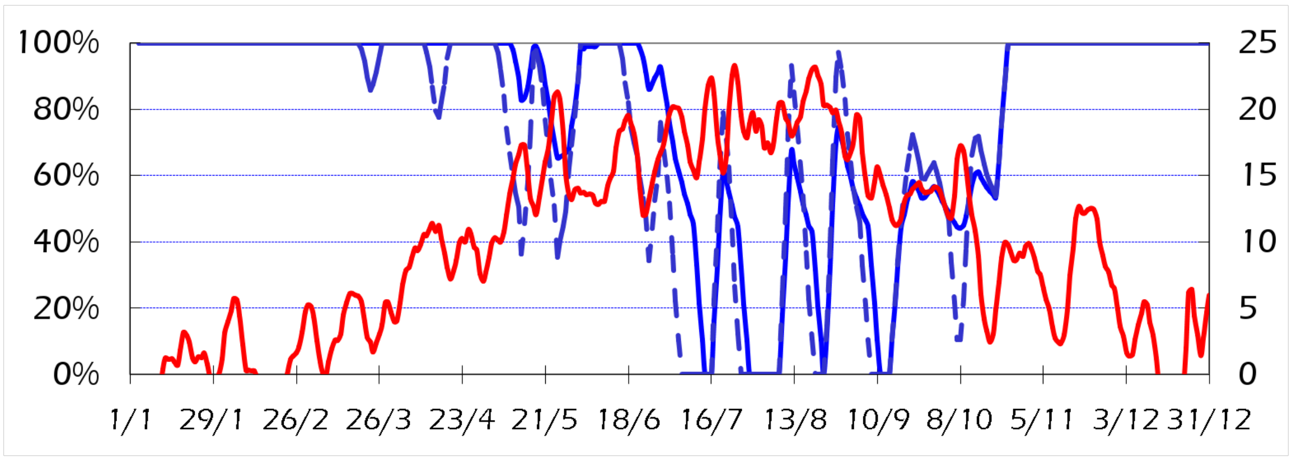


Fig. 17: Water storage capacity and average temperature, La Chapelles en Vercors, 2009 (dry summer)

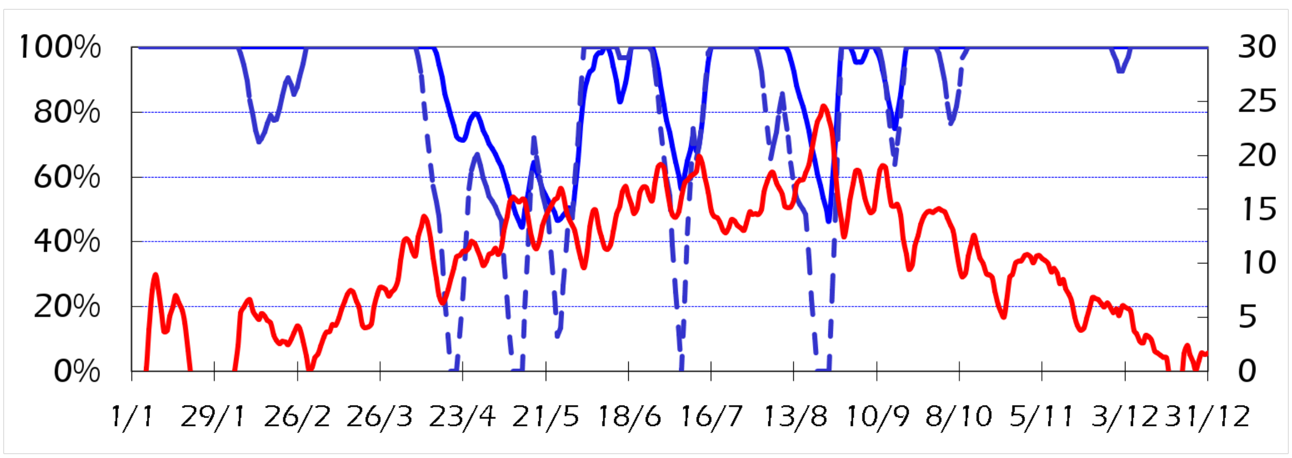


Fig. 17: Water storage capacity and average temperature, La Chapelles en Vercors, 2011 (dry spring)

Weather data from Meteo France, for the stations of La Chapelle en Vercors (rainfall and minimum and maximum temperatures) and Lus la Croix haute (solar radiation and ETP).

Appendix 8: Forage sticks chosen for each workshop

Table 1: Crops distribution over total area for Ardèche system 1

Ardèche 1							
Area (ha)	Type	Descrip -tion	Species	Water storage capacity (mm)	Nutri -tion index	Uses	Harvest dates (°Cdays)
29	PG	Poor pasture	Grass C	50	0.8	G	650-every 800
4.6	PG	Early and productive	Grass A (50%), Grass B (50%)	90	0.9	HG	1000-800-every 600
10	PG	Early and productive	Grass A (50%), Grass B (50%)	90	0.9	GHG	350-800-every 600
18	PG	Late and productive	Grass b	90	0.9	HG	1200-every 800
2.4	TG	Mixed (legumes and grasses)	Lolium perenne (13%), Dactylis glomerata (14%), Festuca arundinacea (23%), Trifolium repens (36%), Trifolium pratense (14%)	120	1	HG	1000-every 600
4.8	TG	Leguminous	Medicago sativa (50%) Dactylis glomerata (50%)	90	0.9	HG	1000-every 600
4.5	C	Cereal for grains					

Table 2: Crops distribution over total area for Ardèche system 2

Ardèche 2							
Area (ha)	Type	Description	Species	Water storage capacity (mm)	Nutri -tion index	Uses	Harvest dates (°Cdays)
5	PG	Early and productive	Grass A (50%), Grass B (50%)	100	0.9	HHG	800-600-every 600
5	PG	Early and productive	Grass A (50%), Grass B (50%)	90	0.9	GHG	350-500-every 600
17	PG	Rich pasture	Grass A (50%), Grass B (50%)	80	0.8	G	400-every 600
5	TG	Leguminous	Medicago sativa	120	1	W	Every 900
17	TG	Mixed (legumes and grasses)	Dactylis glomerata, Trifolium pratense	120	1	WHG	900-1000-every 600

5	C	Cereal for grains					
5	C	Silage sorghum					

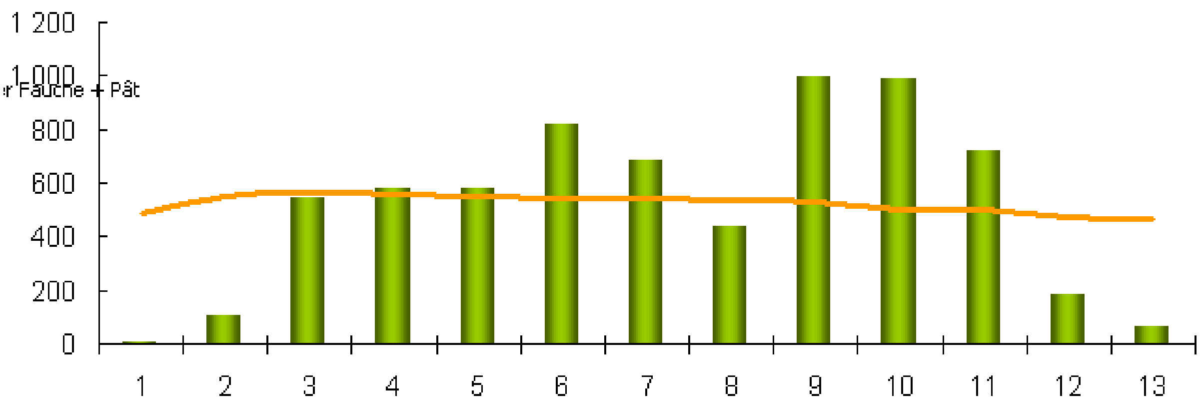
Table 3: Crops distribution over total area for Isère System

Isère							
Area (ha)	Type	Description	Species	Water storage capacity (mm)	Nutri-tion index	Uses	Harvest dates (°Cdays)
30	PG	Early and productive	Grass A (75%), Grass B (25%)	50	0.7	HG	1100-every 600
5	PG	Early and productive	Grass A (75%), Grass B (25%)	50	0.8	SHG	800-1000-every 600
17	PG	Rich pasture	Grass A (75%), Grass B (25%)	50	0.7	G	400-every 600
15	PG	Early and productive	Grass A (75%), Grass B (25%)	25	0.7	HG	1100-every 600
11	PG	Poor pasture	Grass C (100%)	25	0.6	G	650-every 800
10	TG	Mixed (legumes and grasses)	Dactylis glomerata (60%), Medicago sativa (40%)	50	1	WHW	800-1000-800

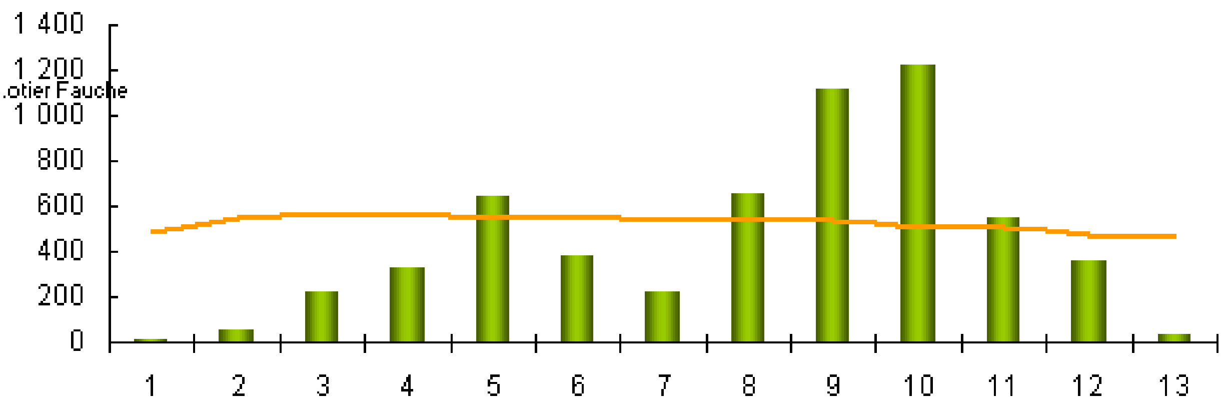
PG= Permanent Grasslands, TG= Temporary Grasslands, C= other Crops
H= Hay, G= Grazed, S = Silage, W= Wrapping

Appendix 9: Pasture available during the different years for each workshop

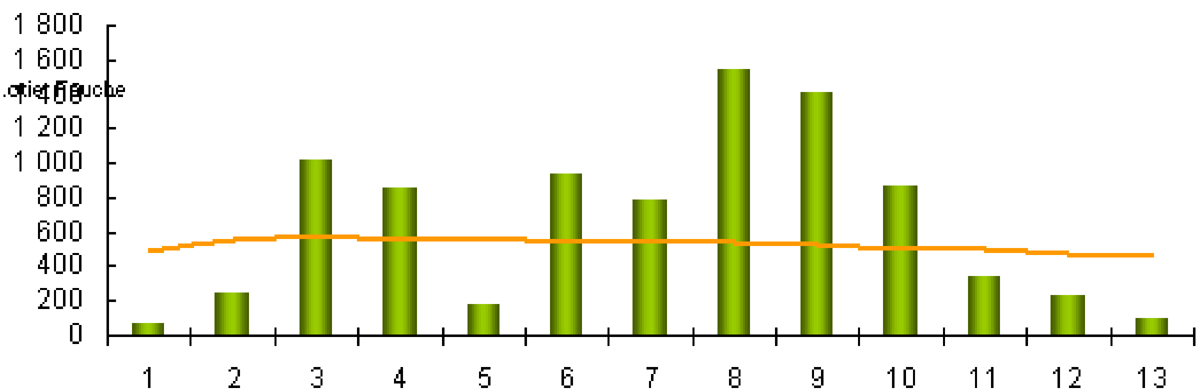
Ardèche 1



Average year, 2009

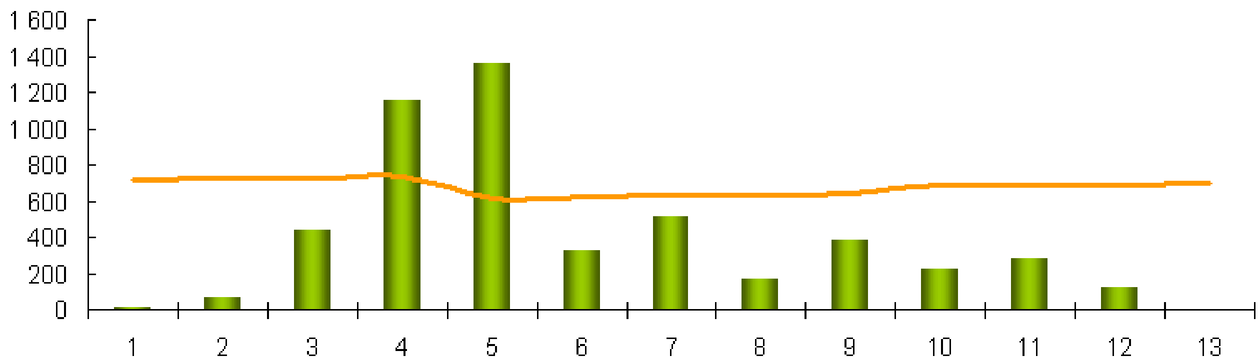


Dry summer, 2005

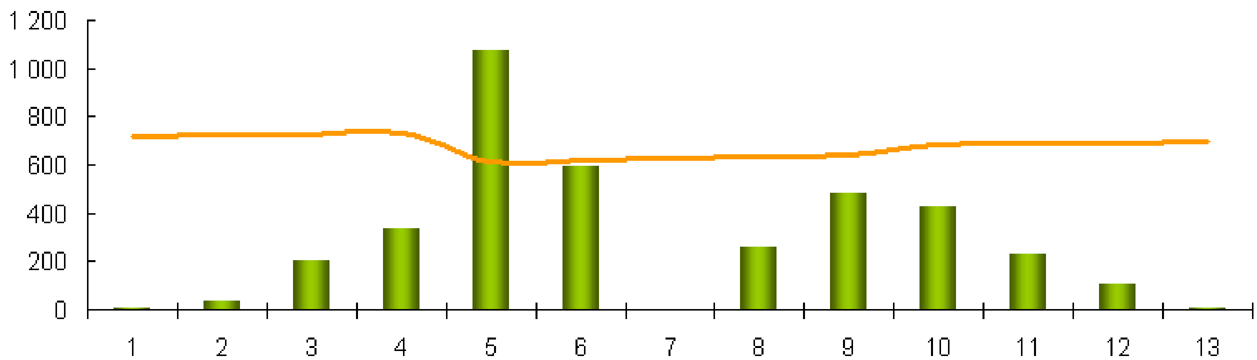


Dry Spring, 2011

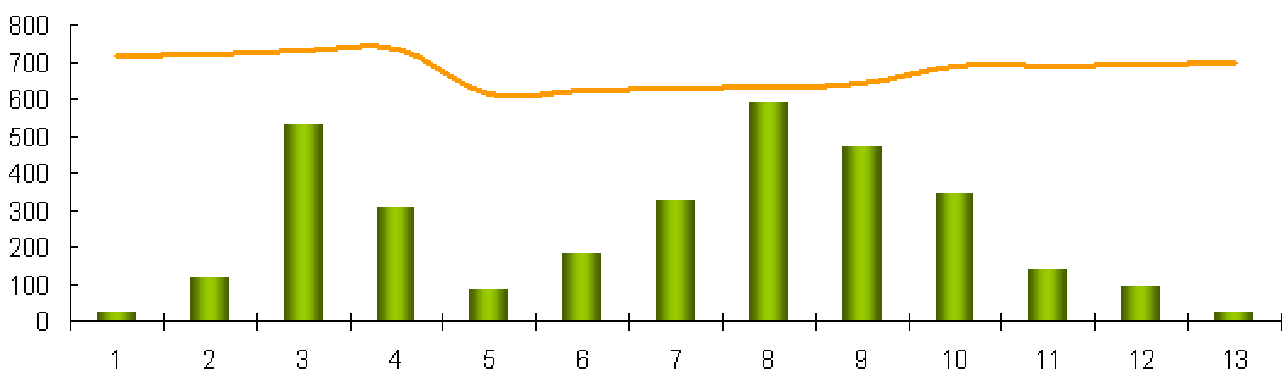
Ardèche 2



Average year, 2009

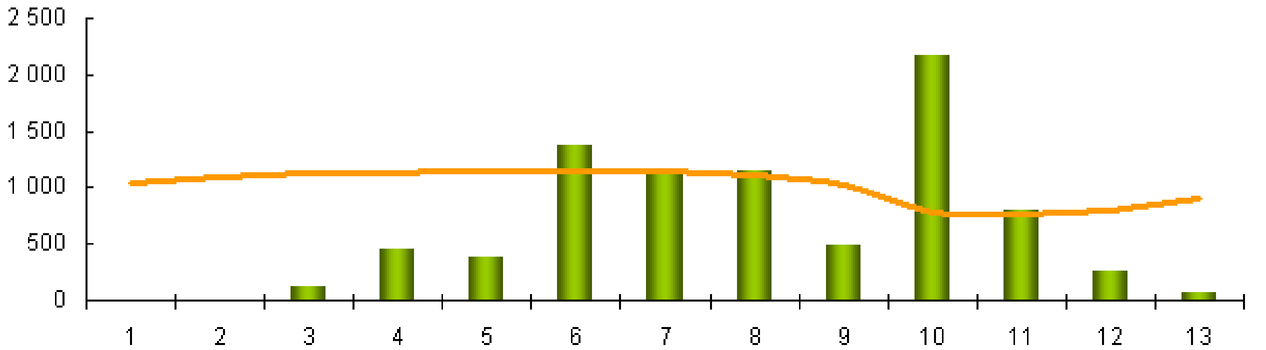


Dry summer, 2005

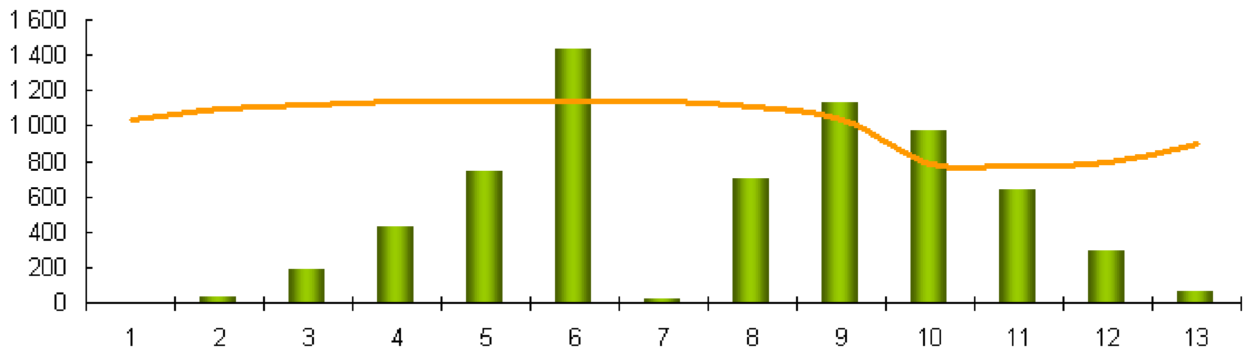


Dry Spring, 2011

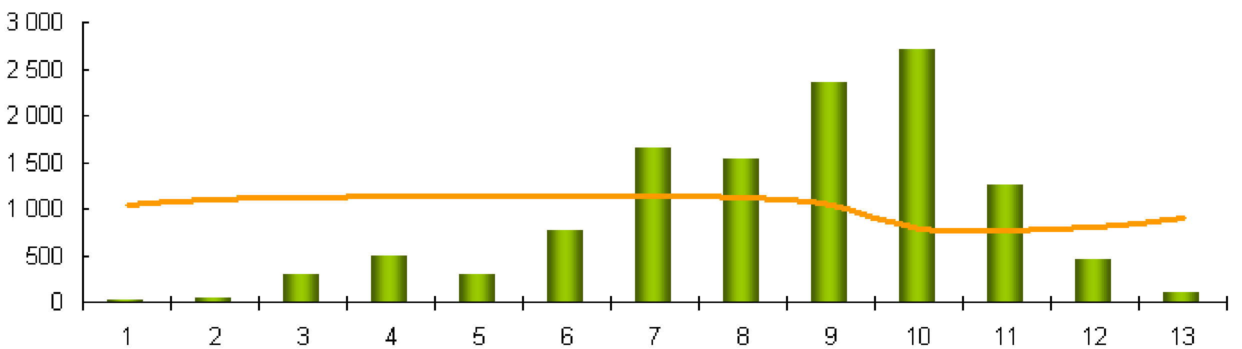
Isère



Average year, 2010



Dry summer, 2009



Dry Spring, 2011

Appendix 10: N, P, K balance

Ardèche 1

Bilan des minéraux

Entrées

	N	P	K
	kg N	kg P	kg K
E1 - Engrais chimiques	328	0	0
E2 - Engrais organiques	0	0	0
E3 - Azote atmosphérique par les légumineuses	0		
E4 - Aliments	822	109	301
E5 - Animaux	0	0	0
Total entrées	1150	109	301

Sorties

	N	P	K
	kg N	kg P	kg K
S1 - Engrais organiques	0	0	0
S2 - Végétaux	0	0	0
S3 - Légumes	0	0	0
S4 - Lait	418	73	143
S5 - Animaux	203	54	26
Total sorties	621	127	168

SAU (ha)
72.0

	N	P	K
	kg N	kg P	kg K
Solde du bilan	528	-18	133
	kg N /ha SAU	kg P/ha SAU	kg K/ha SAU
Solde du bilan	7	0	2

Ardèche 2

Bilan des minéraux

Entrées

	N	P	K
	kg N	kg P	kg K
E1 - Engrais chimiques	**335**	**11**	**35**
E2 - Engrais organiques	**0**	**0**	**0**
E3 - Azote atmosphérique par les légumineuses	**975**		
E4 - Aliments	**4977**	**597**	**1147**
E5 - Animaux	**0**	**0**	**0**
Total entrées	**6287**	**608**	**1182**

Sorties

	N	P	K
	kg N	kg P	kg K
S1 - Engrais organiques	**0**	**0**	**0**
S2 - Végétaux	**0**	**0**	**0**
S3 - Légumes	**0**	**0**	**0**
S4 - Lait	**1853**	**323**	**527**
S5 - Animaux	**272**	**79**	**46**
Total sorties	**2125**	**402**	**573**

SAU (ha)
62.0

	N	P	K
	kg N	kg P	kg K
Solde du bilan	**4161**	**206**	**609**
	kg N /ha SAU	kg P/ha SAU	kg K/ha SAU
Solde du bilan	**67**	**3**	**10**

Isère:

Bilan des minéraux

Entrées

	N	P	K
	kg N	kg P	kg K
E1 - Engrais chimiques	325	184	581
E2 - Engrais organiques	0	0	0
E3 - Azote atmosphérique par les légumineuses	0		
E4 - Aliments	14	2	5
E5 - Animaux	0	0	0
Total entrées	339	186	586

Sorties

	N	P	K
	kg N	kg P	kg K
S1 - Engrais organiques	0	0	0
S2 - Végétaux	0	0	0
S3 - Légumes	0	0	0
S4 - Lait	1584	276	450
S5 - Animaux	273	80	47
Total sorties	1857	356	497

SAU (ha)
88.0

	N	P	K
	kg N	kg P	kg K
Solde du bilan	-1518	-170	89
	kg N /ha SAU	kg P/ha SAU	kg K/ha SAU
Solde du bilan	-17	-2	1

Appendix 11: Carbon sequestration calculation

Ardèche 1	
Animals	Kg C eq/ an
125 Goat	12750
20 Suckling cows	14240
2 Heifers	830
35 young goats	1260
5 males	605
TOTAL Animals	30 t C eq / an
Crops	Kg C eq
Produced on farm	
68.8 ha grasslands	24706
4.5 ha cereal	3528
TOTAL Crops on farm	28 t C eq
Bought	
Cereal	1568
Soja	811
TOTAL Crops bought	2.4 t C eq
TOTAL Crops	30.4 t C eq
TOTAL	60.4 t C eq

Ardèche 2	
Animals	Kg C eq/ an
39 dairy cows	37284
15 Heifers	6225
TOTAL Animals	43.5 t C eq / an
Crops	Kg C eq
Produced on farm	
49 ha grasslands	17596
5.2 ha cereal	4077
7.5 ha sorghum	4740
TOTAL Crops on farm	26 t C eq
Bought	
VL 3L	unknown

Potatoes	295
Dried distiller grains	unknown
Soja	6488
Cereal	1097
TOTAL Crops bought	7.8 t C eq
TOTAL Crops	33.8 t C eq
TOTAL	77.3 t C eq

Isère	
Animals	Kg C eq/ an
50 Dairy cows	47800
15 Heifers	6225
TOTAL Animals	54 t C eq / an
Crops	Kg C eq
Produced on farm	
88 ha grasslands	31601
TOTAL Crops on farm	32 t C eq
Bought	
Cereal	5174
Deshydrated alfalfa	unknown
TOTAL Crops bought	5 t C eq
TOTAL Crops	37 t C eq
TOTAL	91 t C eq

Author:Anne BROGI **Year: 2013**

Topic category:

(Do not write in this box)

TITLE: Fostering adaptation of livestock systems to climate change: implementation of Forage Rummy and implementation analysis in southeastern France

Key-words :(max 6) climate change, adaptation, forage, participatory, agroecology

Mots clés: (6 max) changement climatique, adaptations, fourages, participatif, agroécologie

Résumé: (15 lines)
Dans un contexte de changement climatique diminuant la production fouragère, le conseil agricole évolue pour répondre aux nouvelles attentes des agriculteurs. Le Rami Fourrager a été conçu comme outil collectif, non prescriptif, pour mobiliser les agriculteurs et réfléchir à la conception des systèmes agricoles, à leurs réponses au changement climatique et à des possibilités d'adaptations.

Ce rapport présente l'adaptation du Rami Fourrager en région Rhône-Alpes. Outil perçu comme unique permettant de visualiser l'impact du changement climatique sur les systèmes agricoles, de donner une nouvelle approche du bilan fourrager, ainsi que d'ouvrir la discussion sur un grand nombre de thématiques. Cependant, des problèmes techniques, relatifs aux connaissances et organisationels sont survenus. Ce qui a mené à la formulation de recommendations concernant l'utilisation des données climatiques, le format des ateliers et les profils des participants.

L'analyse des systèmes agricoles et des adaptations proposées à l'aide d'indicateurs agroécologiques pour mesurer l'autonomie, la diversité et l'impact environemental de ces systèmes a montré qu'une optimisation de la production par animal, ainsi que des résoltes précoces, et des mises-bas de printemps pouvaient être des éléments à considérer pour les renforcer face au changement climatique.

Abstract: (15 lines)
In the context of climate change affecting grassland production, the role of extension services is evolving to match Farmers' new expectations. Forage rummy was conceived as a collective non prescriptive tool to engage farmers in reflection on farm systems design, asses their response to the changing climate and reflect on possible adaptations.

This report presents the implementation of forage rummy in the Rhône-Alpes region. It was found to be a unique tool to visualize the impact of climate change on the farm system, giving new insights on forage balance and opening dialogue on multiple issues. However, technical, knowledge related and organizational problems occurred and recommendations for its use were made. They include details on the use of climatic data, format of workshops and profiles of participants.

Analysis of the farm systems and the adaptations proposed through the use of forage rummy was conducted to assess their sustainability. Agroecological indicators measuring autonomy, diversity and environmental impact showed that an optimum production per animal, early forage harvest, and spring calving are aspects to be considered to strengthen the farm systems studied. And that forage rummy can be used in an agroecological approach.

Total number of volumes:1
Number of pages of the main document:50

Host institutions: INRA-Toulouse and Chamber of Agriculture of Ardèche