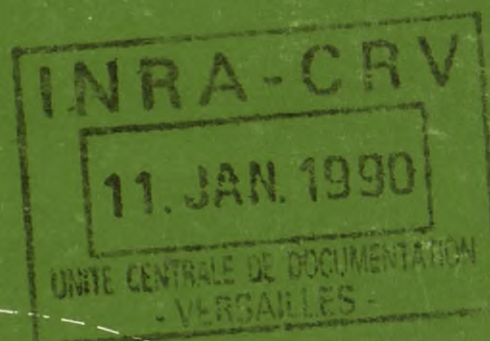


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Grassland Systems Approaches

Some French Research Proposals

Editor : A. CAPILLON



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Some French Research Proposals**

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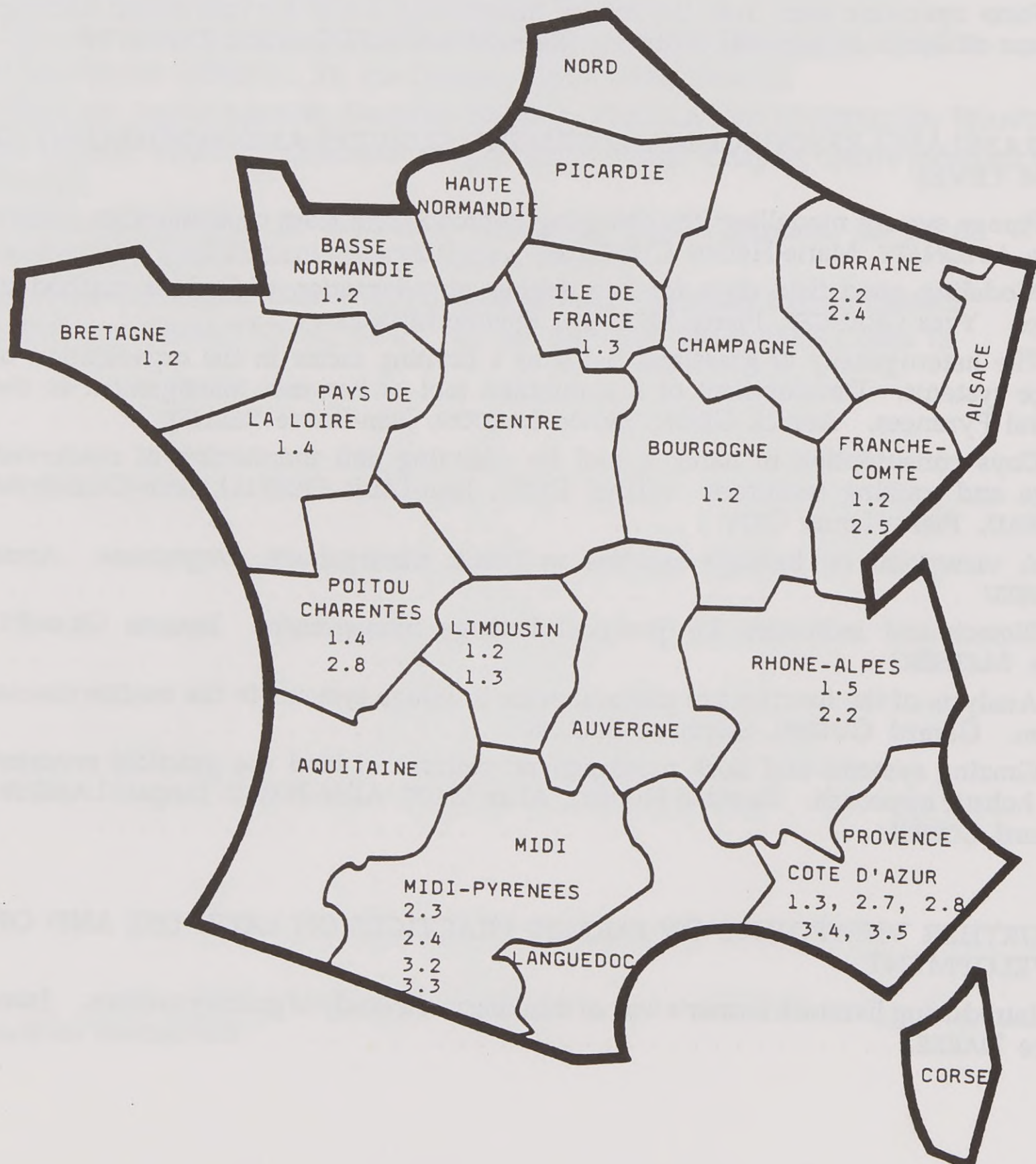
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Foreword

Changes in the objectives of French agricultural policy over the last half-century have had profound repercussions on concepts and approaches in agronomy. Before the Second World War, the salient feature of French agriculture was a diversity of regional agrarian systems. The war years reinforced the endogenous, family-farm type of development, centered on the individual unit and the immediate surroundings.

During the late Forties, this climate was superseded by the will to modernize and to increase interaction with input and output processing industries. The unitary yield of biological stock (plant or animal populations) was a sufficient yardstick of efficiency, whether of farm units or regional or national activity. Faith in research and new techniques was boundless and led to unconditional accumulation of the latter as and whenever they emerged in the production-processing chain, making it more and more dependent on industrial inputs.

The energy crises and awareness of environmental degradation in the Sixties, followed by the saturation of solvent markets, meant that productivity-driven research saw the emergence of a quest for cost-effectiveness and self-reliance (cf. J. POLY "Towards cost-effective and self-reliant agriculture", 1978). This position gave implicit recognition to the value of former models still surviving in areas considered as hostile to technical advance. The standpoint was certainly not nostalgic however and the able choice of catchword explained the political popularity of the concept, since it gave no explanation whatsoever as to which levels of organization should aspire to such autonomy. Did it mean self-reliance on the individual plant level, of plant cover, of production units within farms, of whole farms, or the independence of agricultural areas holding the natural resources of the Nation or indeed of wider entities such as the Common Agricultural Policy ? Expressions such as "the technical itinerary of the crop", the "farm as a system" or "integrated rural development" all reflected a desire for better understanding of the organization of biological, agricultural or rural entities in

order to increase the potential for endogenous use of natural resources.

The proposal for self-reliance was superseded in the Eighties by the call for diversity. This pointed to the fact that self-reliance is only possible on one level of organization if, on the lower levels, other factors can also be organized to reduce dependence on the environment. More specifically, it betokened recognition of the existence of agricultural models that differ widely in their aims, their internal organization (production and techniques) and the way they link in with the economy in general. In short, interdependence between multiple levels of organization has emerged as a fully-fledged factor in development (diversification).

Today, this trend towards diversity is taking on a more worldwide aspect (as an expression of global change) and a more dynamic tendency (the sustainability of agrarian systems). Agricultural activity is seen as an integrant factor of both agribusiness, on one hand, and of the rural environment on the other ; internal balance is a cause for concern. Agriculture is thus seen as part of complex area-specific man-managed system. Agricultural research should be based on the study approaches and methods of these systems associating the protagonists (or subjects) and their projects with the objects or means with which they work. This new angle has led to a fresh spurt of research on agrarian systems and to an enrichment of the issues and approaches of agronomy in the widest sense of the term.

It is no coincidence that herbage production has lagged behind in the yield and productivity movement, on one hand, and has been less influenced by the new methods used in research on the other. Grass is not usually marketed as such. Moreover, due to the low efficiency of conversion from grass to animal production, good grassland management calls for direct grass consumption by herds, and therefore simultaneity between grass growth dynamics and the changing needs of the farm's herd. This synchronization is particularly hard to master when, for dairy herds especially, high milk production targets would suggest that high-level intake should be encouraged. This explains the volume of long-standing research aiming at the adaptation of agronomic techniques to forage systems and the observation of results in animal production terms compared to reference animal husbandry systems.

These technical systems, designed and implemented by researchers soon fell short of widespread user requirements. The study of a variety of situations where the systems proposed were wilfully not applied led some researchers to realize, as early as 1970, that this was not solely due to the ignorance of the farmers : the latter had reasons for their own practice drawn from their situation and their own personal projects. If extension workers managed to fill the gap between Research and Action, social and biotechnical observation and interpretation of the farmer's production practices became a subject for a number of researchers. Research for them had shifted emphasis from a normative, prescriptive role to Action this being the only way to understand the links between the forage systems and the animal production systems. Linear research procedures were giving way to "successive loops" comprising a diagnosis (definition of questions), the elaboration of a suitable frame of reference, a prediction as to the future dynamics of the systems thanks to technical change, and verification/corroboration. The production quotas that hit the dairy industry first and foremost, the reduction of the "prices scissors" (and thus producer leeway) mean that modes of production have greater

repercussions on production systems efficiency today than the quest for maximum yield.

Socio-economic and ecological changes now show the importance of other levels of organization. In the sectors where processing is strong, the diversification of product lines can result in stricter norms for raw materials. The multiple uses of milk, for example, have imposed changing specifications on dairy farmers. In different types of animal production units, grassland can reflect the extremes of man's influence on the natural environment : from nitrate pollution (due to intensive tillage) to the invasion of land "set aside" by shrubs and non-grass species (due to extensive grazing). The appearance of the landscape remains a useful measure of the degree of mastery of the interface between animal production systems and the ecosystem complexes they use ; this factor should be integrated into local or regional planning considerations.

Grassland research should see itself as part of a Action/Research approach to complex man-managed systems. These systems use the interface between the two biological compartments, i.e. herbivores and forage areas, on a number of closely-connected organizational levels.

The aim of this book is to present a collection of French research projects concerning these problems. The idea originated in several French research teams, especially in the Department on Agrarian Systems and Development founded ten years ago in INRA.

This Department's general objective is the study of agrarian systems, i.e. the spatial association of production and techniques implemented by a society in order to meet its needs. Of special interest for this research are the dynamics of these systems, their sustainability : their understanding should help to improve the methodologies of agricultural development.

Its more specific task is to assess the adequacy of available technologies as regards the requirements and constraints of the bio-ecological and socio-cultural environment on land use systems (crops, forestry and animal husbandry). The interdisciplinary field of this research, giving priority to a systemic approach, requires the involvement of scientists from the main research disciplines as well as professors from universities and agricultural training establishments. By confronting on the geographical region and farm level, an analytic and a systemic approach, the department aims to stimulate relationships between agricultural research and its social users.

In practice, the activity of the Department is based on a limited number of projects regionally located around experimental and private farms which provide observation fields representative of the existing and potential environments and is carried out in cooperation with extension service workers involved in agricultural development in these areas.

If this approach was initially applied to problem areas, it is because the hypothesis of the complexity of phenomena was accepted there more readily than elsewhere, being the only indispensable solution to development requirements. But experience has shown that this approach and its methodology are in fact useful on a wider scale. As is often the case, research on off-target situations can give results that are very pertinent to more central topics.

In this work, the English translation of certain terms is difficult, particularly when the concepts and methods referred to are still being elaborated, or still being tested on concrete situations. Comment and criticism are very welcome in this field.

Finally, the priority objective is to raise new issues, to enrich research methods on grassland in order to give better answers to the needs of the farmers. We can certainly not assume that these papers will give rise to operational procedures for Development. Indeed, we should always remain modest. Lengthy comparison and exchange between researchers and the protagonists in the field, between the former's models and the latter's practice will be necessary to achieve this goal.

This "food for thought" will have proved palatable if the workshop that it introduces were to come up with original papers, from researchers from various countries and were to produce material for the publication of Volume II.

Bertrand VISSAC
Head of Department

Introduction

This work was compiled on the occasion of the International Grassland Congress. It aims to encourage exchange with researchers in other countries. It is, *inter alia*, a contribution to the "Research on Grassland Systems" workshop and an invitation to initiate or develop cooperation between teams of research workers.

Most of the authors belong to the Research Department on Agrarian Systems and Development (SAD) of INRA. Five of the eighteen articles were written by researchers from other departments or by development agronomists who have collaborated with SAD in the course of their work.

All the authors deal with decision-making aids in grassland systems. The balance between forage resources and requirements in livestock enterprises in terms of both space and time needs to be managed. For livestock farmers and those who work with them (development and training staffs included), recommendations should be coherent with the pursued aims and the available means ; they should also give answers adapted to the environment. The overall economic context, because of its unpredictability, means that new and improved systems must be designed to be sufficiently flexible and to take account of the corresponding management factors. The task in hand is to find ways of optimizing use of grassland resources and thus get the most out of the grazing species.

This type of programme assumes that methods of research must be elaborated in order to understand the technical choices in animal and forage production ; these technical choices are reintroduced in a wider-based study that includes other parameters affecting the decision-making process of the farmers. The starting point for these studies is the observation of forage areas and livestock farms with a view to understanding and thus improving them.

It is useful to refer to positions stated almost thirty years ago. William

DAVIES in his work "The Grass Crop : its development, use and maintenance" (1960) already felt the usefulness of this approach :

"To know the ultimate reason why the observed response takes place is more difficult and more time-absorbing. It is by the combination of "know how" and "know why" that real progress will be made. Progress is the key word and progress will much depend on research and practice being closely interwoven. Both practice and science must follow the paths of change, each working with the other as one harmonious whole to develop new knowledge and to provide sufficient facilities for the farmer and, through him, for the agricultural industry in general."

French systems described in this work can be studied from a number of different viewpoints, depending on the degree of knowledge of them, but also of the disciplines involved. To the diversity of agricultural situations must therefore be added the multiplicity of research approaches. Pluridisciplinarity of research teams means that several standpoints are compared and an approach is elaborated in terms of the questions we wish to answer.

This thus leads to the representation of the working of grassland systems using modelling or the elaboration of suitable technical frames of reference on the basis of data acquired by more sectoral disciplines (agronomy, animal production...) ; thus, the observation of the feeding of fodder to mountain cattle has demonstrated the importance of winter grazing and has demonstrated the importance of winter grazing and has raised questions on the growth of plant cover in extreme conditions. Other approaches aim to build up scenarii on the implementation of improved or new systems or suggest short, medium or long term appraisal methods. Lastly, using grassland systems as a starting point, clearer understanding of land use and the effect of animal production practices on it is made possible.

This volume aims to raise the question of diversity of approach.

In the first part "Diversity of forage resources and grazing livestock in France" the main lines of current French research on grassland systems are sketched out : A. HENTGEN describes the role of the wide variety of forage resources in a country where agriculture extensively involves the raising of grazing livestock and grasslands. J. BONNEMAIRE and C. RAICHON present the changes in forage resources over the last 60 years and suggest an interpretation of the orientations of five beef production areas in a dynamic approach to agrarian systems. A. BLANCHEMAIN sketches the broad lines of change in sheep production regions, discusses the adoption of a number of modern techniques and suggests solutions for better management of this wide diversity of situations.

To this wide range of geographical regions, we must add the different types of farms in the same region. Full acquaintanceship with the different farm types means that research on forage systems can be designed and targeted and technical proposals can be more finely differentiated. A. CAPILLON et al., B. JEANNIN and B. CRISTOFINI present and illustrate this approach with two regional studies. The second part : "Grassland resource management : surveys and modelling at farm level" presents approaches used for the understanding and improvement of grassland systems at various levels of integration : the plot, total farm surface, herd, farm...

The economists J.M. ATTONATY and M.H. CHATELIN put forward an analysis of the evolution of their modelling approaches and show that the farmer himself must be taken into account at the design stage of any model.

Two articles give an account of forage harvesting management for the plots on one farm ; Y. GRANGER et al., for the climatic risk appraisal in hay drying and A. GIBON et al., for the simulation of harvesting management.

Two other articles discuss the management of forage resources from the point of view of their use by the herd : M. DURU et al., suggest a concept enabling interpretation of the farmers' decisions as concerns grazing and stock control : "days in hand". They apply the approach to dairy farms.

A. MATHIEU uses a survey method to show different ways of managing pasture land integrating chronological order and any adjustments that affect the herd or the forage supply during that period : J. GILIBERT and A. MATHIEU suggest sward and herd condition indicators for grassland management. G. GUERIN and S. BELLON show how their approach to the forage system can describe farmers practice in the use of varied plant cover in the Mediterranean area and the specific role of each plot of the farm. B. HUBERT et al., put forward a trial modelization of annual use of grazed plots on a farm in order to appraise the efficiency and sustainability of the systems.

The third part, "Further viewpoints on farm practices, on land use and on development", is a collection of articles giving other points of view on the grassland systems.

J.P. DARRE reminds grassland systems analysis experts that livestock farmers have their own ideas and these must not be ignored when researchers claim to supply decision-making aids. J.L. ROUQUETTE describes an original technical reference build-up experience using groups of farmers and suggests systems considered sustainable and accessible to other farmers.

The last three papers deal with the relationships between grassland systems and the use of space. G. BALENT puts forward a hierarchical analysis of the ways in which space is used by a pasture system in the Central Pyrenees. E. LANDAIS and J.P. DEFFONTAINES base their study on the observation of shepherd practices in the Southern Alps in order to analyze the management of a pasture area. Lastly J.P. DEFFONTAINES and S. LARDON suggest the wider view of agrarian systems in order to build up an approach to grassland management seen in terms of spatial management.

In compliance with the usual procedure of research institutions, the drafting committee has selected articles and overseen the publishing of the work. This publication aims to promote exchange and discussion between members of the international scientific community and therefore includes reports on completed research or on ideas for research or articles on approaches to grassland systems. Each article is therefore published under the sole responsibility of its author(s).

We hope that this volume will interest the reader and provide food for thought and debate on ideas and methods and thereby enhance the corpus of knowledge of both the reader and the authors !

The Organizing Committee

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Regional diversity in forage resources in France

Philippe LAFITE

1. Diversity of forage resources and grazing livestock in France

The diversity of forage resources in France is the result of a long history of agricultural development. The country is divided into several regions, each with its own specific forage resources. The diversity of forage resources is also reflected in the diversity of grazing livestock. The main types of grazing livestock in France are cattle, sheep, and horses. Each type of livestock has its own specific requirements for forage resources. The diversity of forage resources and grazing livestock in France is a result of the country's long history of agricultural development and its diverse geographical and climatic conditions.

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1. Diversity of forage resources and grazing livestock in France

Regional diversity in forage resources in France

André HENTGEN

Summary:

The raising of grazing livestock plays an important role in the agricultural economy of France. The last French National Agricultural Census in 1979 (RGA, 1979) gives a wealth of data concerning the technical and economic orientation (OTEX) of French farms: for 57.3% of these grazing livestock generating at least 1/3 of the gross margin. Other important data concerning the Utilized Agricultural Area and the area devoted to permanent grassland, leys and annual forage crops show the importance of forage production in France. A specialized survey was carried out on farms with some level of livestock grazing and helped to specify some aspects and to emphasize inter-regional diversity. It is concluded that any study or research programme aimed at development must take this diversity into account and attempt to understand the various combinations of the factors of production in order to open up possibilities for more operational diagnosis and better adapted technical references that can then be used for extension work and development.

The raising of grazing livestock is an age-old aspect of farming that still plays an important role in the agricultural economy of France today.

Sully, the Minister of King Henry IV in the late 16th century is famous for the much-quoted phrase: "Tillage and grazing are the teats that suckle the French nation" and his observation is still largely valid today. Animal husbandry has however undergone dramatic changes since then and today faces a difficult socio-economic context.

In the years after World War II, mechanization and the progress in the fertilizer industry in particular led to a decline in the proportion of grazing livestock raised on some farms in areas where cereals or industrially-used crops became more attractive alternatives.

Farm specialization observed over the last thirty years has reinforced this trend but has led to an increase in animal husbandry in other regions.

1. Animal Husbandry in France

The last French National Agricultural Census, in 1979, (R.G.A. 1979) showed that cattle were raised on 58.3 % of the 1,262,672 farms covered by the Census; 41.2 % owned dairy cattle. 15.6 % of all farms raised sheep, 9.8 % goats and 8.4 % equines. In this breakdown it should be remembered that one farm may rear several species.

Dairy farms are located principally in the West of France, in Auvergne, in the Franche-Comté, Rhône-Alpes, and to a lesser degree in Lorraine and the North of France. Farms specializing in beef production are also found in the West and in the breeding areas for beef cattle which are in and around the Massif Central and parts of South-West France. On many mixed farms, both dairy and beef cattle generate income and in some cases the by-products of dairy farming — cull cows, grass beef, baby beef or dairy heifers — are reared.

Sheep farming tends to be located South of the Loire in less favoured areas: the Centre-West, in dry and Mediterranean uplands. Sheep are usually reared for meat apart from some regions where their milk is used for high-quality cheese (South of the Massif Central, Pyrénées-Atlantiques, and Corsica). Herds of goats are mostly raised for milk (meat is a by-product) and are found in three main regions: Poitou-Charentes, Rhône-Alpes and the Centre.

Lastly, horses are rarely bred as a dominant activity on farms but are raised throughout France.

Livestock are sometimes reared on farms where the main economic enterprise is different: a few animals may help to use residual areas unsuitable for cropping or by-products of crops, but the revenue from livestock rearing contributes very little to overall farm income.

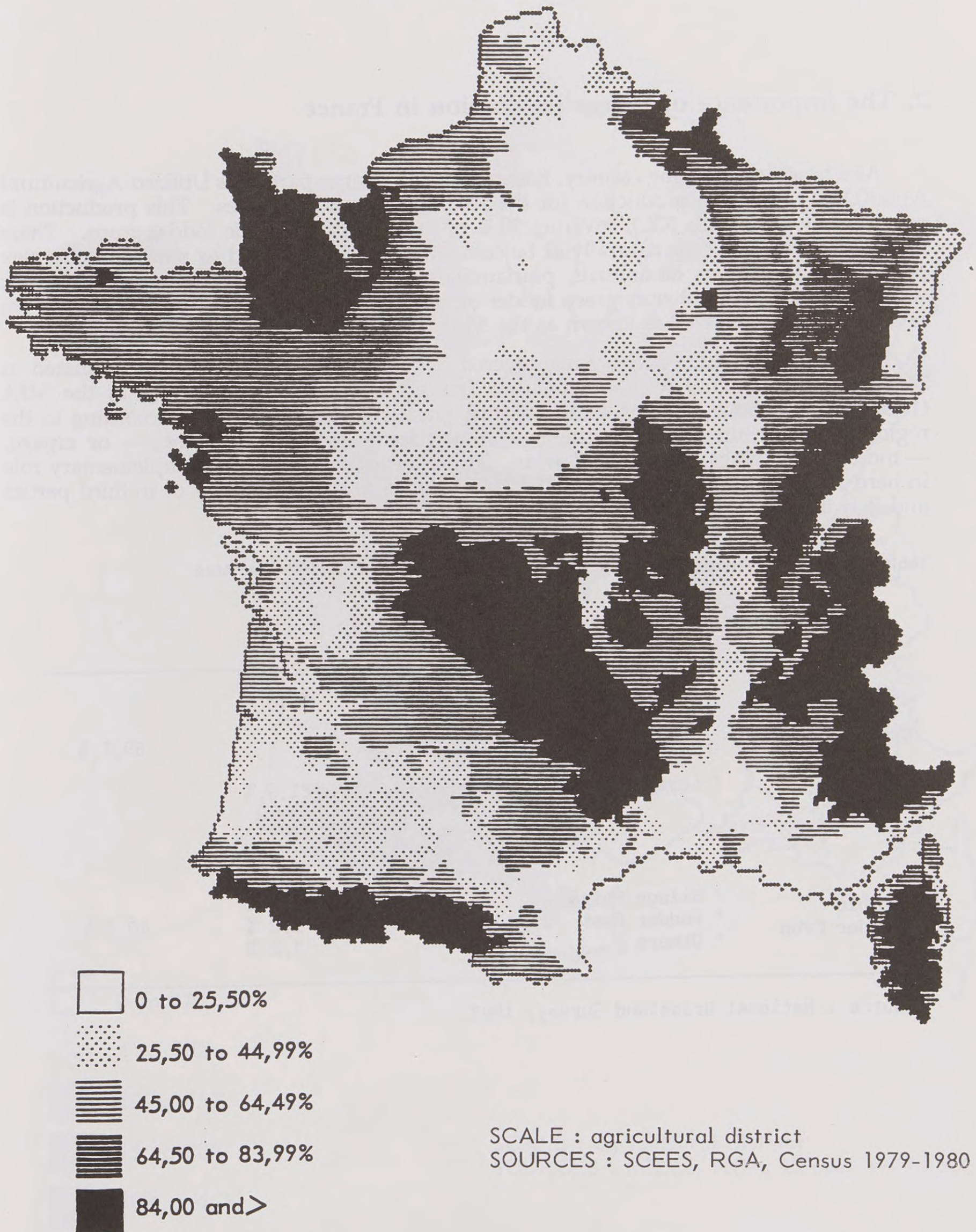
Table 1 — Classification of herbivorous livestock farms according to techno-economic orientation in French farms as a whole (OTEX) (RGA (Farm Census), 1979: 1, 262,672 farms in census)

Orientations	%	
Cattle, specialist dairy	15.4	
Other dairy cattle	5.9	
Beef cattle	7.1	43.1 a)
Mixed dairy and beef cattle	3.9	
Other herbivores	10.8	
Particularly dominant herbivores	3.9	
General Cropping with herbivores	4.6	14.2 b)
Herbivores with General Cropping	5.7	
Total	57.3	

a) Percentage of herbivores in the make-up of the gross margin is over two-thirds

b) Herbivores make up over one third but under two-thirds of the gross margin

Figure 1 - Percentage of Main Fodder Area in the Utilized Agricultural Area (U.A.A.)



The percentage of livestock revenue in the gross margin of farms classified in the 1979 Census according to their technical and economic orientation (OTEX) gives details of the contribution of grazing livestock to overall income. (Table 1)

It is worth noting that this classification shows that for 57.3 % of French farms, grazing livestock generate at least one-third of the gross margin.

2. The importance of forage production in France

As a livestock breeding country, France allocates a large part of its Utilized Agricultural Area (UAA) to forage production for the feeding of grazing species. This production is provided by grasslands (GL), covering 50 % of the UAA, and arable fodder crops. These plant resources can occur naturally or be cultivated, can be provided by simple or complex plant populations, can be annuals, pluriannuals or perennials, can be harvested once or several times a year, either as green fodder or for conservation (hay and silage). The sum of surface areas involved is known as the Main Fodder Area (MFA). (Table 2)

In 1979, the Main Fodder Area covered 56 % of the UAA which was estimated at 26,496,574 hectares (ha) for the whole of France (Fig. 1). We should add to the MFA (16,546,297 ha) about 2 million ha of off-farm grassland variously named according to the region, the parcours — rough grazings in dry areas of Southern France — or alpage, — mountain grazings — in upland areas. These areas play a definite complementary role in herd feeding during the summer; the land belongs to the community or to third parties and it is usually used collectively (F. SPINDLER, 1984).

Table 2 — Types of French Forage Resources as a Percentage of Main Foder Area

Grasslands	* Permanent Grasslands (exclusive of rotational cropping systems)	67,8 %	89,7 %
	* Leys (rotation grassland)	21,9 %	
Arable Fodder Crop	* Silage Maize	8,1 %	10,3 %
	* Fodder Beet	1,0 %	
	* Others	1,2 %	

Source : National Grassland Survey, 1982

Figure 2 - Percentage of Leys and Arable Fodder Crops (Rotation Forage Area) in the Utilized Agricultural Area (U.A.A.)

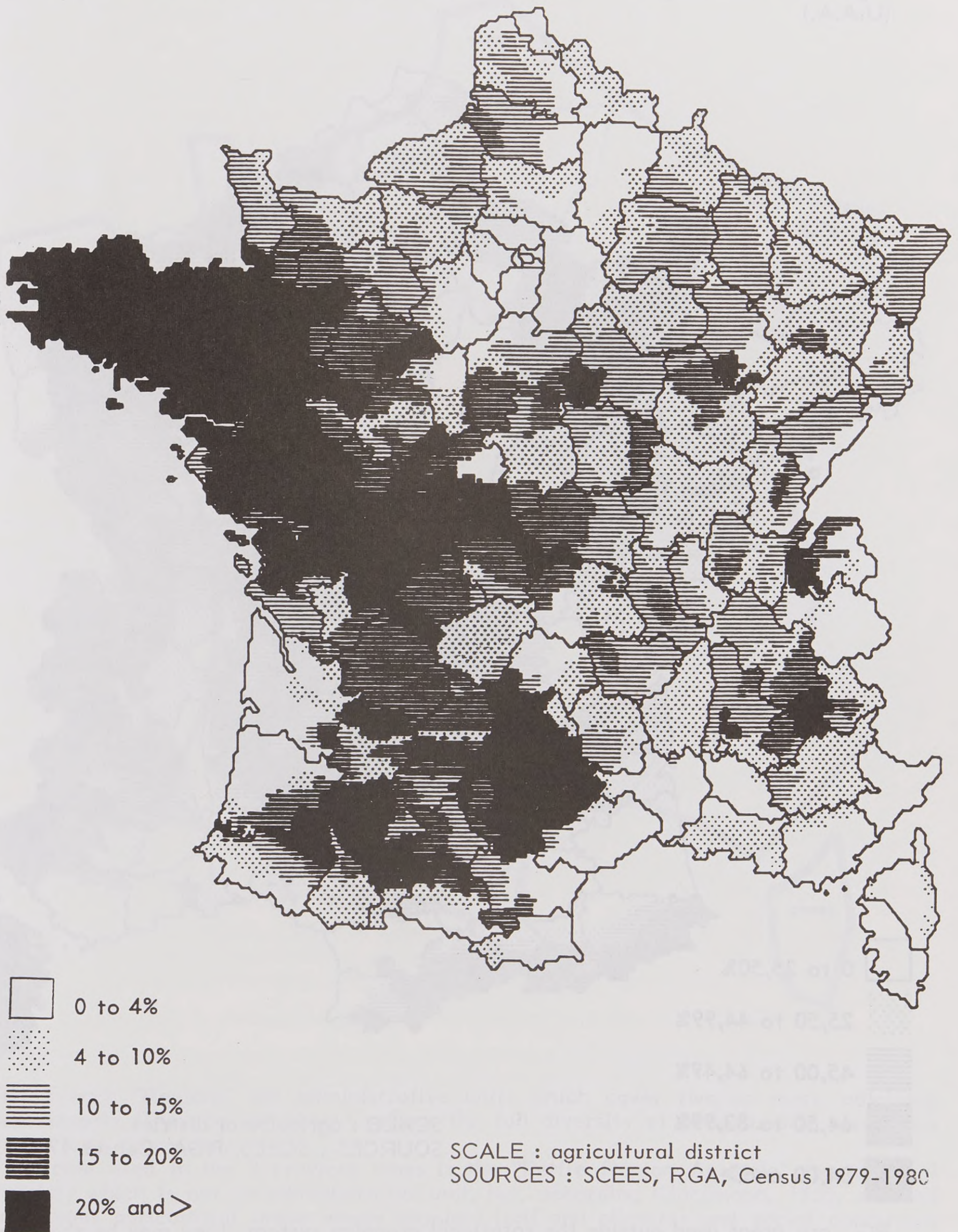
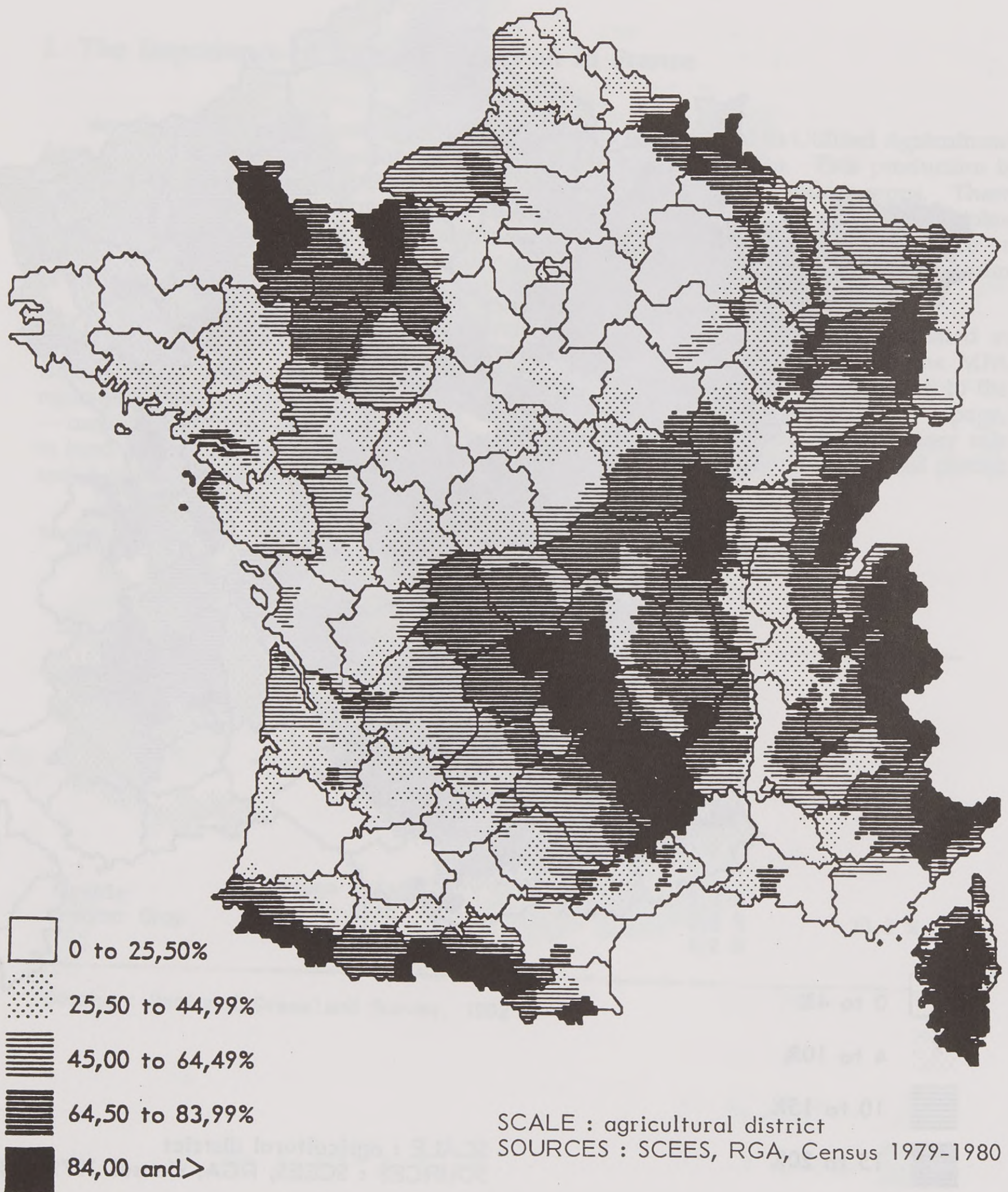
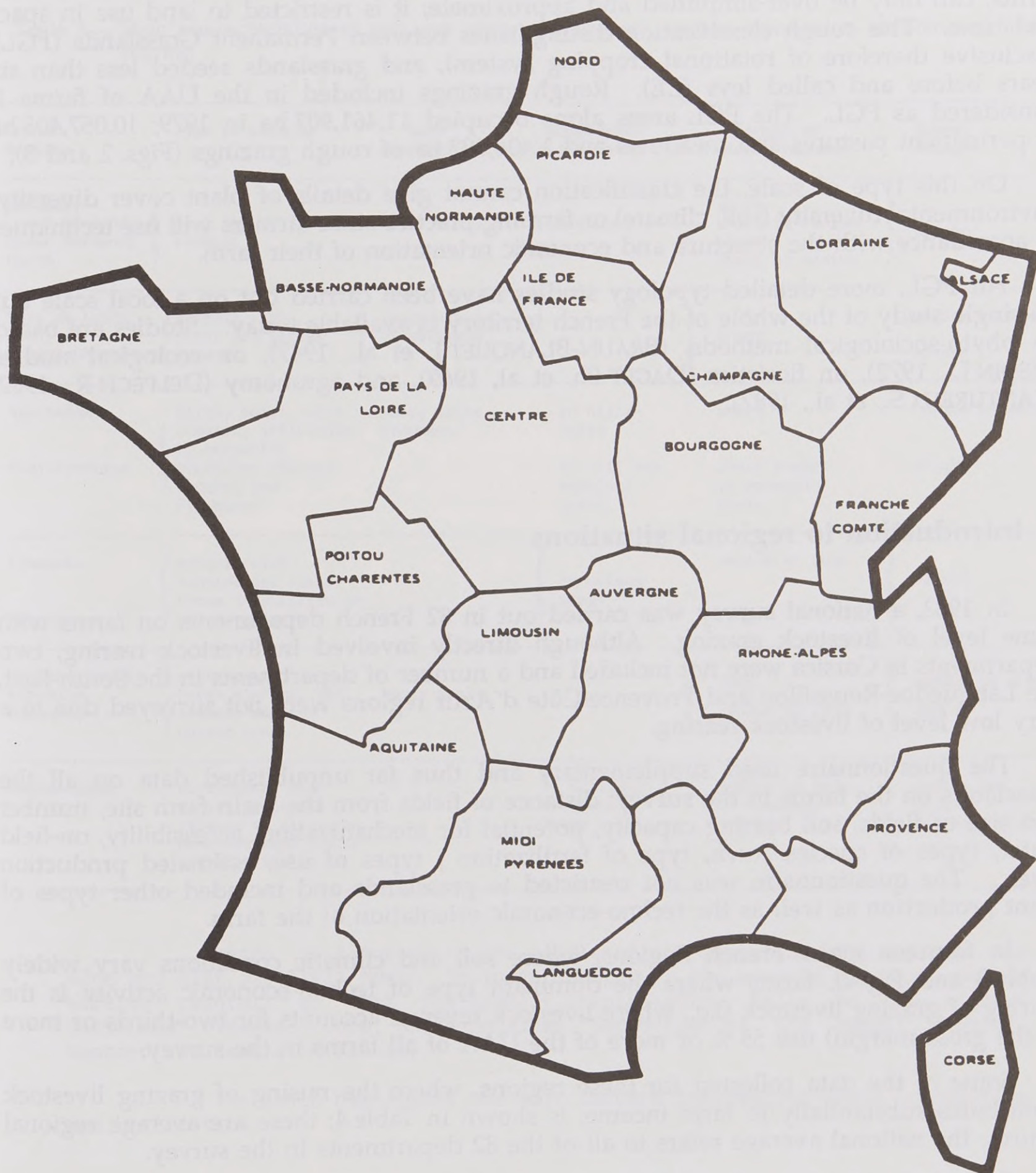


Figure 3 - Percentage of Permanent Grassland (PGL) in the Utilized Agricultural Area (U.A.A.)



PGL are areas used outside the rotational cropping system. They may be the result of natural herbage growth or of seeding over 5 years earlier.
 At the time of the Census 886,140 French farms, or 70.2% of those covered owned PGL.

Figure 4 - French regions



The French "Regions" are administrative units which cover two or more adjoining departments. They do not always reflect the full diversity of pedoclimatic conditions in the area concerned.

The scale used in the 3 previous maps is the "Petite Région Agricole" (agricultural district) which is not an administrative unit, but, according Klatzmann, 1955, a small contiguous agricultural areas where physical (soil and climate) and social conditions (rural settlement, farming structures, farming systems...) are homogeneous.

3. Grasslands

Any classification of grasslands (GL) in the National Agricultural Census on French farms, can only be over-simplified and approximate; it is restricted to land use in space and time. This rough classification distinguishes between Permanent Grasslands (PGL), (exclusive therefore of rotational cropping system), and grasslands seeded less than six years before and called leys (LE). Rough grazings included in the UAA of farms is considered as PGL. The PGL areas alone occupied 11,461,907 ha in 1979; 10,057,405 ha of permanent pastures and meadows and 1,404,502 ha of rough grazings (Figs. 2 and 3).

On this type of scale, the classification cannot give details of plant cover diversity, environmental diversity (soil, climate) or farming practice since farmers will use techniques in accordance with the structure and economic orientation of their farm.

For PGL, more detailed typology studies have been carried out on a local scale but no single study of the whole of the French territory is available today. Studies are based on phyto-sociological methods, (BRAUN-BLANQUET J. et al., 1947), on ecological studies (HEDIN L., 1972), on floristics (DAGET Ph. et al, 1969), and agronomy (DELPECH R., 1982; PLANTUREUX S., et al., 1987).

4. Introduction to regional situations

In 1982, a national survey was carried out in 82 French departments on farms with some level of livestock grazing. Although directly involved in livestock rearing, two departments in Corsica were not included and a number of departments in the South-East, the Languedoc-Roussillon and Provence-Côte d'Azur regions were not surveyed due to a very low level of livestock rearing.

The questionnaire used supplementary and thus far unpublished data on all the grasslands on the farms in the survey: distance of fields from the main farm site, number and size of fields, soil bearing capacity, potential for mechanization, accessibility, on-field water, types of species sown, type of fertilization, types of use, estimated production level... The questionnaire was not restricted to grasslands and included other types of plant production as well as the techno-economic orientation of the farm.

In fourteen major French Regions, where soil and climatic conditions vary widely (Table 3 and Fig. 4), farms where the dominant type of techno-economic activity is the rearing of grazing livestock (i.e., where livestock revenue accounts for two-thirds or more of the gross margin) use 55 % or more of the UAA of all farms in the survey.

Some of the data collected for these regions, where the raising of grazing livestock contributes substantially to farm income, is shown in Table 4; these are average regional figures; the national average refers to all of the 82 departments in the survey.

Table 4 shows inter-regional diversity and calls for a number of comments.

— Farm size or the Agricultural Area used (UUA) by the farmer in hectares will affect the choice of techniques and degree of intensiveness in farming the "Land" factor. Average regional values vary but are fairly low overall. In one region alone, Burgundy, specializing in beef production, average farm size is over 40 ha. In Brittany, on the other hand, where intensive dairy farming is the dominant type, the average farm size for the region is only 17 ha.

— The proportion of Main Fodder Area in the Utilized Agricultural Area (MFA/UAA ratio) reflects the degree of specialization on the farm. The sample for the 1982 survey

only covered farms with some sort of grazing species activity. The importance lent to so-called cash crops is not insignificant even in the 14 regions where livestock rearing is dominant. This type of farming mix does in fact influence the farm in terms of work organization, equipment, investment potential...

Table 3 — Main characteristics of soil and climate of French regions involved in herbivorous livestock rearing

French Regions	Type of climate	Soil constraints	Topographic constraints	Length of winter housing	Summer drought
Brittany Lower Normandy Upper Normandy North	cool, moist oceanic	heavy soils	frequent	short short to medium short short to medium	slight
Pays de Loire Poitou-Charentes	oceanic with drier and warmer summers	large areas of wetlands		short	medium to severe severe
Aquitaine Midi-Pyrénées	fairly moist, warm oceanic, influenced by bordering mountains (Massif Central and Pyrenees)	heavy soils frequent	in hilly areas in hill and mountain areas	short short except in mountain areas	medium to severe slight
Limousin Auvergne	oceanic with continental influ- ences intensified in upland areas		in upland areas	medium to long long	slight
Franche Comté Lorraine Burgundy	continental : long, harsh winters; wet summers esp. in upland areas	heavy soils		long medium to long	medium to slight medium
Rhône-Alpes	continental with marked contrasts related to altitude; Mediterranean influ- ences in the south		in hill and mountain areas	medium to long in mountain areas	medium to slight (in mountain areas)

France is situated in the middle of the temperate zone between the 42nd and 51st parallels North. It is influenced by the oceanic climate. Relief affects rainfall so that the highest precipitation falls on the highest altitudes (Vosges, Jura, Northern Alps, South-East of the Massif Central, Western and Central Pyrenees).

The table highlights the main factors influencing grass production and utilization.

In six regions, the MFA/UAA ratio is 75 % or over: Brittany, Lower Normandy, Franche-Comté are regions where dairy farming is dominant; this is also the case for the Loire Valley, and the Auvergne, where livestock production concentrates either on dairy or beef production, and finally the Limousin where beef production is dominant.

— The proportion of Grasslands in the Main Fodder Area (GL/MFA ratio) is high both nationally and regionally. The ratio is in fact 85 % or over in 12 regions, but lower in Brittany and the Loire Valley; the latter use more of the MFA for Silage Maize (SM/MFA), 19 % and 17 % respectively.

Table 4 — Regional data on forage areas on farms raising grazing livestock (National Grassland Survey, SCEES, 1982)

Regions	Ave. UAA (ha)	MFA % UAA	LG % UAA	SG % LG	LG % MFA	LPG % MFA	FM % MFA	LU /ha MFA	TCU in %	FU /LPG %	FU /SG %	FU /LG %
Brittany	17	75	50	66	66	25	19	1,5	66	8	43	51
Lower Normandy	22	85	75	9	88	79	10	1,2	49	59	11	70
Upper Normandy	31	53	45	11	86	77	9	1,5	55	56	10	66
North	28	40	34	8	85	77	9	1,8	61	44	7	51
Loire Valley	27	77	61	33	78	52	17	1,2	50	27	26	53
Poitou-Charentes	32	55	48	43	86	49	8	1	52	25	34	58
Aquitaine	18	58	54	29	93	66	4	1,2	55	37	25	62
Midi-Pyrénées	26	63	60	34	95	63	3	0,9	48	35	33	68
Limousin	26	87	84	17	96	79	2	1	39	60	18	78
Auvergne	31	83	81	14	97	83	1	0,9	41	61	15	76
Franche-Comté	32	80	78	9	98	86	2	0,9	46	60	10	70
Lorraine	39	65	59	8	92	83	7	1	48	55	9	64
Burgundy	45	62	59	13	95	83	3	1	39	56	14	70
Rhône-Alps	18	72	69	14	95	82	3	0,8	42	53	16	69
National average	28,6	63 %	56 %	23 %	88 %	68 %	8 %	1,1	48 %	40 %	22 %	62 %

— The proportion of sown grass or leys in grasslands (LE/GL ratio) varies greatly from one region to another. The ratio is 23 % countrywide and particularly high in Brittany, (66 %), in Poitou-Charentes (43 %) and to a lesser degree in the Midi-Pyrénées (34 %) and the Loire Valley (33 %).

The data provided by grassland surveys carried out in 1982 gave supplementary unpublished detail on the type of species grown (Table 5): alfalfa or red clover, sown singly or with grasses, Italian rye-grass, hybrid or perennial rye-grass, cocksfoot and tall fescue sown alone or with white clover and lastly, a mix of several grasses and one or several legumes.

Plant breeding developments over the last 40 years have led to the creation of new varieties with well-defined characteristics (HENTGEN A., 1972); the survey also showed how these varieties were used. (DESROCHES R. et al., 1984).

— Data from the Grassland Survey on animal populations on farms gave an opportunity to estimate stocking rates expressed as Livestock Units per ha MFA (LU/MFA). Compared to rates calculated for other EEC countries, stocking rates are fairly low, not exceeding 1 unit per hectare in six regions out of 14.

— The production level of grasslands remains modest. This survey includes an intensification indicator: the Technical Coefficient of Utilization (TCU) or the difference between actual production estimated to include fertilization and types of management practised by farmers, on one hand, and the production level theoretically possible by optimizing these two production factors; the latter estimation is based on regional experimental references collected by the survey. Production expressed in tonnes of dry matter was calculated per major type of grassland and for all plots on the farms in the survey (HENTGEN A., 1984).

The values given in Table 4 are therefore averages on the sum of all the farms. They are particularly low for regions subject to the influence of the Continental climate.

Table 5 — Types of Leys as a Percentage of Main Fodder Area

Legume pure stand	* Lucerne	3,1 %	3,7 %
	* Red Clover	0,5 %	
	* Others	0,1 %	
Grass pure stand or with clover	* Italian Rye Grass	4,8 %	7,9 %
	* Cocksfoot	0,4 %	
	* Tall Fescue	0,4 %	
	* Perennial Rye Grass	2,0 %	
	* Others	0,3 %	
Association one grass + one legume			4,0 %
Grasses Mixture			5,9 %
Legume Mixture			0,4 %

Source : National Grassland Survey, 1982

— Data collected in the same survey enabled a forage inventory to be established, giving the energy contribution of the various forage resources (HENTGEN A., 1986). Table 4 gives the Percentage of Fodder Units (FU in %) contributed by Permanent Grasslands (PGL), by Leys (LE), and for total grasslands (GL).

The ratio varies considerably from region to region confirming the herbage accumulation role of some regions where Grasslands are prevalent in the utilized Agricultural Areas (GL/UAA ratio). The share of Fodder Units contributed by Grasslands is 70 % or more for Lower Normandy, Limousin, Auvergne, Franche-Comté, Burgundy; for the first four, the GL/UAA ratio is 75 %, 84 %, 81 %, and 78 % respectively; for Burgundy, the percentage of grassland in the UAA is lower — 59 % — but the percentage of grassland in the MFA is prevalent at 95 %.

5. From field to farm: other causes for diversity

Any account of inter-regional diversity in France based solely on the annual statistics available is insufficient. These statistics can never reflect diversity within one region nor, a fortiori, differences between farms with very similar soil and climate.

Any study or research programme aiming at development must take this diversity into account and attempt to understand the various combinations of the factors of production — Land, Capital and Labour — managed by the farmer on a day-to-day basis. How can we reflect the farmer's capacity to adapt to a changing indeed uncertain economic context? How can we give finely-tuned technical advice and forge better decision-making tools? An

input-output approach is insufficient and long-term studies on the way the system operates are required. For livestock farmers, forage production is not an end in itself — forage has to be transformed in a processing system. The farmer has to produce, manage and use these resources to meet the needs of animals raised for a definite purpose. Year in year out, he has to juggle with the produce of a large number of parcels fed to one or several herds whose needs change during the year depending on their stage of development and the size of herd present, and in addition, make allowance for a stock of conserved forage to cover the period when housing is necessary.

The targeted management of forage resources is what is known as the "Forage System". Studies and research programmes at the level of individual parcels can give yield breakdowns but this approach often means that not all of the factors causing variation are taken into account in the study. For the study of an individual farm, the experimental approach no longer suffices to reflect the technical results obtained; important production data, such as the dates of use for grassland, are not always in an experimental situation.

The concept of a Forage System or Grassland System (where grassland is dominant on the farm) should make the phenomenon of interaction between the various factors of production easier to grasp, thus opening up possibilities for more operational diagnoses and better-matched technical references that can then be used for extension work and development.

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Résumé :

L'élevage d'herbivores joue un rôle important dans l'économie agricole de la France. Le dernier Recensement Général de l'Agriculture fournit de nombreuses données sur les orientations technico-économiques des exploitations agricoles (OTEX) : pour 57,3 % d'entre elles, les herbivores produisent au moins 1/3 de la marge brute. D'autres données sur la SAU et les surfaces consacrées aux prairies permanentes, prairies artificielles et fourrages annuels montrent l'importance de la production fourragère en France. Une enquête spéciale a été réalisée dans les exploitations ayant des herbivores, permettant de préciser certains aspects et de mettre en évidence la diversité entre régions. Il ressort de ce constat que tout programme d'étude ou de recherche axé sur le développement doit tenir compte de cette diversité, étudier les diverses combinaisons de facteurs de production, afin de formuler des diagnostics plus opérationnels et des références mieux adaptées pouvant être utilisés pour le développement et la vulgarisation.

Feed resources utilization : historical background and state of some livestock production areas

Joseph BONNEMAIRE, Camille RAICHON

Summary:

In the long term and at national level, the composition of French livestock has changed considerably: fewer horses, more cattle and at present increasing numbers of monogastric animals. Similarly, the respective proportion of the various feeds also changed: industrial feeds and maize increased, replacing annual forage crops, straw... Locally, each livestock production area underwent its own specific pattern of change. In some, livestock husbandry has remained practically unaltered since the XIXth century. In others, progressive changes occurred. Others again experienced dramatic changes after a long period of stability. The reasons for these diverging changes are to be sought in the strategies of social groups in each region.

The present forage area situation (HENTGEN, see paper 1.1) is the result of profound changes in French livestock production since the end of the second World War. This phenomenon has shown itself in different ways throughout the various regions. The analysis of this specialisation and differentiation process is based on the overall development of stock, feed resources and the history of five livestock production areas.

1. Evolution of overall national forage survey from 1929 to 1986-87: consequences on livestock productivity

Six reference years have been chosen to represent this evolution (CAVAILHES et al. 1987). 1986 and 1987 being the most recent years for which we have been able to obtain statistical data; 1955, 1970 and 1980 being taken as general reference years for French agriculture; 1938 giving the agricultural situation before the dramatic upheavals caused by the war and mechanisation and 1929 being the only period between the two wars in which detailed agricultural statistics were taken.

1.1. The needs of the various species

The agricultural statistics that have been used give the number of each species of animal and its category. In order to detail the farming productivity and production factor criteria, it is necessary to add together the various animal species and compare the stock across the years. We have therefore converted all the animals into Livestock Units (LU). One LU equals 3,000 Feed Units (FU). This system gives a common denominator to account for the entire stock, independent of species, breed, age, production level and period. For example, a LU corresponds to a 600 kg dairy cow producing 3000 kg of milk per year, 5 ewes and their train or young animals, 0,5 sow and its annual production of pigs and... roughly 60 laying hens.

The total number of LU underwent a gradual increase until 1955 and then went through a period of rapid growth that came to an end at the beginning of the 1980's: + 17.7 % between 1955 and 1970; + 10.2 % between 1970 and 1980; - 3.5 % between 1980 and 1987 (table and figure 1).

The cattle LU are preponderant and increased after the war from 62 % of the total stock in 1938 to approximately 70 % since 1970 (cows representing nearly 50 %).

Sheep and goats represent between 5 and 6 % of the total LU. There was a progressive disappearance of equines over the entire period under consideration, these representing a mere 1 % of the total LU in 1987 as against 15 % before the war.

The overall position of herbivores has shown a slight reduction since the 1950's, but nevertheless remaining slightly above 75 % in 1987.

Pigs represent between 10 and 11 % of the total. Poultry and rabbits, which only represented 7.5 % in 1938, have increased throughout the period, slowly until 1955 and more rapidly since then. The LU calculation for monogastric animals conceals two phenomena: a particular increase in the real number of animals compensated by productivity increases (improvement in food conversion indices, increase in the rate of reproduction and numeric productivity).

Table 1 — Changes in livestock composition expressed in LU from 1929 to 1970 (in millions of LU and by percentage)

LIVESTOCK	1929		1938		1955		1970		1980		1987	
	Nb.	%	Nb.	%	Nb.	%	Nb.	%	Nb.	%	Nb.	%
Cows	7,38	40,2	7,28	40,6	8,10	43,2	10,83	49,1	11,96	49,4	11,21	47,8
Other cattle	3,79	20,6	3,77	21,1	4,23	22,6	4,96	22,5	5,10	21,1	5,03	21,5
Sub. total cattle	11,17	60,8	11,05	61,7	12,33	65,8	15,79	71,6	17,06	70,5	16,24	69,3
Equines	2,82	15,4	2,39	13,3	1,94	10,3	0,38	1,7	0,27	1,1	0,27	1,1
Sheep Goats	1,21	6,6	1,18	6,6	0,94	5,1	1,21	5,5	1,59	6,5	1,45	6,2
S.T. Herbivorous	14,62	79,6	14,62	81,6	15,21	81,2	17,38	78,8	18,92	78,1	17,96	76,6
Pigs	1,78	9,7	1,91	10,6	1,94	10,3	2,40	10,9	2,56	10,6	2,59	1,1
Poultry Rabbits	1,38	7,5	1,39	7,8	1,59	8,5	2,27	10,3	2,75	11,3	2,9	12,4
S.T. monogastrics	3,16	17,2	3,30	18,4	3,53	18,8	4,67	21,2	4,84	21,9	5,49	23,4
TOTAL	18,36	100	17,92	100	18,74	100	22,05	100	24,3	100	23,45	100

1.2. The role of grasslands in feed resources (Table and Figures 2 and 3)

Areas used for the production of feed resources have changed dramatically since 1920. These are now specialised areas; fifty years ago fallow land and cereal stubble were used as pasture land for flocks: cereal straw was used for winter feed. It was necessary to take these "forage" categories into account in order to make a historic comparison, despite the difficulty of estimating these resources.

Feedstuff resources between 1929 and 1986 underwent a dramatic growth, increasing from 52.2 to 86.7 billion Feed Units (FU). This increase has been accompanied by a major modification in the composition of the resources.

Fodder root and tuber crops represented 7 billion FU in 1929, 8.2 billion in 1938 and only 1.4 billion in 1986. Their proportion has dropped from 13.5 % to 1.7 % of resources. The potato is largely responsible for this drop.

Fallow land and cereal straw supplied 7.7 billion FU in 1929, fallow land resources had virtually disappeared by 1955, nevertheless straw consumed by animals still represented 1.3 billion FU in 1986.

The resources from milk consumed on the farm has remained relatively stable (1.6 to 1.9 billion FU). In the interval, part of the cattle herd (multipurpose to begin with) became specialised in suckling whilst the rest became specialised in dairy with, as a corollary, an important role for commercial feeds in feeding the calves from these dairy herds.

Table 2 — Changes in the composition of forage areas (in millions of ha and by percentage of the Main Fodder Area)

	1929		1938		1955		1970		1980		1986	
	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%	Nb	%
Permanent Grass	10281	52,4	11774	54,8	13950	57,8	13932	68,1	12883	67,7	12114	66,2
Leys	3684	18,2	3634	16,9	4493	18,6	4153	20,3	3591	18,9	3302	18,0
Root and Tuber crops	1414	7,0	1553	7,2	1091	4,5	910	4,5	308	1,6	246	1,3
Annual forage crops	802	4,0	716	3,3	1484	6,1	980	4,8	1754	9,2	2180	11,9
Cereal crops	3328	16,5	3111	14,5	2704	11,2	461	2,3	482	2,5	462	2,5
Fallows	680	3,4	680	3,2	412	1,7	0	0	0	0	0	0
TOTAL	20189	100	21473	100	24134	100	20436	100	19018	100	18304	

The sown grasslands underwent the same type of cycle. They covered 600,000 ha. in 1938, twice that area in 1955, and twice that again in 1970. Between 1970 and 1980, the progress slowed down and only showed a 300,000 ha. increase. Since then the temporary grasslands have remained stable and, according to our statistical estimates, produced 10.8 billion FU in 1986.

The legume leys underwent a large production increase between 1929 and 1955, this being essentially due to an increased production (from 2.9 to 4.1 tons of dry matter for clover for example). Since 1955 their surfaces have undergone a large reduction. In 1980 there were only 670,000 ha. of lucerne and 1986 saw this surface drop to less than 500,000 ha.

The annual forage crops represented 1.3 billion FU in 1929 and 1938 and more than 13 billion in 1986. The growth started in 1970 thanks to an extended production of fodder maize and Italian Rye-grass which is strongly linked to the maize in certain production systems. In 1955, 220,000 ha. of fodder maize produced 0.88 billion FU; in 1986, 1.6 million ha. supplied 11 billion FU, representing 12.8 % of all resources.

The industrial feeds underwent the same growth pattern. Virtually nonexistent before the war, the consumption of compound feed was estimated to represent more than 15 million FU in 1986 (including suckling products). Most of the feed is used for pigs and poultry. Ruminants only used 21.5 % in 1980, with the exception of suckling feeds.

This increase in compound feeds has not been to the loss of the cereals consumed on the farm but to other industrial products such as bran, molasses, etc. The cereal feeds represented 6.7 billion FU in 1938 and approximately 10 billion since 1970. Oats were the main cereal crop in 1938, but this has been progressively replaced by corn and, most importantly, barley, due to the disappearance of draught horses and the increased production of dairy cows. The oilseed cakes consumed directly as a complement to these cereals have accompanied their increased consumption: 0.5 billion FU in 1938 and 1.4 billion in 1980.

All other feed categories have undergone a strong increase.

Until 1970, the permanent grasslands (PG) had an increasing important position in providing animal feed. They increased from 10 to 14 million ha. between 1929 and 1955. They remained stable at that size until 1970 and have been slowly decreasing since. Yields have undergone a continued increase. In 1938 the grasslands produced 1,550 FU per ha., which increased to 2,200 FU in 1955 and 2,780 FU in 1986. The total PG production in 1986 represented nearly 30 billion FU, being a 113.7 % increase since 1938.

Table 3 — Changes in feed resource composition (in millions of FU and by percentage)

	1929	%	1938	%	1955	%	1970	%	1980	%	1986	%
Permanent Grass	16176	31,0	13950	28,9	19312	32,5	30491	40,3	34582	37,0	29724	34,3
Temporary Grass	878	1,7	837	1,7	1981	3,3	7523	9,9	12987	13,9	10872	12,5
Legume leys	5853	11,2	4504	9,3	6951	11,7	5645	7,5	3416	3,4	2278	2,6
Total Grasslands	22907	43,9	19291	40,0	28244	47,6	43659	57,7	48729	52,2	42874	49,4
Fodder maize	632	1,2	632	1,3	880	1,5	3704	4,9	8648	9,3	11167	12,9
Other annual forage	663	1,3	699	1,4	2379	4,0	1286	1,7	1042	1,1	2163	2,5
Roots	7072	13,5	8237	17,1	8167	13,8	5304	7,0	2263	2,4	1467	1,7
Fallows - Straw	7705	14,8	6195	12,8	6750	11,4	1068	1,4	1447	1,6	1328	1,5
Grain	6769	13,0	6956	14,4	6881	11,6	10220	13,5	10898	11,7	9305	10,7
Oilseed cakes	540	1,0	540	1,1	2130	3,6	8160	10,8	15498	16,6	15680	18,1
Formula feed												
Milk	1867	3,6	1867	3,9	1724	2,9	1573	2,1	1734	1,8	1987	2,3
Misc.	4059	7,8	3811	7,9	2233	3,8	702	0,9	825	0,9	766	0,9
TOTAL	52214	100	48228	100	59388	100	75676	100	93340	100	86737	100

1.3. Development of farm productivity: (Table and Figure 4)

This growth and the modifications to the forage resources have permitted a considerable increase in the efficiency of French farming in the period under consideration.

The total production of 2 million tons of animal protein in 1987 is a result of the + 111.4 % increase in relation to 1938 and + 64 % in relation to 1959. The period between 1938 and 1987 saw a doubling in the quantity of produced milk and an even greater total quantity of meat (approximately + 120 %) and eggs (approximately + 160 %). However, the relative drop during the same period of the price for these animal products (more noted for all meats and eggs than for milk) led to the final farming production (final animal production), expressed in value (constant Francs), to only increase by 25 % between 1938 and 1987 (stable between 1938 and 1959).

Nevertheless, forage resources have been transformed with an increasing efficiency (alongside an improvement in their average quality), as an LU (3,000 FU) supplied an average of 87 kg of animal protein in 1987 as against 53 kg in 1938, representing a 60 % increase. But the "herbivore" LU obviously produces less protein than a "monogastric" LU: 47 kg as against 80 kg in 1938 and 73 kg as against 124 kg in 1987.

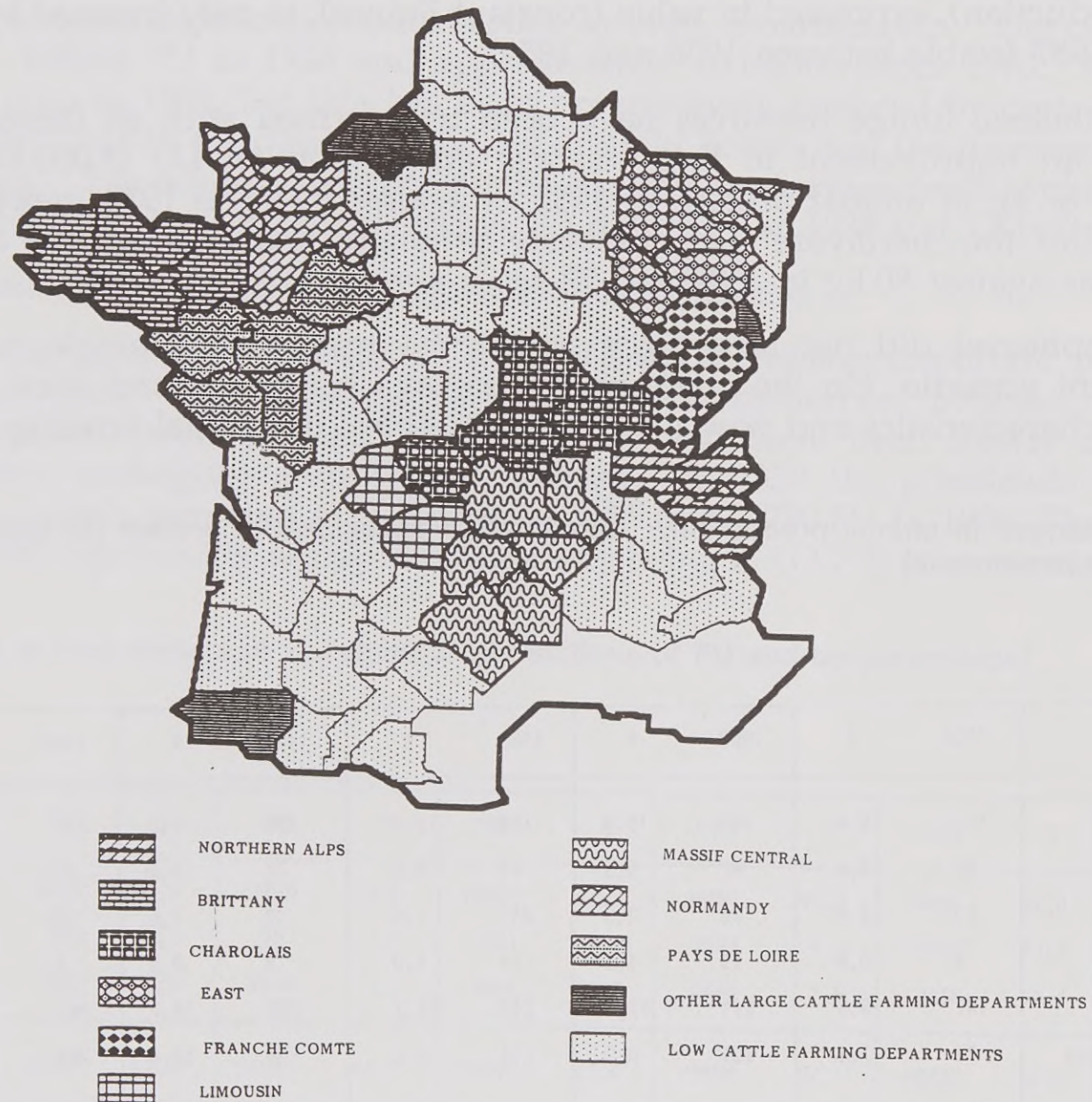
This upheaval did not take place within the context of a single national farming development scenario. On the contrary, the regions have kept and even increased their particular characteristics and now often present highly individual farming systems.

Table 4 — Changes in animal production. Composition expressed in protein (in millions of tons and by percentage)

	1938	%	1959	%	1962	%	1970	%	1980	%	1987	%
Large cattle	147	15,6	183	15,0	210	15,6	235	15,6	296	15,5	333	16,7
Calves	65	6,9	67	5,5	74	5,5	74	4,9	77	4,0	69	3,5
Sheep - Goats	23	2,4	28	2,3	217	1,6	22	1,5	33	1,7	50	2,5
Horses	8	0,8	15	1,2	14	1,0	8	0,5	4	0,2	3	0,2
Pigs	147	15,6	211	17,3	218	16,2	222	14,7	267	14,0	280	14,0
Poultry - Rabbits	74	7,8	101	8,3	114	8,5	156	10,4	243	12,8	290	14,5
TOTAL MEAT	464	49,2	605	49,7	651	48,2	717	47,6	920	48,3	1025	51,3
Eggs	42	4,4	60	4,9	64	4,7	79	5,2	102	5,4	109	5,5
Milk	438	46,4	552	45,4	634	47,0	710	47,1	883	46,4	861	43,2
TOTAL	944	100	1217	100	1349	100	1506	100	1905	100	1995	100

2. The diversity of regional evolutions

Three milk and two beef producing regions have been chosen as examples amongst the cattle farming regions (map n°1) in order to illustrate the diversity of regional evolutions. These are Brittany and Normandy in Western France, the Franche Comté to the East and Charolais and Limousin in the middle of the country. In a first analysis, three criteria have been chosen to underline this diversity: the proportion of cultivated forage in the Main Forage Area, the stocking rate of the forage areas by herbivores and the total number of LU farmed per male worker unit.



Map n° 1 — The main cattle farming regions

These regions group together the 39 French departments in which cattle production represented more than 50 % of the Final Agricultural Production (FAP) in 1980 or in which the Main Forage Area (MFA) represented more than two thirds of the Utilized Agricultural Area (UAA).

The proportion of cultivated forage in the MFA from 1938 onwards was highly varied (Figure 5): ranging from 14 % in Limousin to 40 % in Brittany. The cultivated forage in this latter region has continued to increase in importance and reached 76 % in 1980. The growth was particularly rapid between 1970 and 1980 (+ 33 %). Other regions went through other evolutions: the Franche Comté, Charolais and Limousin cultivated more forage in 1955 than in 1938. In the Limousin region this progression continued up to 1970, whilst

during the same period two other regions were already beginning to restrict their cultivated areas. Normandy went through yet another evolution: a reduction of cultivated areas up to 1970 followed by a rapid increase (+ 95 %).

The apparent stocking rate (not corrected for feed concentrated supply), that is to say the number of herbivore LU per hectare of main forage area, varies greatly from one region to another (Figure 6). In 1938 there were 1.2 LU in Brittany and 0.61 in Franche Comté. In 1980, the figure in Brittany had increased to 1.51 whereas that of Limousin, the Franche Comté and Charolais was still below 1, despite the more or less important increases since 1955.

Herds size in all regions have undergone major developments since the war. In 1938, Brittany farmers only reared an average of 5.11 LU each (Figure 7) with the smallest farming structures of all the regions under study. In 1980, they reared 29.5 LU which placed them at the top of the league with an increase of 129 % between 1955 and 1970 and a 106 % increase between 1970 and 1980. Normandy, which had been the most important milk production region in France before the war had the largest number of livestock per farmer: 7.8 LU. 1980 has seen that position drop to behind that of Brittany (23 LU). The other regions have more or less developed in the same direction as Normandy.

In order to understand these different developments it is necessary to seek answers in the relative position of each region at the moment that the mixed crop/livestock farming system suddenly developed in the 19th century, the types of progress that were then proposed and set up in each region and in the social evolutions that either sustained or held back agricultural development.

2.1. The Limousin region

This central Western region is made up from a succession of granite and metamorphic plateaus at an altitude of less than 1,000 m, cut by valleys, stretching from West to East. Rainfall can be greater than 1,500 mm per year (DELTEIL, 1988).

In the 19th century, it was a region of heathland and poor food crops suffering from a large population emigration. Small farmsteads began to develop at the beginning of the 20th century under the influence of large landowners and butchers with a particular farming objective: suckler calves fed on fodder roots and tubers. This type of farming underwent a dramatic drop in the 60's.

After the second world war the large landowners, who refused the 1946 farming status, decided to use their farms themselves by introducing a very extensive production system: grass lambs grazed outdoors all year round. The end of the 1960's saw the large cattle farms converting to this technique, at first for the breeding animals and then for an entirely new production: lean 7 to 9 month old autumn weaned calves to be sent to Italy for fattening. Small farms still produce suckling calves and fattened cattle.

The agricultural exodus over this same period (1950-1970) was so large that it allowed 1,500 families from the West of France as well as Holland to migrate to the Limousin region and to set up milking farms using new techniques such as maize silage.

As a result, 1970 saw three farming sectors in the Limousin region: outdoor rearing by the local farming "aristocracy", traditional small farm productions and dairy farming by the immigrant farmsteads.

But this situation did not stabilise. Certain large farms, not sufficiently large to adopt a complete all year round outdoor production, adopted a "semi outdoor production" (loose housing, long term fertilised pastures and rotational grazing). In addition, small farms increasingly used maize silage in the fattening feed instead of hay, cereals and tubers. 1970

also saw the beginning of farmers trying to separate themselves from the economic power of the butchers and cattle dealers by creating their own marketing structures and by strongly promoting the Limousine breed.

At present sheep production is undergoing a crisis as a result of the fall in prices resulting from the setting up of E.E.C. regulations. Sheep farmers have a tendency to use a reasoned level of intensification (8 to 10 ewes per ha.). Suckler calf production has not recovered its strong position since the 1980 consumer boycott against the use of anabolic treatments. The setting up of milk quotas led to large number of cattle being slaughtered and this has had a negative effect on beef prices over the last few years. As a result, the fattening stations in Italy have become the main market for cattle production in Limousin.

2.2. The Charolais region

At the beginning of the 19th century (CALVAILHES, 1988), the steel industry in this region in the centre of France followed the example of their British counterparts and set up a cattle farming system to cover their transportation requirements. After 1860-1880, the transportation revolution, which opened consumption places of the North France for meat produced in this areas and which favoured the importation of cereals, led to the conversion of cultivated fields into grasslands.

The natural disposition of the Charolais breed for beef production and the proximity of consumption centres led to a generalisation of this farming system throughout the region. As a result, the end of the 19th century saw the Charolais as a region specialised in an extensive farming system under the general control of the large rural landowners. This system has continued until the present day with small changes and, unlike what was happening in the rest of France, has had important extension phases during certain periods.

This system is based on an extensive use of the land and the livestock: the grasslands are not very fertilised, grazing is open, silage is rare, genetic improvement is limited by the already remarkable performances of the Charolais breed and by difficult selective breeding work (natural mating, complicated performance control); the feed system complies with the grass growth cycle.

This system may appear old-fashioned today, but the economic results have shown its great success. Since 1938 there has been a great development of work productivity measured in Francs and 1980 saw the Charolais attain the same level as the other farming regions. As a result, the "Charolais system" appears to be a coherent and rational model that obtains good economic results through the extensive use of production factors, land and livestock.

This atypical strategy is the result of four dominant social group in the Charolais. Firstly the large number of cattle dealers who are experts in their field and dominate nearly all animal sales and who are naturally opposed to all modern marketing methods. Secondly the group of breeders, made up from well-known farming families, who control the breed improvement, obtain the prizes in cattle shows and monopolise the export market. The third group is made up from wealthy tenants farmers using large land areas who are opposed to the adoption of intensive techniques adapted to more limited use structures which could endanger their large farms and their economic advantages. Lastly these landowners refuse to consider tillage of grasslands because tilled land prices have long remained below those of grasslands in this region. These four groups have a vested interest in retaining the "Charolais system" and continue to oppose the dominant evolution of a national agriculture.

2.3. Brittany

Brittany, located in Western France, is a low-lying peninsula with an oceanic climate. At the beginning of the century it was a mixed crop and livestock farming region with small, often tenant, family farms. The land is intensely cultivated and the production primarily consumed on the farm. There was no real agro-food industry in the region before the 1960's (DAUCE, 1986).

1965 saw the beginning of an agricultural revolution that transformed the region. On the one hand the mixed crop and livestock farming system became progressively more specialised in milk and more efficient through the introduction of high performance techniques. Forage production represents nearly all farming surface, using intensive cultivation systems: temporary grasslands, maize silage, etc. At the same time the livestock was completely renewed through the replacement of the local Brittany breed by other more productive breeds (Normandy, then French Frisonne Black Pied followed by Holstein). The average milk yield rapidly became one of the highest in France. In addition, intensive production in artificial conditions (pigs, poultry) began to develop in 1955 alongside the production systems described above. These systems are strongly tied to compound feed industries. An upstream and downstream agro-food industry, often on a cooperative basis, is beginning to develop in the region; this is much assisted by the proximity of major ports, such as Lorient, Brest and Roscoff.

These factors make up the dynamic "Breton agricultural model" which is based on a highly intensive animal production, the generalised purchase of the means of production and a complete insertion in the marketing exchange circuits whilst retaining modest farming structures based around the family unit. It is simultaneously a very high capital and family based agriculture.

This radical transformation was carried out as a result of the enthusiasm shown by young farmers operating within the framework of a dynamic catholic movement: the JAC (Jeunesse Agricole Catholique), aided by highly directive technical assistance from companies and public information services and pushed by the desire to attain income parity with other professions. The agro-food companies played a major role in this development. They offered integration contracts, high performance techniques (breed improvement, feeding, etc.) and organised milk collection units. It is this connection between modern small farmers and cooperatives that created the new Breton agriculture. Brittany is the highest milk production, poultry production and porcine production region in France.

2.4. The Normandy Bocage

This grassland region, which has always been close to important consumption centres and with highly diversified transportation systems (rivers, ports, roads), developed its grasslands and beef and dairy cattle farms particularly early in its history. The Carentan region has, for example, been exporting butter to Paris since the 18th century and the Pays d'Auge which had been supplying Paris with meat for a long time, started sending cheeses to Paris in the middle of the 19th century (GILBERT, LAURENT, VIVIER — to be published).

The Normandy farming system is based on the production of milk and meat using a single breed. After a rapid expansion in the first half of the 20th century, the Normandy breed, N°1 in France in 1950, underwent a regression because of its dual-purpose production character. However, its genetic improvement has undergone a clear progress over the last few years.

Similarly, the Normandy farmers who prefer to produce milk and meat using a single breed also produce cider and cattle on a same plot of land. These two productions are

closely interwoven and at the heart of the Normandy grassland system where the "pré-planté" (pasture with apple trees) concept corresponds to a well defined set of practices that is particularly characterised by low fertilisation levels: the Normand bocage farmer has always considered that his animals are more important than his grasslands.

The bocage farming structures in Normandy, larger than the national average in 1938, have generally grown at a slower rate (until 1980) and the reduced agricultural investments after the oil crisis can clearly be seen in this region. The Normandy bocage (alongside the Limousin region) holds first position when placed against other cattle regions in terms of the Main Forage Area (MFA) proportion of the Utilised Agricultural Area, despite the fact that the latter has recently decreased. The cultivated grasslands only represented 13 % of total grasslands in 1986. The expansion of maize since 1970 has caused a marked increase in all cultivated forage in the MFA.

The strong position held by Normandy amongst cattle regions, both in terms of forage area stocking and work productivity, has led to a reassessment of the opinion that Normandy farms are not intensive. The mixed milk and meat Normandy farming system has remained relatively constant since the war: the production of fattened cattle (based on grazing) was dominant in 1938 (except in the Manche region which specialised in milk production) and has retained its position of importance in 1980 (41 % of final animal production as against 53 % for milk and 6 % for calves). The cattle dealers and animal shows have played an important role in this regional non specialisation which now presents itself through a varied number of farming systems (even though they have become more simplified).

2.5. The Massif du Jura region

Located in Eastern France, the Massif du Jura covers part of the Franche Comté region. It is made up from a succession of limestone steps with an altitude varying between 200 and 1,400 m.

The milk production economy in the region has for quite some time relied on the manufacturing of a long conservation hard cheese: gruyere (PERRIER-CORNET, 1986). The milk is taken to the village cooperative by the farmers in the mornings and evenings. The product is transformed by a salaried cheese-maker and the ripening process is carried out by local skilled independant small firms. Regional farm specialisation in milk products dates back a long time in history.

Starting in 1850 this system began to spread over nearly all the Franche Comté region and by the 1950's the region had a very homogenous physiognomy as the extension was accompanied by the unification of the dairy livestock through the Montbéliarde breed, a highly productive local Red Pied breed, and an extension of the permanent grasslands. The system is organised around strong community bases: village cooperatives, communal land, grouped housing, an early insertion in commercial exchanges alongside educated and qualified farmers with a good technical understanding of animal farming.

Since the 1960's, agricultural development has been through the modernisation of farms that have progressively become more specialised in milk within a small scale cheese transformation system. This evolution has combined extensive forms (enlargement of farms by incorporation of other farms and the breaking up of communal land, forage production essentially from permanent grasslands, silage prohibition) and intensive forms based around the animal (genetic improvement of the animal and husbandry techniques, careful use of feeds, etc.). The pivotal point for the agricultural growth in the region was the improvement made to the performances of the local Montbéliarde breed and the important use of concentrated feeds.

This type of development is linked to the manufacture of a highly appreciated long conservation cheese which created a particular market and legally protected itself by creating an "appellation d'origine". This original move offers an economic advantage that largely compensates for the added costs linked to the particular production and transformation techniques. It is around this advantage (exclusivity) that convergences of interests were formed between the local trade and the relatively well off and wealthy peasants in the Massif du Jura region, creating an economic balance that avoided the need to adopt intensification and industrialisation models.

However, this development is currently causing a number of uncertainties : the intensive running of the farms runs counter to working conditions, the increasingly important financial constraints and the entrance of new industrial capital in the cheesemaking business.

Conclusion

This rapid review of the history of farming in these five regions shows the variety and the complexity of the causes of dissimilarity in the regional conditions. The Limousin region has evolved in stages, in which each category of farmer has successively introduced a production system adapted to his farming structures. On the other hand, the Charolais region does not seem to have changed its situation very much since the beginning of the century. Most of the changes have been blocked by the interplay of the various social groups who want to retain the status quo. Brittany remained stable but fairly backward until 1960. The changes were so brutal and generalised that it rapidly became the most important farming region in France under the forceful thrust of its young farmers. Normandy, well known for its pre-war farming production, has made relatively few changes in its structures, techniques and productions and, as a result, has lost the advantages that it held over the other regions. The Franche Comté was able to introduce a constant level of progress throughout the period whilst retaining its production framework and regional products.

HENTGEN (1986) demonstrates that the production and use of forage can only be understood and evaluated within the farming context. But, over a long period and on a regional level the evolution of farms can be interpreted as a dynamic understanding of regional agricultural systems. It is often social group strategies and their relationships within this framework that supply the key to explain the evolutionary logic of such agricultural systems.

It is nevertheless extraordinary to note that the regional examples given in this paper show that the most fundamental disruptions and changes in direction are often due to factors that are both external to the regions under consideration and to agriculture. As examples we can cite the transportation revolution at the end of the 19th century and the manpower requirements in the industry after 1950, the unlimited offer of agricultural products due to the Common Agricultural Policy (CAP), the recent setting up of quotas, the importation of the Holstein breed, the technical progresses in agricultural machines, etc. Each region, in accordance with its natural productive and social specificities at a particular moment develops a different and specific technical and organisational response to these disruptive factors.

FIG.1: CHANGES IN THE LIVESTOCK COMPOSITION

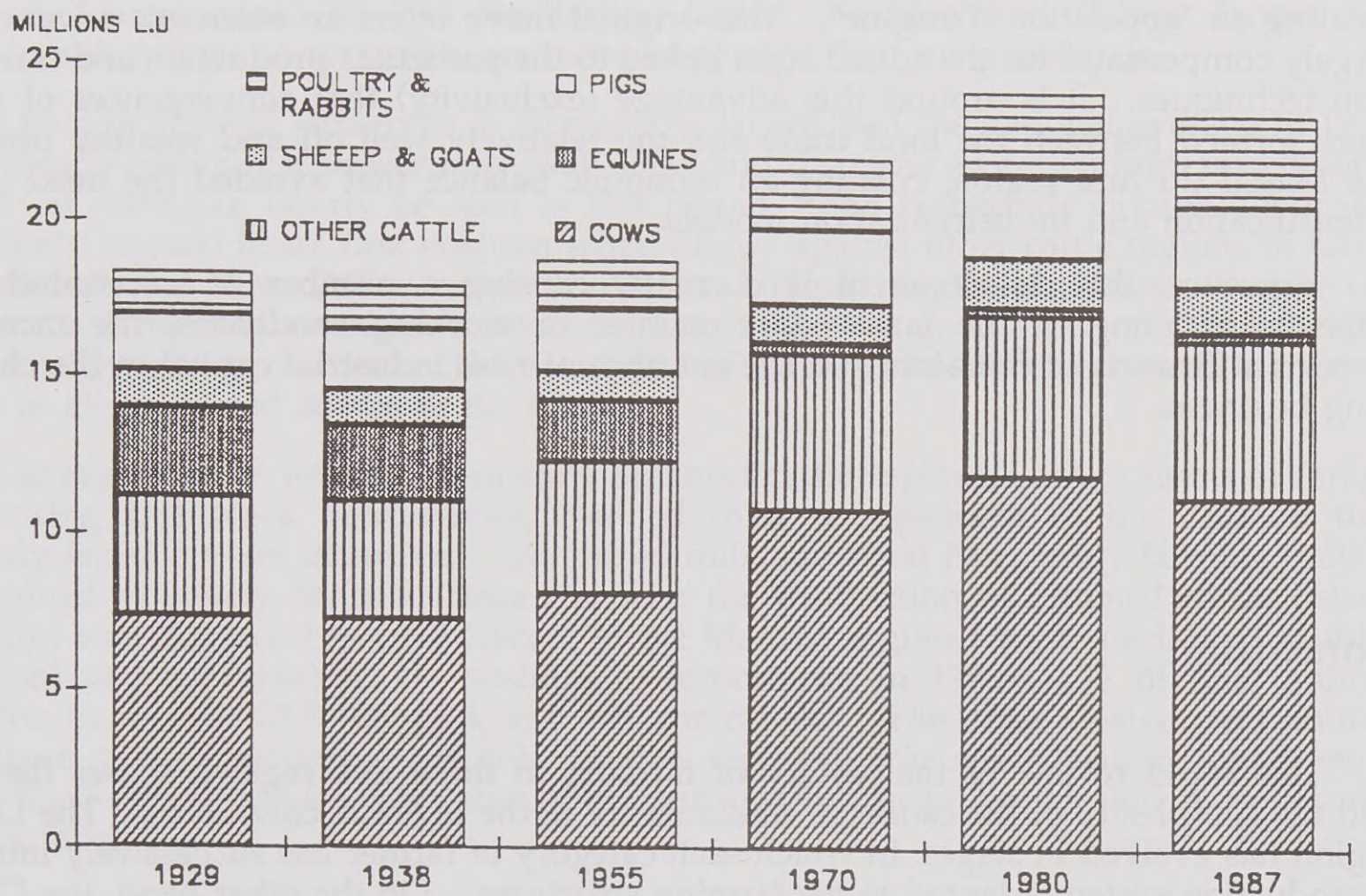


FIG.2: CHANGES IN THE COMPOSITION OF FORAGE AREAS

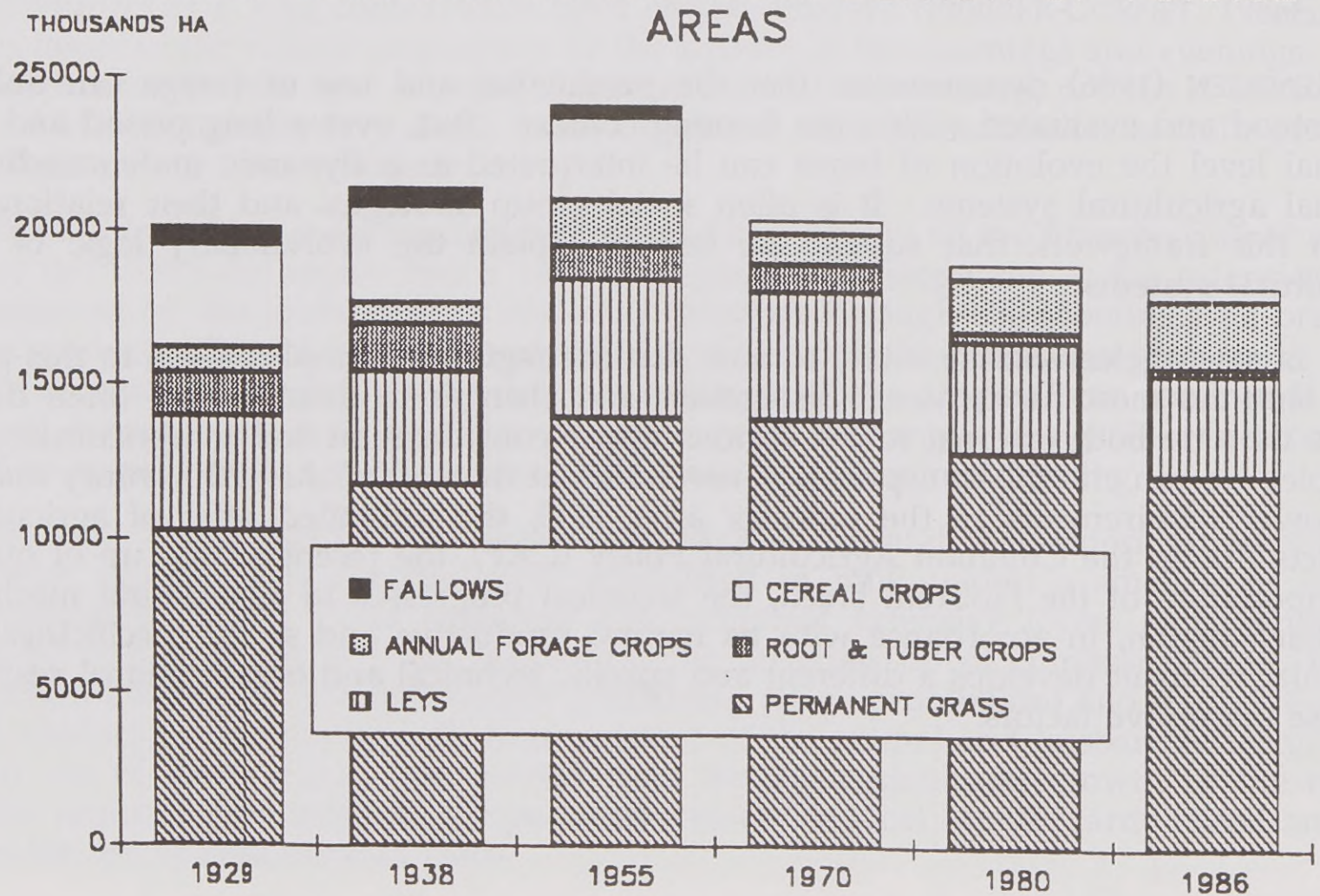


FIG.3: CHANGES IN THE FEED RESOURCE COMPOSITION

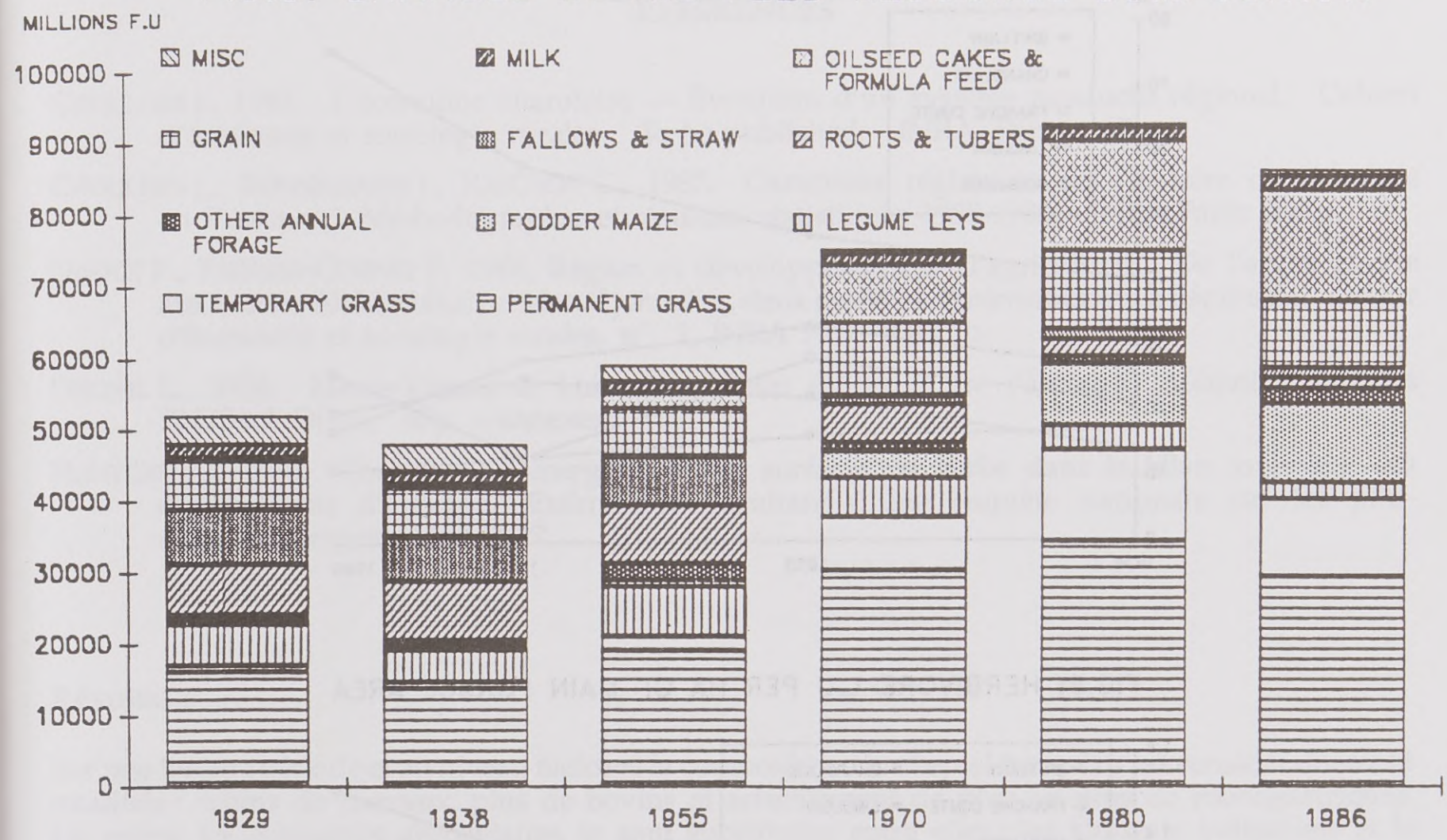


FIG.4: ANIMAL PRODUCTION EXPRESSED IN PROTEIN

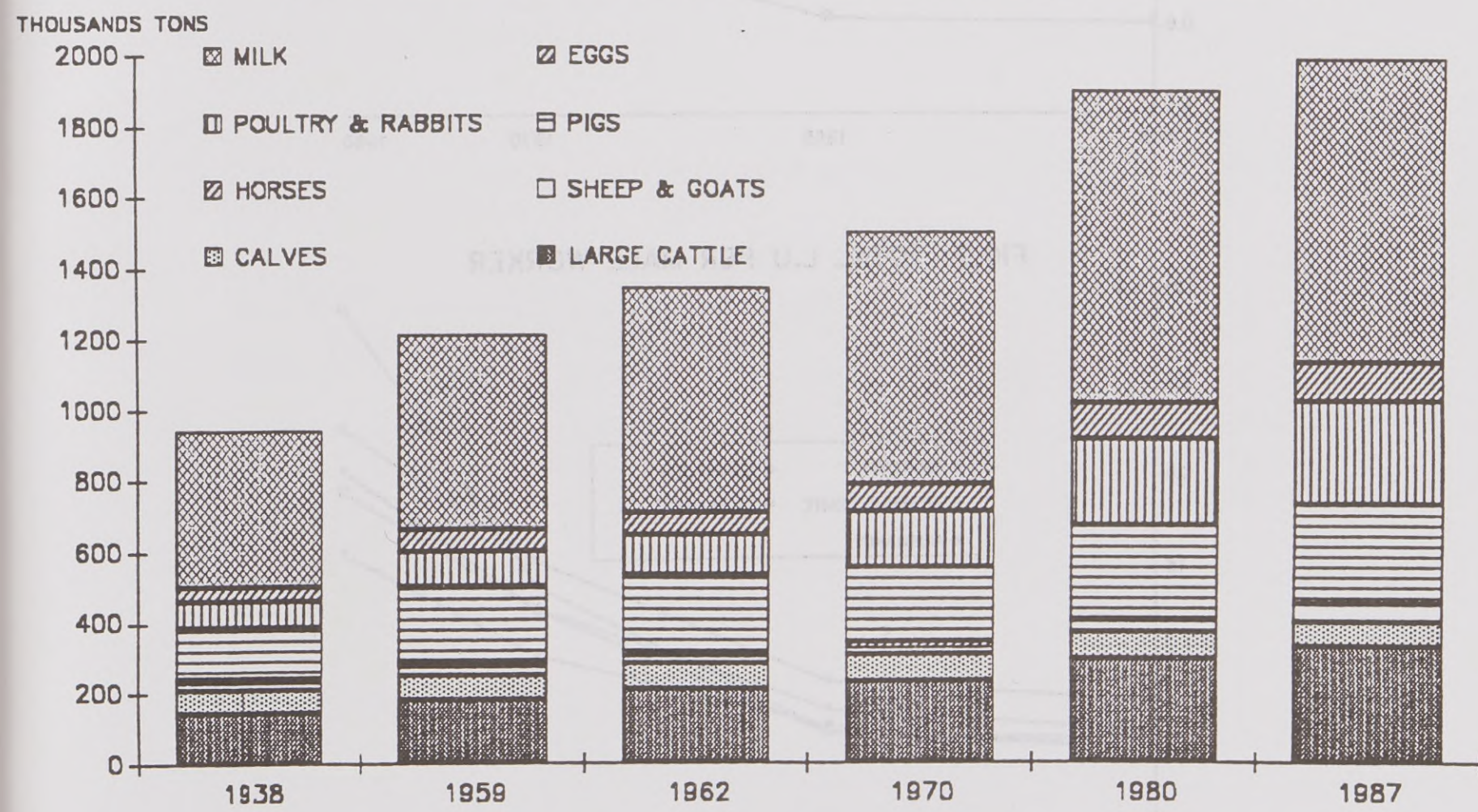


FIG.5: PROPORTION OF CULTIVATED FORAGE IN THE MAIN FORAGE AREA

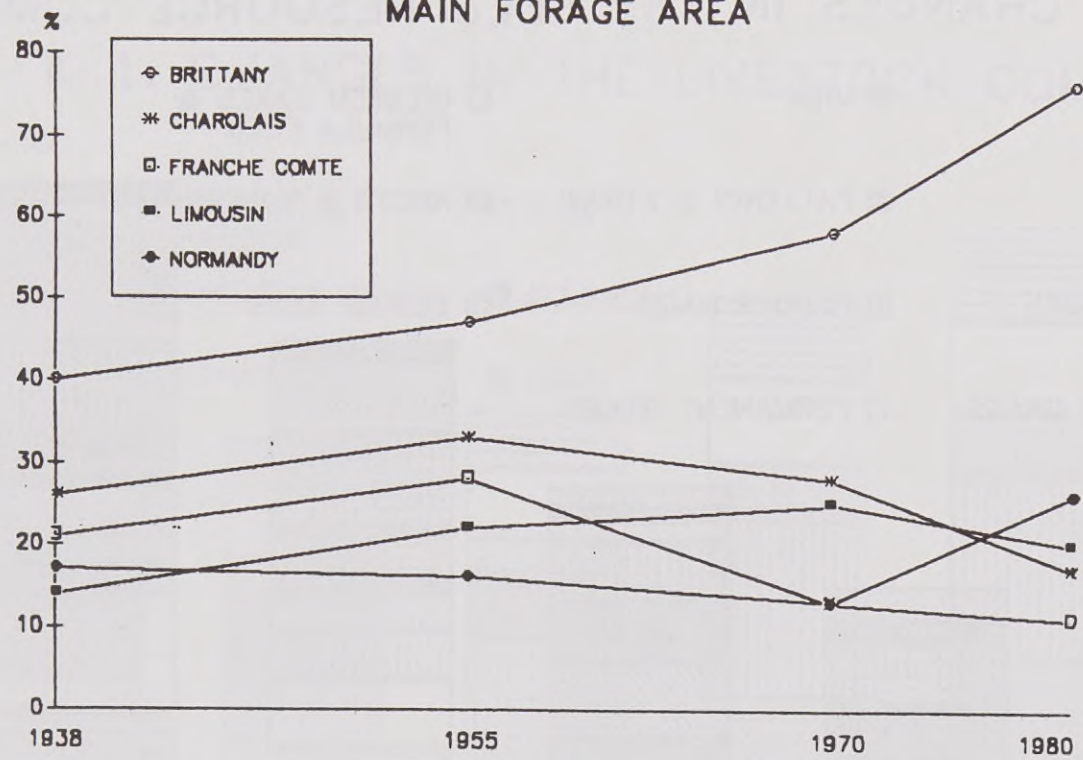


FIG.6: HERBIVORE L.U PER HA OF MAIN FORAGE AREA

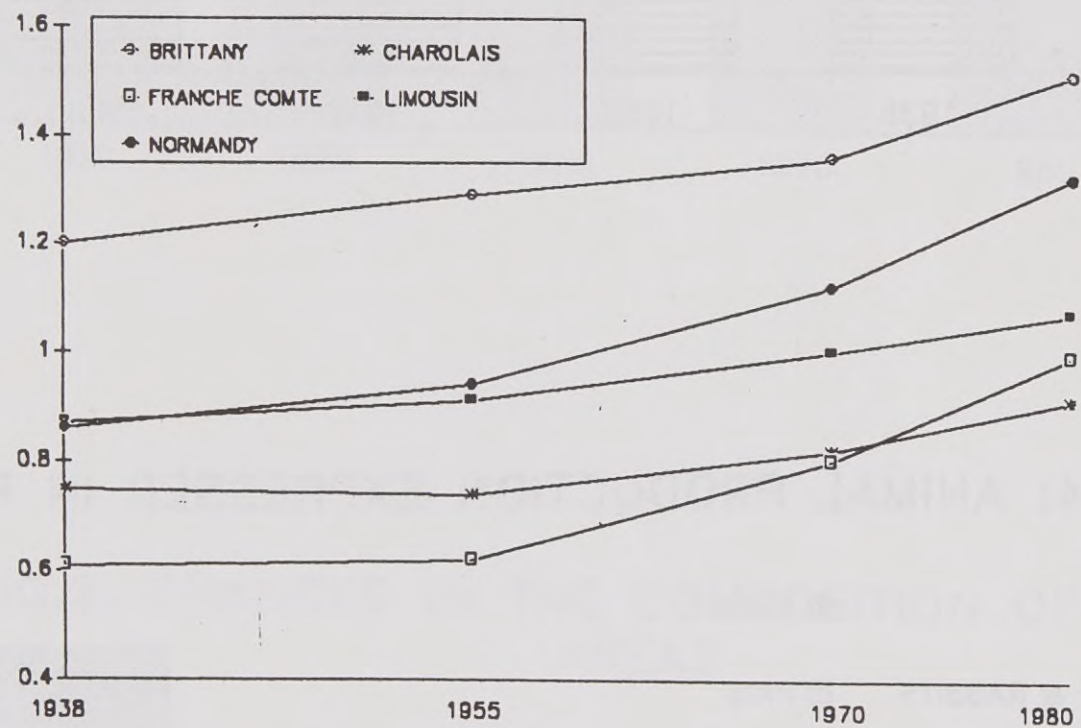
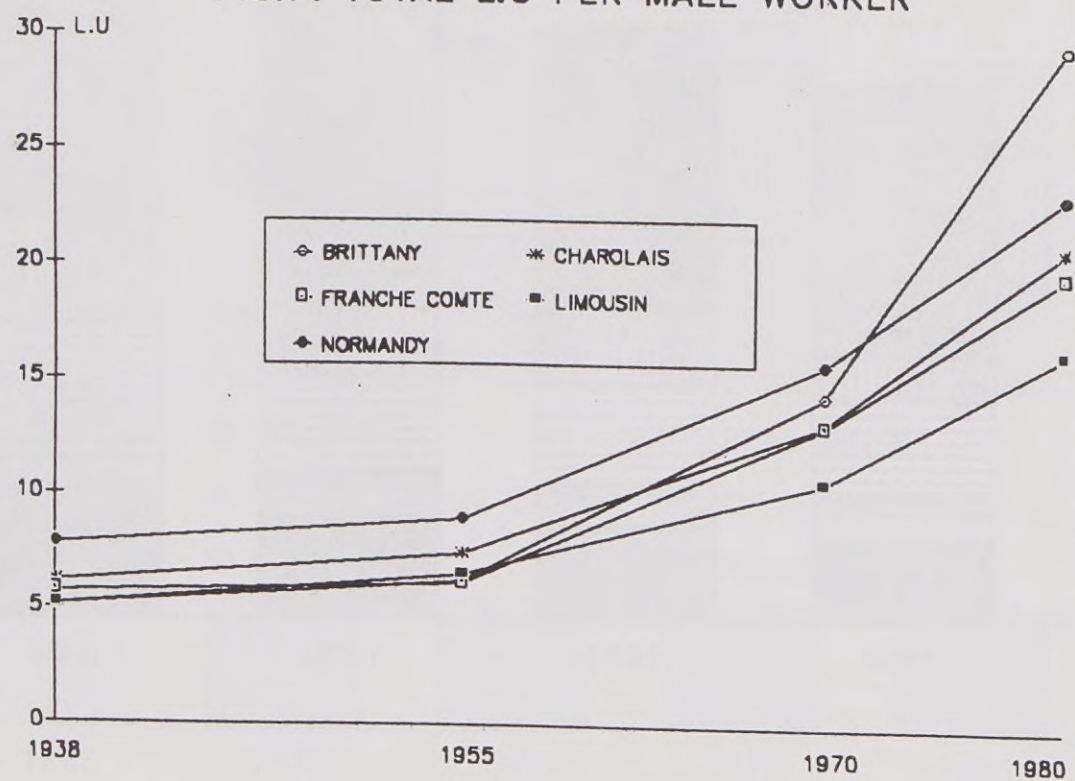


FIG.7: TOTAL L.U PER MALE WORKER



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Résumé :

Sur une longue période et au niveau national la composition du cheptel français s'est considérablement modifiée : moins de chevaux, plus de bovins et actuellement de plus en plus de monogastriques. De même les ressources alimentaires se sont substituées entre elles : les aliments industriels et le maïs augmentent aux dépens des fourrages annuels, des pailles... Cependant chaque région d'élevage a connu une évolution particulière. Certains ne se sont pratiquement pas transformés depuis le 19^e siècle. D'autres ont changé progressivement, d'autres encore ont connu un brutal bouleversement après une longue période de stabilité. C'est dans les stratégies de groupes sociaux de chaque région qu'il faut chercher l'explication de l'évolution des systèmes agraires.

The diversity of sheep production systems in France: a first analysis

Antoine BLANCHEMAIN

Summary:

Sheep production, which only represents 2 % of the final French agricultural production, permits agricultural activity to survive in a great number of difficult areas. The diversity of the farming and production systems is a key point in sheep farming. However, recent history shows an evolution of these various systems towards a modernisation technical model that is, nonetheless, limited. The future potential of this type of farming seems to rest in the development of modern pasturing techniques that adapt both the adjustment and the renewing of low cost natural resources in regions where its prime economic function would be to maintain the rural landscape.

Sheep production in France only represents a small part of the final agricultural product (2 % in 1984), but sheep farming has the advantage of maintaining an agricultural activity in a great number of difficult regions.

The great diversity of agricultural environments (climate, relief, rainfall, soil types...) in France, has led farmers to perfect flock management and breeds and to adapt these to local conditions. However, recent history has shown an evolution of the various production systems towards a modernised technical model that has a number of limitations.

Which leads us to ask what future developments can be anticipated in French sheep farming methods? Can they be adapted to the various regional conditions and, more particularly, will they be able to make good use of the forage resources in difficult environments?

1. Examples of recent evolution in production systems

It is possible to analyse the evolution of 4 main sheep production systems in France over a 50 year period (1935-1985).

1.1. Decline of the Provence transhumant system

This system developed from the feudal system initiated in the XIIIth century and has retained its main characteristics: no land ownership but dominance by one social group (the lowland dwellers) over another (mountain dwellers), allowing a low-cost use of natural grasslands throughout the year.

This system, which relied largely on the skills and knowledge of the shepherds, began its decline as the costs of renting winter grassland and purchased fodder began to increase (hay from Crau [Rhône delta] being particularly sought after by horse breeders) and land became more scarce as a result of intensive fencing caused by urban expansion and the increasing number of roads, etc.

1.2. Disappearance of the "gleaner" flocks in the Parisian Basin

This extensive sheep farming system was completely overtaken by the modernisation of crop farming techniques. It was not able to offer the shepherd a work productivity equal to that provided by the tractor driver who was able to use a wide range of modern techniques and equipment.

1.3. Creation of the "Centre-West" extensive system

Nevertheless, the same period saw the development of an extensive system on poor heathland (Montmorillonnais, Confolentais, Haut Limousin in central France). Landowners decided to group their plots to create large owner-occupied units in order to avoid the inconveniences of fencing-in those areas where, in the XIXth century, sharecropping agriculture had permitted large families to live on small areas of land.

A hardy breed of sheep and systematic fencing, permitting the use of fallow land for grazing, have been instrumental in replacing family labour by capital.

By economizing on the renewal of the land's agricultural capacities (hydromorphy, floristic degradation) and investments, this system had, until recently, given an excellent level of work productivity.

1.4. The attempts to modernise farmyard flock farming in the Prealps

The development of modern markets has led small mixed cropping farms to progressively abandon all their commercial production.

In the XIXth century, a flock of 15 to 30 sheep provided all essential needs in terms of meat, milk, wool and, most importantly, manure. The XXth century has seen these farms trying to enter into the modern intensification-specialisation process by increasing flock size to 200 or more sheep. The system has tried to use as many modernising techniques as possible to increase productivity, such as investments in sheepfolds, mechanisation to create winter forage stocks, genetic improvement of livestock and lambing acceleration techniques but numerous observations show that the farms that have managed to control the development process are those that have succeeded in being able to use low-cost grassland resources which become available as a result of population moving away from the country; but even this has been at the cost of a generalised lowering of agricultural land capacities.

The example of the Southern Alps seems to be fairly representative of the evolution in the sheep-farming systems which have in fact only developed in economically poor areas (A. Blanchemain, G. Gleyser, P. Martinand, J.P. Platon, 1985). This situation allows us to raise the following two questions that we consider essential:

— Is the intensification-specialisation process a failure? Is it merely a setback? Can the failure be avoided?

— Does the relationship between the natural grazing resources and the resources derived from arable land dictate the management systems for all sheep farms?

2. Limitations to the technical modernisation model

Research and Development, with assistance from the various public authorities, developed a technical model capable of leading to a totally controlled mutton production system (J.P. Boutonnet, P. Martinand, 1979).

This model, based on specialisation, forage intensification and increase in individual animal performances was supposed, through the use of modern techniques and equipment, to increase the work productivity level without using a greater land area. The results, some thirty years after the system was put into operation, have been fairly unsatisfactory.

2.1. General comment

2.1.1. Meat production still remains uncontrolled

Table 1 — Mutton production increase factors in France.

	Meat Production		Number ewes		Average Carcass weight		Number lambs per ewe	
	1000 t.	index	10 ⁶	index	kg	index	number	index
1970	117.4	100	6.4	100	16.9	100	1.05	100
1975	131.1	117	6.3	98	17.8	105	1.15	109
1980	173.6	148	8.3	128	18.6	110	1.13	108

Source J.P. Boutonnet, C. Remus and Y. Riou, 1981

The production increase is essentially due to the expansion of stock and increased carcass weight, but there has been very little individual performance improvement (20 %), proof of the lack of availability or inefficiency of the model.

Because it has never been possible to efficiently control production, the offer has shown itself unable to meet to an ever-growing demand and, as a result, the gap between the two continues to increase and the position of this production type continues to weaken within the overall French economic context.

2.1.2. There are few specialised sheep farms

If the specialisation criteria is taken as the part represented by meat sales within the total Gross Product of a sheep farm, it may be seen that there are very few farms (4,310) where this represents more than 2/3rds of the figure whilst at the same time providing a sufficient economic dimension (more than 200 ewes). There appear to be two major obstacles standing in the way of the growth of specialised sheep farms.

2.2. First obstacle: the difficulty in mastering the forage system

Controlling this system is both necessary (the element of chance is not acceptable in intensive production) and difficult. A case study carried out in the Limousin region showed that this parameter (expressed in the number of lambs produced per hectare of forage) has a greater effect on the economic result than the use of hormone techniques, aimed at increasing the production rhythm.

Table 2 — Results from specialised sheep farms in the Limousin region

	Farms using hormone techniques		Farms not using hormone techniques	
	intensive forage (+10 lambs/ha)	extensive forage (-10 lambs/ha)	intensive forage (+7 lambs/ha)	extensive forage (-7 lambs/ha)
Lambs produced/ ha sheep MFA	12.43	7.96	8.64	5.91
GM/sheep LU	2 280 F	1 699 F	2 130 F	2 017 F
ILEC/Farm	68 146 F	30 995 F	57 086 F	35 818 F
ILEC/MLU	43 326 F	19 869 F	47 572 F	30 614 F

Source J.P. Platon, 1983

MFA = Main Fodder Area

GM = Gross Margin

ILEC = Income from Labour and Equity Capital

MLU = Man Labour Unit

This observation is confirmed for farms mixing sheep and cattle where these have been fattened on the farm, which obviously requires a good forage control.

The fact that this mixed production allows a better and more complete use of the forage resources is probably the reason that this is used so frequently. In France, 50 % of sheep enterprises are incorporated in beef production farms in which the two operations provide 2/3rds of the Gross Product (OTEX: other dominant grazing livestock) (OTEX: Orientation technico-economique de l'exploitation = techno-economic orientation of farms).

This phenomenon is even more pronounced in Great Britain where this orientation represents 21.4 % of farms (A. Blanchemain et al, 1988).

On the other hand, the specialisation-intensification model that often leads to an acceleration of lambing cycles causes imbalances between the forage calendar and the feed requirements calendar which can only be compensated by costly storage of forage.

It should also be noted that periods when mutton production was stepped up have until now, coincided with periods in which the prices are high. This occurred in France between 1960 and 1978 due to the market protection from imports, and from 1980 to 1988 in Great Britain, due to a favourable trading structure.

2.3. Second obstacle: workload and strenuousness

All techniques aimed at increasing the individual productivity of female animals raised for their meat requires an increased amount of work: lamb care, bottle feeding hormone treatments and insemination of the mothers, forage feeding in the sheep-folds, etc. This work is generally strenuous and is normally only acceptable as a badly paid family occupation and not by salaried staff, this being the opposite of the intentions of the model.

This explains why the high performance intensification systems that were recommended until fairly recently for stepping up meat production, such as multiple lambing or three lambings in a two year period, are currently being abandoned and replaced by simpler systems.

3. The lessons of history

Each of the intensification process phases (increase in female productivity, acceleration in reproduction rates, lowering the selling age of the lambs carcass, quality of the carcasses) requires a heavy use feeds from arable land, such highly nutritional forage, cereals, etc.

On the other hand, it can be seen that in the past all the large sheep stocks were developed on natural grassland. This was nearly always the result of a forced land use policy which was itself the result of a supply policy concerning essential requirement products, such as wool. This happened in Provence in the XIIIth century, the Spanish Meseta in the XVth century and in Australia in the XIXth century. The only real sheep planning policy in France occurred during the First Empire when by increasing the proportion of Merino blood in Provencal flocks, the imperial Government hoped to produce enough wool cloth for the "Great Army".

Meat production was never considered as being more than a side product from grazing livestock living on natural grassland, and this type of sheep husbandry was never able to respond to the increasing meat demand of the population. It was necessary to turn towards other types of animals and other resources, mostly cultivated, and cereals in particular to answer this need.

Be that as it may, that situation still exists and the majority of grazing livestock meat consumed in the world come from farms where the animals are reared for other uses (dairy cows). The response to the increased meat consumption demand has essentially been through the use of a cereal based production (pigs, poultry).

The recent example of the development of sheep farming in Great Britain, which one might have thought would be based on an opposite premise, does not disprove this, quite the contrary. This development is in fact based on a strong division of labour between a farming system that produces reproducing females and lean lambs on natural hillside grasslands and a farming system that aims to multiply and fatten the products (lambs) on intensively cultivated resources (forage crops, catch-crops, cereals). This division is

encouraged by the State whose subsidies are reserved for hill sheep farms, on condition that the latter only keep flocks that gives little direct meat production. It is nevertheless remarkable that the administrative classification criteria for hill sheep farms is taken as the percentage of roughage (from natural grasslands) in the ewe feed (in weight or in surface).

In other words, the recent increase in mutton production is a result of the increase in cultivated resources in the lowlands, but it remains contained within the limits of the growth of the hillside reproducing stock, which is accompanied by a certain degradation of the grasslands and the shutting down of small, non-profitable, units.

Thus the two following propositions, previously discussed in examples cited above, are found to be proven:

- 1 — intensification is only possible if prices are high;
- 2 — extensification is only possible if the usable agricultural area per inhabitant is sufficiently large.

4. The future: development of new pastoral techniques to better control the various situations

The diversity of French sheep farming systems, which is virtually impossible to break down into types, is merely a reflection of the regional or individual conditions which are best expressed by the Natural resources/Cultivated resources relationship. Thus, the near future is not going to offer any technical improvement greater than a significant improvement in the use of natural resources, this being the key to the meat orientated sheep farming economy. As French farmers have said: "during high price periods the rangeland are only used as a safety valve; during low price periods, the expensive cultivated grass is left and the sheep are grazed on the rangelands, but we are still not very good at this" (F. Ehrard, G. Guérin, 1988).

This new know-how will require a more controlled management of the adjustment between the feed requirements of the animals and the availability of natural resources.

As far as the first point is concerned, the following may be cited as an example (B. Dedieu, E. Courant, 1988):

— the management of ewe body resources, alternating emaciation periods during a high production period and weight gain periods on high-quality natural pastures.

— The choice of additives (nitrates) capable of increasing the capacity of the animals to consume rough feeds (foliage) by stimulating ingestion and digestion.

Concerning the second point; new observations and research pathways have been developed to individualise the various natural production to be found in area or on a farm as feed resource units whose use or stockpiling should be organised in function of a previously defined animal production programme.

Given the generally large range of resources occurring on farms (particularly in dry mountainous regions as well as in large crop farms where less productive areas will also become marginalised), it is possible to devise a sufficiently wide range of farming methods for each particular case based on date(s) of use as well as on intensity of use, stocking rates and length of stay of animals on each grazing parcel.

For a production type that represents an infinitesimal part of the Gross National Product and which thus has no chance of forming part of a national policy requirement, it becomes clear that the best chance for the wide range of individual conditions lies in

the development of modern pasturing techniques that adapt both the adjustment and the renewing of low cost natural resources.

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Résumé :

Les productions ovines qui représentent seulement 2 % de la production agricole finale française, permettent de maintenir une activité agricole dans de nombreuses zones difficiles. La diversité des systèmes d'élevage et de production est une des caractéristiques de cet élevage. Cependant l'histoire récente montre une évolution de ces différents systèmes vers un modèle technique de modernisation qui a pourtant ses limites. Les perspectives d'avenir pour cet élevage semblent résider dans la mise au point de techniques modernes de pastoralisme conciliant à la fois l'ajustement et le renouvellement des ressources spontanées peu coûteuses, dans des régions où il aura pour fonction économique principale l'entretien de l'espace rural.

Understanding the diversity inside a region: a tool for the development of a research programme on forage systems

Alain CAPILLON, Léon DAMOUR, Geneviève DAVID,
Alain HAVET, Yves PONS

Summary:

A research programme on forage systems and livestock production relating to the preoccupation about landuse is being conducted in the French Atlantic Marshlands. The conception of the programme presupposes a close knowledge of various farming systems.

The programme has two goals:

- obtaining references suitable for better use and management of grasslands in intensive cattle farms,
- providing packages to manage livestock economically in order to avoid the abandonment of agricultural landuse.

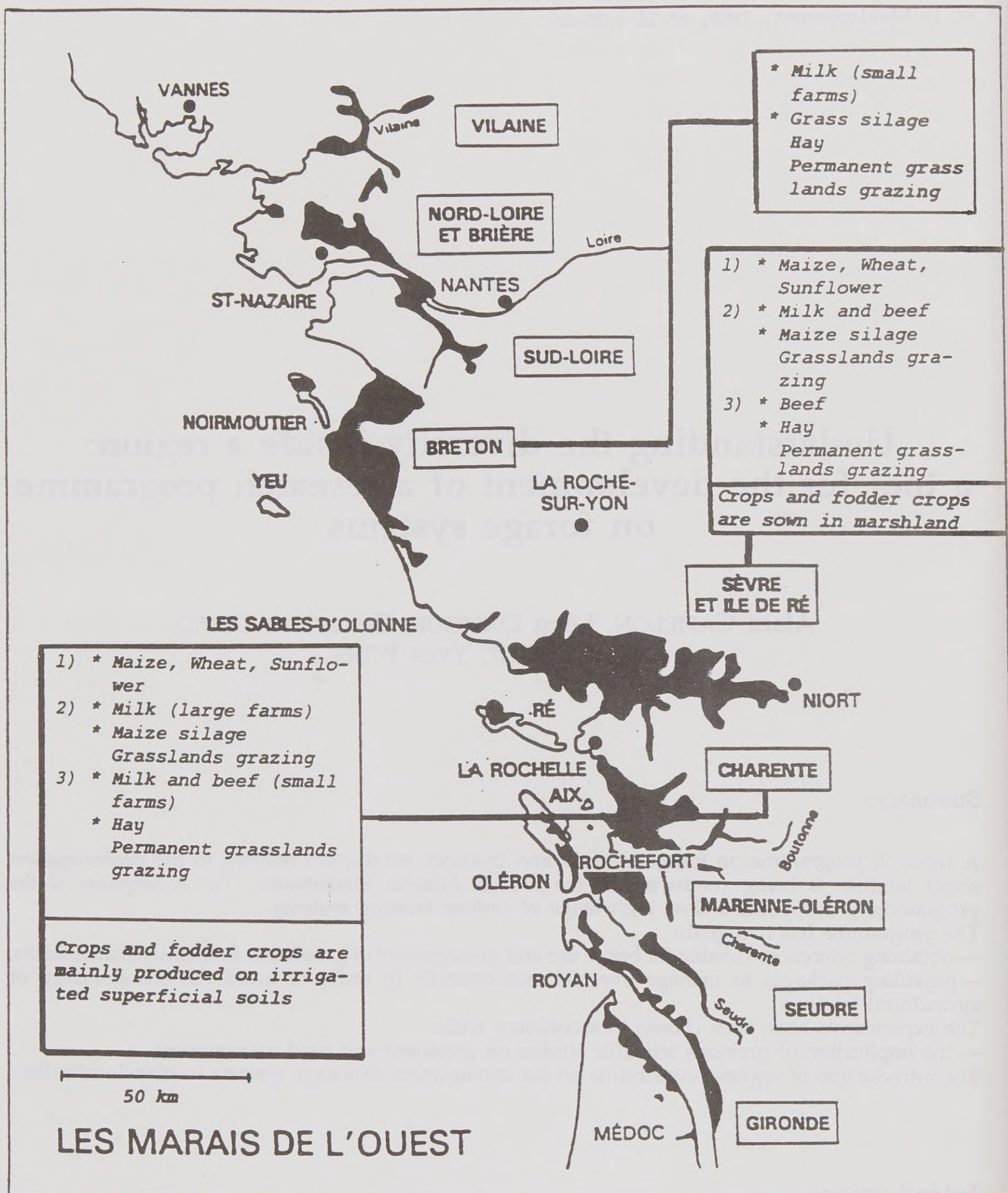
The experiments have been chosen in accordance with:

- the implication of previous scientific studies on grassland and herd management,
- The introduction of regional constraints on the management of forage systems in plots localisation.

Introduction

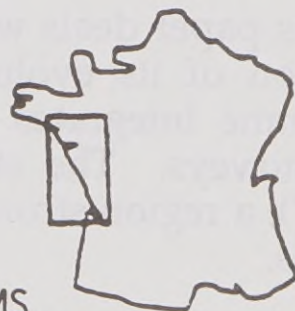
This paper deals with a process in which the current situation of local agriculture and prediction of its evolution are the bases of a research-development programme. The programme integrates monitored experimental designs on an experimental station and farms surveys. The study is conducted in the French Atlantic Marshlands ("Marais de l'Ouest"), a region strongly marked by agriculture, one of the main manpower and landuse activities.

These soils result from the reclamation of old sea bays by man all along the Atlantic Coast (Fig. 1).



Farms types identified thanks to an order number are presented according to :

- main production outputs
- fodder systems



**FIGURE 1 - DIFFERENT PRODUCTION SYSTEMS
IN THE WEST FRENCH CENTRAL ATLANTIC MARSHLANDS**

Different intensification levels have led to diversified agriculture. In the case of livestock production, there are both extensive farms where animal feed is based on hay and more intensive farms with grass and/or maize silage. Milk and beef productions are the prevailing enterprises (Table 1 shows the diversity of dairy farmers).

Table 1 — Main characteristics of stock feeding in the farm under investigation in the Marais de Charente (from Capillon et al., 1988)

MILK SYSTEMS TYPES	SIZE MILK PRODUCTION	COW FEEDING	
		WINTER	SPRING AND SUMMER
EXTENSIVE PRODUCERS	* 50 - 80 ha * 15 - 30 cows * < 3500 kg milk	* 20% maize silage * 25% hay from per- manent grasslands	Permanent grasslands grazing ; sometimes small addition of maize silage or hay
SMALL SIZE INTENSIVE PRODUCERS	* 50 - 95 ha * 20 - 45 cows * 4500-6000 kg milk	* 45% maize silage * 20% hay from temporary grasslands * 15% grass silage from temporary grasslands	Temporary grasslands grazing or green fodder feeding + maize silage
LARGE SIZE INTENSIVE PRODUCERS	* > 100 ha * 50 - 80 cows * 5000-6000 kg milk	* 60% maize silage * 15% hay from alfalfa or intensive permanent grasslands * 10% grass silage from temporary grasslands	Fodder crops
SPECIALIZED PRODUCERS	* 50 - 65 ha * 40 - 80 cows * 5000-6000 kg milk	Over 75% maize silage sometimes alfalfa	* 50% maize silage * 30% grass silage from temporary grasslands * Rotational grazing or green fodder feeding

In every type, heifers graze permanent grasslands in the marshlands during spring and summer ; even in the most intensive types, farmers rarely feed hay to them.

Milk production is expressed in kg milk per cow and year.

1. The plan of action for the analysis and the diagnostic on local agriculture and for predicting its evolution

On the basis of management results of several herds at the station of "Saint Laurent de la Prée", of technical and economic surveys in a network of farms and of classifications based on farm functioning, constraints on local agriculture were pinpointed and integrated into the programme definition. This knowledge is structured through a double stratification:

— according to natural characteristics (soil zoning was done with the aim of discussing possibilities and constraints for herbage production (Fig. 2)).

— according to farm functioning: size, production output and management, the family's desires and strategic choices.

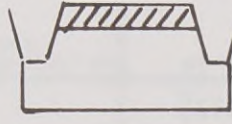
	MARSHLANDS			SUPERFICIAL SOILS
	Stable soils	"Intermediate" soils	Non-stable soils	
HYDRAULIC WORKS	 Tile drains	 Cambered beds and ditches	 Open ditches	Irrigation
PRODUCTION CHOICE	All crops Intensive fodder: Maize silage Grasslands	Autumn cropping Fodder crops : Temporary grass- lands	A few crops in rotation Longtime grass- lands	All crops Alfalfa Temporary grass- lands Maize silage

Figure 2 — Hydraulic works and possible uses of different soils types (from Damour & Pons, 1979)

1.1. The results and lessons drawn from this approach of the region: the function of grasslands on the farms

1.1.1. Possibilities and constraints for herbage and animal production

The consequences of natural characteristics are the following:

— high potentialities for maize silage production on deep or irrigated superficial rendzina and in good marshlands (stable clay), but no possibilities for crop farming in unstable clay or hardly accessible land, so that grasslands are mainly localized in the marshlands (Damour, 1981; Damour & Pons, 1979; Collas et al., 1984; Pons, 1988);

— too much water in winter and in early spring, early and prolonged dryness: herbage production occurs essentially during spring and is difficult to exploit. First grazing at the right time, even early silage are often impossible or cause environmental deterioration because of poor soil bearing capacity. With late harvesting, regrowth is not sufficient to be used and the harvested fodder is of poor quality.

Concerning forage systems, the storing of important stocks for herd feeding in winter and summer is a necessity. In answer to this situation, different solutions are adopted in the different localities (Fig. 1). Only the three main areas: "Marais de la Sèvre", "Marais Breton", "Marais de la Charente" are considered here.

In one case (Marais de la Sèvre), farms are mostly composed of stable clay soils: intensification of livestock production is based on maize silage (sometimes alfalfa). Grasslands are close to disappearing. At present, livestock production is on the decrease and grain growing is expanding (Capillon & Tagaux, 1983, 1984(a), (b)).

In another case (Marais Breton), where farms size is very small and plots are small and scattered, livestock is the main source of profit. Even when maize growing is possible, its intensification will have to go through the intensification of grasslands.

Lastly, in one region (Marais de la Charente), farms have the use of both superficial soils and unstable clay soils; collective water management system is not sufficient for regulating the water level. Most fodder stocks come from irrigated superficial soils (maize

silage, temporary grassland). Grasslands — an important part of the agricultural area — are greatly under-used, in spite of a high level of costs. Otherwise, the low density of farms and the decrease of livestock husbandry create a process of abandonment of agricultural land use, which is a danger for the balance of the whole area (Capillon et al., 1988).

1.1.2. Which future systems can be considered?

In the whole region of the "Marais de l'Ouest", studies on the functioning of extensive systems show that this type of farm cannot be reproduced because of high age of farmers, ancient equipment and farm buildings, economically low profitable herds (Capillon et al., 1988).

Even the intensive systems have to improve technical and economic performances. Some farms have the possibility of shortly giving up animal production providing they combine favorable conditions : sufficient farm size and quality of equipment and buildings, plots grouped together, a hydraulic and drainage system. But for others, the preservation of livestock production is an economic necessity; improved management and use of grasslands seem essential.

In the current situation of agricultural land abandonment, only intensive farming can prevent the problem for spreading.

1.2. Orientations and issues for research

Three ways of improving herbage and animal production corresponding to three main research lines are defined according to the farmers' needs in the region:

— Management of annual fodder cropping in the marshlands, particularly of maize (for maize, the main problems relate to management rather than extension, because accessibility is a major constraint and water supply for irrigation is limited). This point is taken into account in a research program including crop management and its consequences for water quality and will not be further mentioned here.

— Improved use of grasslands in intensive cattle farms.

— Development of economic ways to raise livestock to reduce the risks of agricultural land abandonment.

Three types of objectives are required for this research:

— getting technical references,

— providing diagnostic methods for extension agents,

— providing guidelines for the introduction of proposed innovations on farms.

2. Use and management of grasslands on various types of cattle farms

2.1. Intensive cattle farms

The bad quality of fodder produced in undrained grasslands does not fit with herd requirements in intensive husbandry. However, on plots where the water level can be controlled but which cannot be ploughed, intensive management of grasslands is worthwhile in several ways: it allows to increase the safety of livestock feeding (high need of forage stocks), to cut down production costs by improving forage quality, and if necessary to convert a part of the forage area into cash crops. The study focuses on Tall Fescue swards.

2.1.1. Agronomic issues

As 3/4 of herbage production is achieved during spring in this environment, optimal management technics must be defined for this period. The objective is to improve both forage quantity and quality for the whole spring cycles.

The programme aims at conceiving and then proposing different types of technical management that permit to obtain forage suited to various cattle feeding requirements. For this, grass growth models are needed.

Herbage growth during the first cycle has been studied extensively and is well simulated (Lemaire & Salette, 1982): it is however necessary to test the validity of these models in this constraining environment. Figure 3 illustrates results of this test for Tall Fescue.

Figure 3-a shows that:

- The growth is linear with the accumulated temperature.
- N application in autumn has an effect on the "earliness" of growth but not on growth rate. The effect of the date of last cut is slight.
- The growth rate (about 11 kg Dry Matter per °C.Day) is lower than the reference given by Lemaire & Salette (1982).

Figure 3-b shows that the excess water during the spring limits absorption of nitrogen and as a result growth (Lemaire & Salette, 1984).

As for the following cycles information is scant, an in-depth study of regrowths has been undertaken.

Several rhythms of grassland use are considered. Different technics are applied: date of first cutting (giving the date of the beginning of regrowth), level of N fertilization and water supply. This creates a range of sward types (regrowth with or without grass ears) and of microclimatic conditions for grass growth, that are useful in developing the models.

The chosen range of cutting dates also enables to discuss the results in relation with agricultural processes suited to intensive farms such as pasture, early or late silage or early hay making. The agricultural feasibility of these technics is taken in account, particularly in connection with soil bearing capacity.

A great variability of growth has been observed, according to soil conditions. To extrapolate the models to various conditions, a survey of a range of plots, chosen on the basis of soil quality (sodium status) and recording of the water table, is needed.

2.1.2. Designing a plan of action

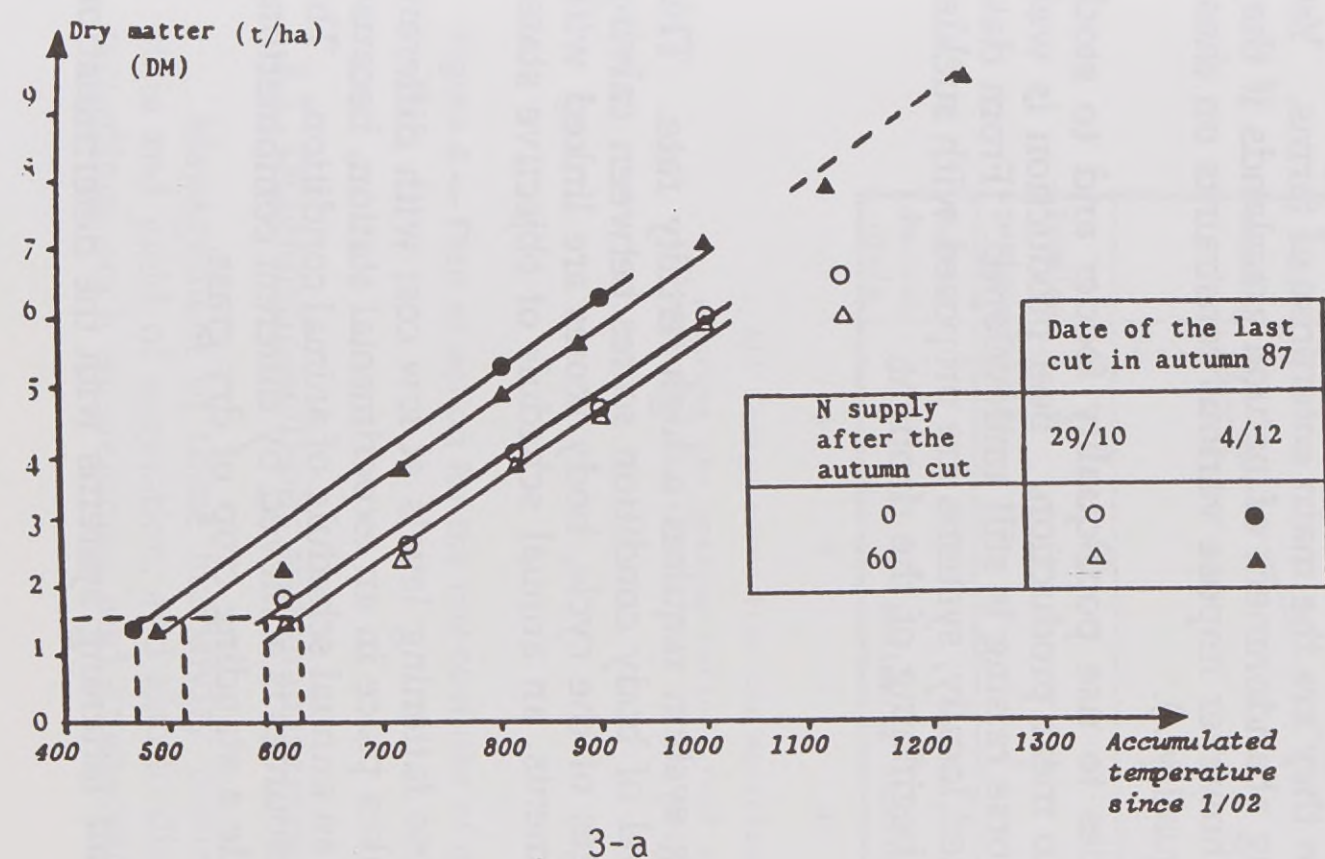
To construct the models, experiments had to be carried out in an experimental station where different managements of Tall Fescue are monitored. Grass growth is followed on a weekly step; recordings on the physical environment and plants are made.

At the same time, some farm plots are followed and information on the management of their forage system is collected.

2.1.3. Diagnostic methods and management indicators

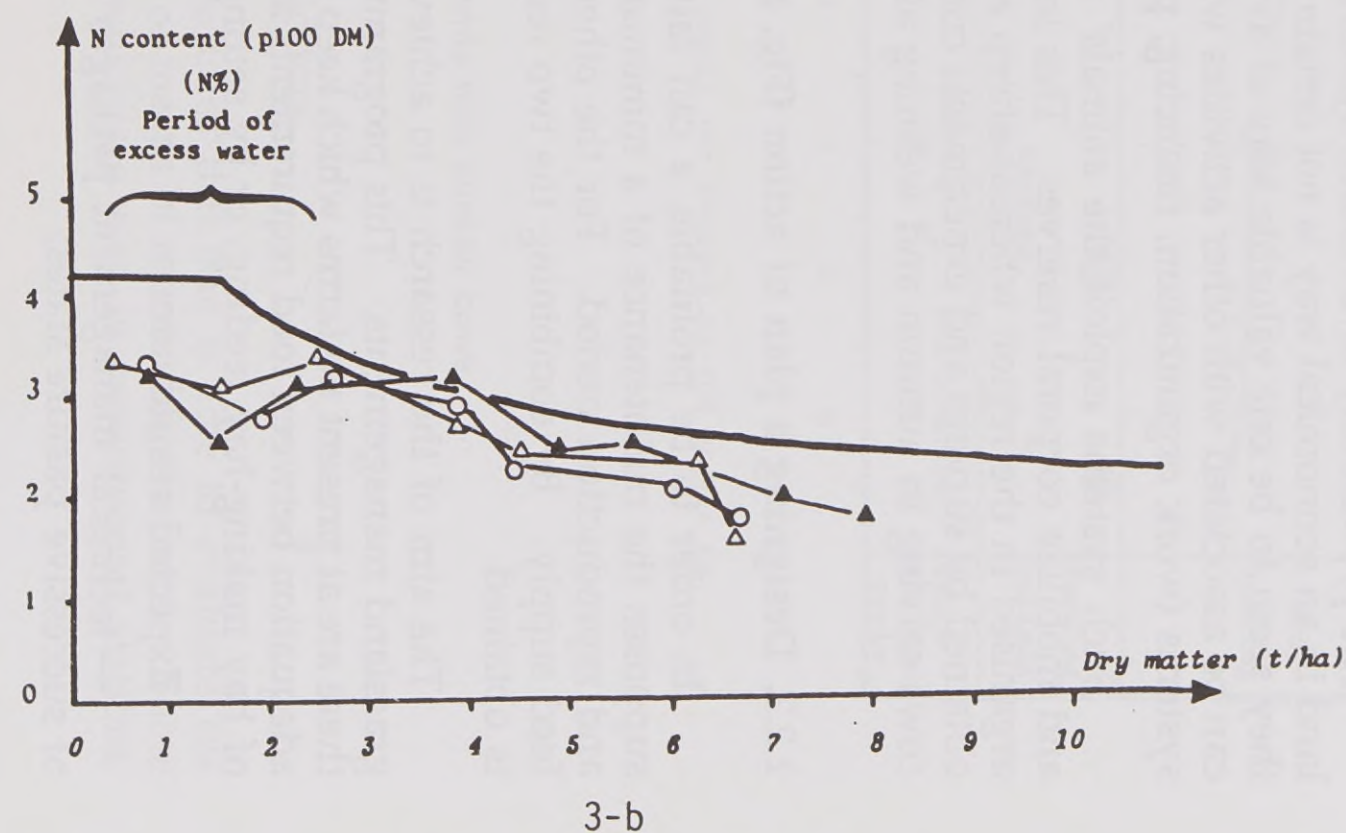
Concerning grassland management, aid to decision making requires:

- to define the right periods for observations on the grasslands,
- to give to extension agents and farmers simple indicators, which allow the latter to make technical choices, according to the state of the vegetation and probable consequences on regrowth.



(1) N = 180 units/ha on all treatments in February
 $DM = b (\Sigma\theta - a)$, where $\Sigma\theta$ is the accumulated temperature since 1/02 ($^{\circ}\text{C} \cdot \text{Day}$)
 (LEMAIRE & SALETTE, 1982)

● $b = 11,1 \text{ kg DM}/^{\circ}\text{C} \cdot \text{Day}$ ($r^2 = 0,999$)
 $a_{1,5} = 466 \text{ }^{\circ}\text{C} \cdot \text{Day}$
 ▲ $b = 10,9 \text{ kg DM}/^{\circ}\text{C} \cdot \text{Day}$ ($r^2 = 0,996$)
 $a_{1,5} = 504 \text{ }^{\circ}\text{C} \cdot \text{Day}$
 ○ $b = 10,8 \text{ kg DM}/^{\circ}\text{C} \cdot \text{Day}$ ($r^2 = 0,987$)
 $a_{1,5} = 592 \text{ }^{\circ}\text{C} \cdot \text{Day}$
 △ $b = 11,3 \text{ kg DM}/^{\circ}\text{C} \cdot \text{Day}$ ($r^2 = 0,991$)
 $a_{1,5} = 620 \text{ }^{\circ}\text{C} \cdot \text{Day}$



(2) Reference curve : $DM < 1,3 \text{ t/ha} \rightarrow N\% = 4,2$
 $DM > 1,3 \text{ t/ha} \rightarrow N\% = 4,79 (DM)^{-0,32}$
 (LEMAIRE & SALETTE, 1984)

FIGURE 3 - GROWTH AND DILUTION CURVES FOR TALL FESCUE

Fig. 3-a - First cycle growth of Tall Fescue
 (CV Clarine)(1)

Fig. 3-b - Dilution of N during the first cycle growth(2)

2.1.4. Introduction of proposed technical management packages on farms

Farms are not all able to adopt one or other type of grassland management: this depends on their structure, their functioning, their requirement towards cattle feeding and forage production.

Using the results obtained on the experimental station and on farm plots, and those from monitoring the use of forage and cattle management on well documented farms, one intends to carry out different simulations in order to define the conditions of adoption of the proposed management packages. For example, proper management of Tall Fescue requires that the farmer be able to sow it, to cultivate it, and to feed his cattle from it. For instance, certain modes of harvesting such as silage suppose structural commodities: adapted equipment as well as adequate cowhousing. Manpower resources are also a main factor.

Another purpose of simulation will be to define the modifications involved at the forage system level:

- changes in forage stocks, including maize silage,
- combined management of the different grassland plots on the farm,
- gain of land area which can be allocated to cash crops.

2.2. Low-cost raising of suckler cows

2.2.1. Livestock production and economic issues

The profitability of livestock systems with little work involved and using agricultural land in an economical way is not certain when they are the main enterprise of farms. Yet, they seem to be one valuable way of avoiding abandonment of natural grasslands if they can be associated with other activities which however impose various constraints on these systems (work organization, financing, plot quality...).

Such systems exploit the animals' abilities to use poor-quality fodder and to stock and mobilize corporal reserves. This leads to meat production. Beef production is well organised in the region whereas sheep and horse raising is still undeveloped. From data obtained by surveys and experiments conducted locally, systems are proposed with suckler cows calving in autumn and weaning at the beginning of the drought.

2.2.2. Designing a plan of action (Fig. 4)

In order to be profitable, a calf fattening system requires a high fertility rate. This supposes the maintenance of a minimum level of body condition scores between calving and reproduction period. For the other stages of the cycle, body scores are linked with feed supply. By combining the two requirements, an annual schedule of objective states is obtained.

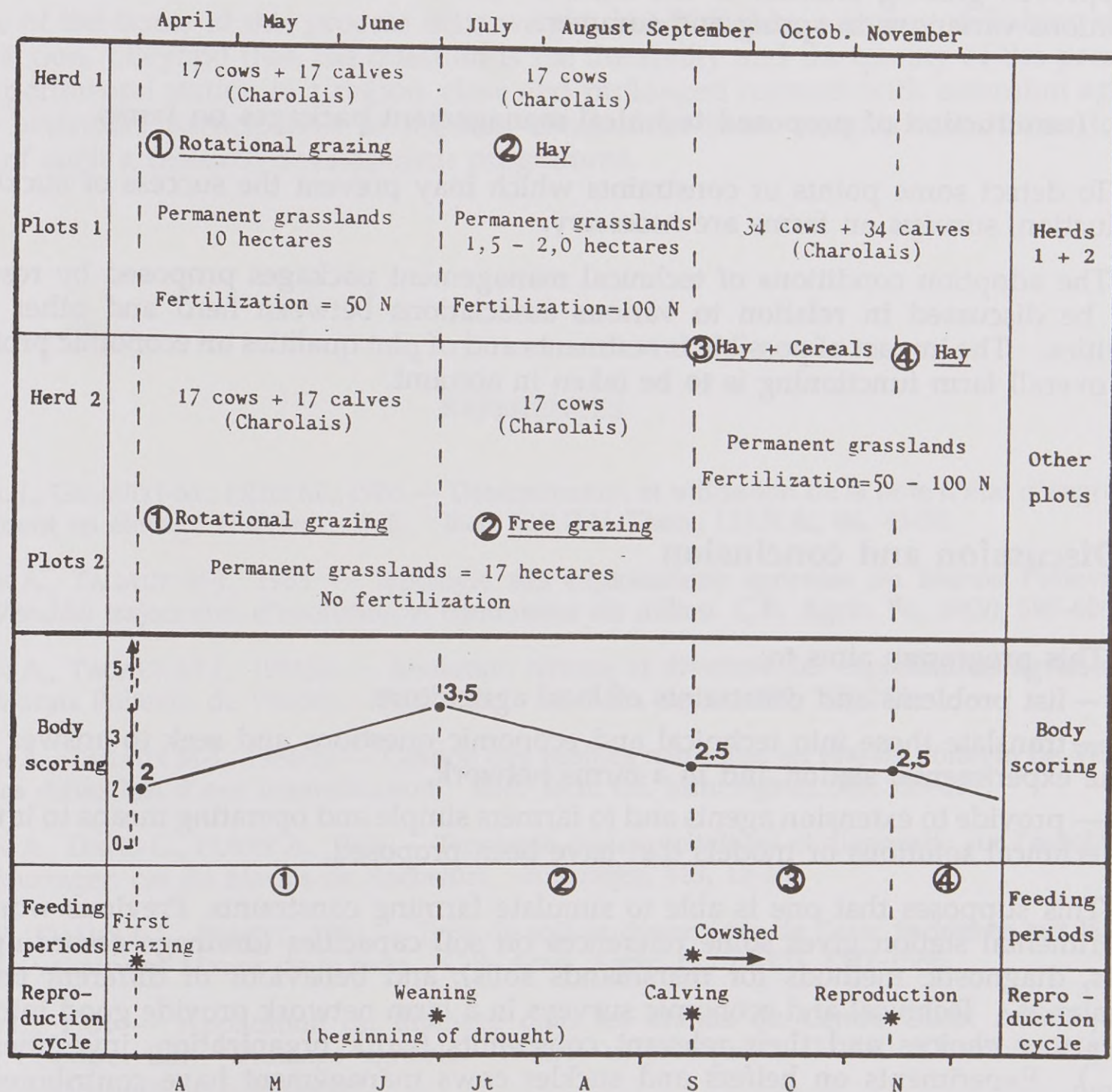
The aim of the research is to achieve these fattening levels at low cost with different grassland managements. This programme takes place in an experimental station, because there are at present no farms which keep such an annual schedule of animal condition. The adequation between food requirements and resources is achieved by different combinations of hay making-hay feeding, or by setting aside a standing crop of dry grass.

Expected results are:

- technical management packages for calf fattening systems with the determination of successive pasture states;

— economic references and references on work organization to test the incorporation of these models into systems with various constraints. In case of non-appropriateness with regard to the objectives defined, adjustments will be introduced.

This plan of action is allowed to turn for several years because of climatic risks, which may be important in a non artificial environment.



. All forage comes from the marshlands

. During the grazing period, feed energy supply per hectare is 50% higher in the first herd than in the second one

Figure 4 — Plan of action for the low-cost use of grasslands with suckler cows

2.2.3. Diagnostic methods and management indicators

Management of these husbandry methods requires that one is able to evaluate the state and yield of vegetation, and also to dispose of means of monitoring the herd. Some recordings such as weighing and grass cutting, which are used in experimental stations,

are impracticable in the fields for farmers and extension agents. These must therefore be provided with other kinds of indicators.

One of these concerns grassland condition and is based on a method for assessing quality by observation of the physiognomy of plants (Mathieu & de Vaubernier, 1988).

Another concerns body scoring of cows (Agabriel et al., 1986). Because it is difficult to approach grazing animals in the field, a visual method has to be found to monitor conditions variations in spring and summer.

2.2.4. Introduction of proposed technical management packages on farms

To detect some points or constraints which may prevent the success of suckler cows production, surveys on farms are necessary.

The adoption conditions of technical management packages proposed by researchers may be discussed in relation to various associations between herd and other farming activities. The impact of possible investments and of plot qualities on economic profitability and overall farm functioning is to be taken in account.

3. Discussion and conclusion

This programme aims to:

- list problems and constraints of local agriculture,
- translate these into technical and economic questions and seek to answer to them in the experimental station and in a farms network,
- provide to extension agents and to farmers simple and operating means to implement the technical solutions or models that have been proposed.

This supposes that one is able to simulate farming constraints. Previous work in the experimental station gives some references on soil capacities (drainage according to soil types, diagnostic methods for marshlands soils), and behaviour of different temporary grasslands. Technical and economic surveys in a farm network provide good information on farmer choices and their relevant constraints (work organization, investment capacity...). Experiments on heifers and suckler cows management have contributed to the development of sustainable systems, taking into account technical references and the main agricultural constraints.

The development of a consistent and rigorous method is necessary to catch the complex farming reality and to restore one "image", as faithful as possible of the facts: this allows to draw and organize problems at farm or regional levels.

Solutions to these agronomical problems require theoretical in-depth studies and setting up experiments in the research station. As far as the low-cost exploitation of grasslands with suckler cows is concerned, the experiment is not "standard" with a fixed plan of action. On the contrary, it is designed to evolve according to the results and problems generated by initial choices: the translation of the initial question on production, labour and cost objectives into grassland and herd management may have brought forward problems to be solved or bypassed during the experiment. The process is the following: conception of a solution, installation, assessment of results in relation to objectives using recordings and diagnostic methods, examination of the problems raised, redefinition of the solution.

The implementation of the proposed techniques by farmers calls for the provision of appropriate diagnostic tools and for examining the conditions of incorporation into production systems: repeated surveys on farms at the same time as experiments are necessary.

The importance of the farmers' network created by the experimental station at "Saint Laurent de la Prée" is noteworthy: these farmers, because they are known by the researchers and because their farms are included in regional classifications, allow to test the general process. So, results of on-farm-trials can be extended to suitable farm types.

One of the limits of this process is its weight, but it enables a correct definition of the plan of action. Beyond that, the question is the durability and the quality of the presence of an experimental station in a region: close and prolonged contacts with extension agents, training activities, participation in regional committees seem essential conditions to the success of such a research-development programme.

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Résumé :

Une recherche concernant les productions fourragères, la conduite des troupeaux, en relation avec des préoccupations d'utilisation du territoire, est menée dans les Marais de l'Ouest français. La mise en oeuvre et la conception organisée de ce dispositif supposent une connaissance de l'agriculture régionale : contraintes liées au milieu et au fonctionnement des exploitations.

Deux finalités sont poursuivies :

— disposer de références pour une meilleure utilisation de la prairie dans les élevages intensifs en relation avec l'évolution de l'agriculture locale et l'objectif général de réduction des coûts de production,

— utiliser des espaces, aujourd'hui en déprise, grâce à des troupeaux conduits de la manière la plus économe possible.

Le choix des méthodes et l'implantation des sites d'observation se font selon leur pertinence sur le plan scientifique et selon leur représentativité vis-à-vis de l'agriculture locale.

Forage functioning on the farm: a useful concept for specialized back-up relevant to farms in regional contexts

Bernard JEANNIN, Bernard CRISTOFINI

Summary:

The concept of "forage functioning" seems to be more appropriate for investigating regionally complex farming systems than an approach focusing on the forage sub-system *sensu stricto*. The Northern Alps G.I.S. has brought together for a number of years researchers and professionals in agriculture from a range of institutions.

The "systems" part of this programme developed models on the operation of various types of farms, while the "forage" part accumulated references and models adapted to regional practices. The paper describes some interactions between these two approaches and the prospects they offer, and materializes the relevance of the concept of forage functioning for agricultural development.

Our frequent attempts to define or circumscribe the "forage system" have usually given disappointing results. Difficulties arise whenever the "forage system" is seen as a sub-system, in the strictest sense, within the farming system, i.e., considered in isolation from the "rest of the farm". An overall consensus is rarely reached on the boundaries of this sub-system within the farming system: should it stop in the feeding-trough? Should it include economic results and therefore, necessarily in real terms, aspects of herd performance and management? This lack of consensus becomes open discord when the idea of establishing a list of factors making up the Forage System is put forward. Little by little, we are obliged to include in the list almost every "factor" of the farming system as a whole. As soon as we go beyond forage tests carried out on experimental farms, the real farming forage problems experienced in the field in their regional context show up the totally artificial nature of any breakdown into forage sub-systems. This is especially true in the Northern French Alps where very often the farmer does not see himself as a grass producer, or even as a milk producer, since his main occupation is farmhouse cheese-making, and his ancillary activity is the provision of tourist facilities.

What determines the farmer's farming options, and especially his choice of a forage system, are concerns such as the best marketing dates for his cheese and the requirements

of the cheese quality label (no silage, restrictions on the breed of cow, etc.) since they affect his income directly.

Our experience and that of the Chambers of Agriculture in the area show that it is vain to suggest improvements to the forage system that are "right" in absolute terms, but over-abstract, since the farmer cannot integrate them into the overall running of his farm unless they acknowledge the restrictions of his system as a whole. His limitations often have little to do with forage: cheese-making, land ranging over different altitudes, marketing, twofold occupation.

However, even in such complex agricultural structures, some analyses of the "Forage System" may sometimes prove useful: those wide enough in which the "Forage System" considered is fairly close to the overall operation of the farming system seen from the forage production viewpoint. In this case the idea of circumscribing, a priori, a separate forage sub-system should be rejected and all aspects of the overall farming system (including tourist facilities) should be potentially admissible.

Since the concept of a forage system too often lends itself to the image of a separate sub-system within the farming system and is unsuited to our present purpose, for clarity's sake, we prefer the concept of "Fonctionnement fourrager" or forage functioning in the farm (i.e. the global functioning of the farm considered from the forage angle, which matches the methods used in the Northern Alps).

Naturally, if we wish to investigate forage functioning on farms, we still have to acquire the precise knowledge and references on forage needed to build up this particular view of the farm.

What data have to be collected, what references pinpointed not only to describe forage functioning on the farm, but to influence it and improve it in the field? This is the question behind our pluridisciplinary study that has been underway for the last few years in the Northern French Alps.

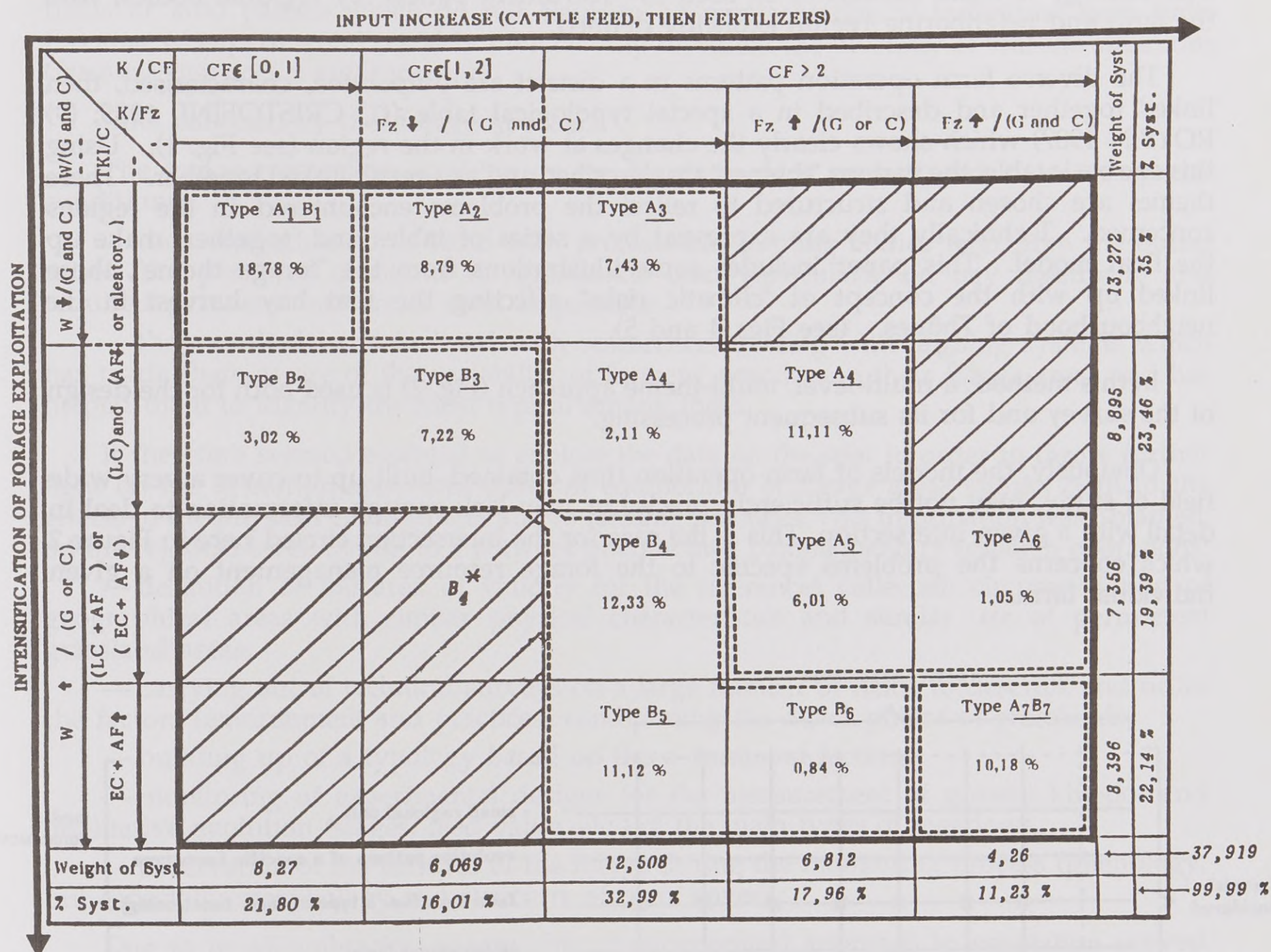
1. What material is available to back up the study of "the forage viewpoint onfarm operation" in the northern Alps G.I.S.?

The Northern Alps G.I.S

Over ten years ago, links were established between INRA researchers and farmers over a forage question: the question was, "Our hay meadows are deteriorating, and are full of dicotyledons, what is the solution?"

We soon realised that the farming systems of the region were extremely complex: seasonal migration of farmers and stock up to 10 times per year, from chalet to chalet at various altitudes on the mountainside; exchanges of animals for both summering and overwintering; quality label cheese-making (no silage); environmental restrictions (slope gradients, duration of snow cover, solifluction). This meant that one could not just advise the application of weedkiller, or ploughing and reseedling, or even more abstractly, earlier mowing, or heavier stocking rates, to any farmer in any context.

Very shortly, other teams of researchers from a number of other bodies came to join the programme. They included specialists in soils, animal husbandry, mountain grazing, breeds, cheese-making etc. The Northern Alps G.I.S. (Groupement d'Intérêt Scientifique) was founded to coordinate and provide a framework for all the research and development programmes undertaken. It is a joint group of départemental and regional professional bodies and researchers which is fairly rare in France. It is now beginning its second 4-year term.



Pattern A : Farm growth is achieved through herd growth : cattle numbers increase rapidly with, initially, purchase of large quantities of hay. Cattle housing soon becomes insufficient (A4). For types at the end of the evolution pattern an effort at mastering the forage system (early cutting, aftermath) again allows a relative forage autonomy.

Pattern B : Farm growth is achieved with relatively stable herd : the effort is concentrated on better management of the forage system from the onset. Hay is only purchased exceptionally. Low animal numbers are compensated by a policy of quality cheese-making and farm gate marketing, which ensures remunerative prices for farm milk production, and by twofold activity.

Figure 1 — A typology of farming systems in the Thônes Country (Haute-Savoie, France).
Frequency of types of farm functioning and farm evolution patterns (From D. ROYBIN)

Data collected by the "systems approach"

One of the first teams to start work was the "systems approach" team using an original methodology to build models to be used as "instrument panels" by regional bodies, with the farm and neighboring region explicitly defined.

The diverse farm operation patterns in a district are pinpointed, characterised, then linked together and described in a special typological table ((1) CRISTOFINI, 1985; (9) ROYBIN 1987) which shows clearly the changes at work in the region (see Fig. 1). Using this one basic table, the various "themes" are described and as a result linked together. These themes are chosen and structured to reflect the problems encountered in the regions concerned. Technically they are expressed by a series of tables and, together, make up the final model. This paper includes some illustrations from the "forage theme", those linked up with the concept of "climatic risks" affecting the first hay harvest in the neighbourhood of Thônes. (see Figs. 4 and 5).

In this method, a multi-level, multi-theme approach (Fig. 2) is used both for the design of the survey and for its subsequent processing.

Obviously, the models of farm operation thus obtained, built up to cover a very wide field of study, may not be sufficiently precise or may lack enough information to deal in detail with a given intersection. This is the case for the intersection circled here in Figure 2 which concerns the problems specific to the forage resource management on a given individual farm.

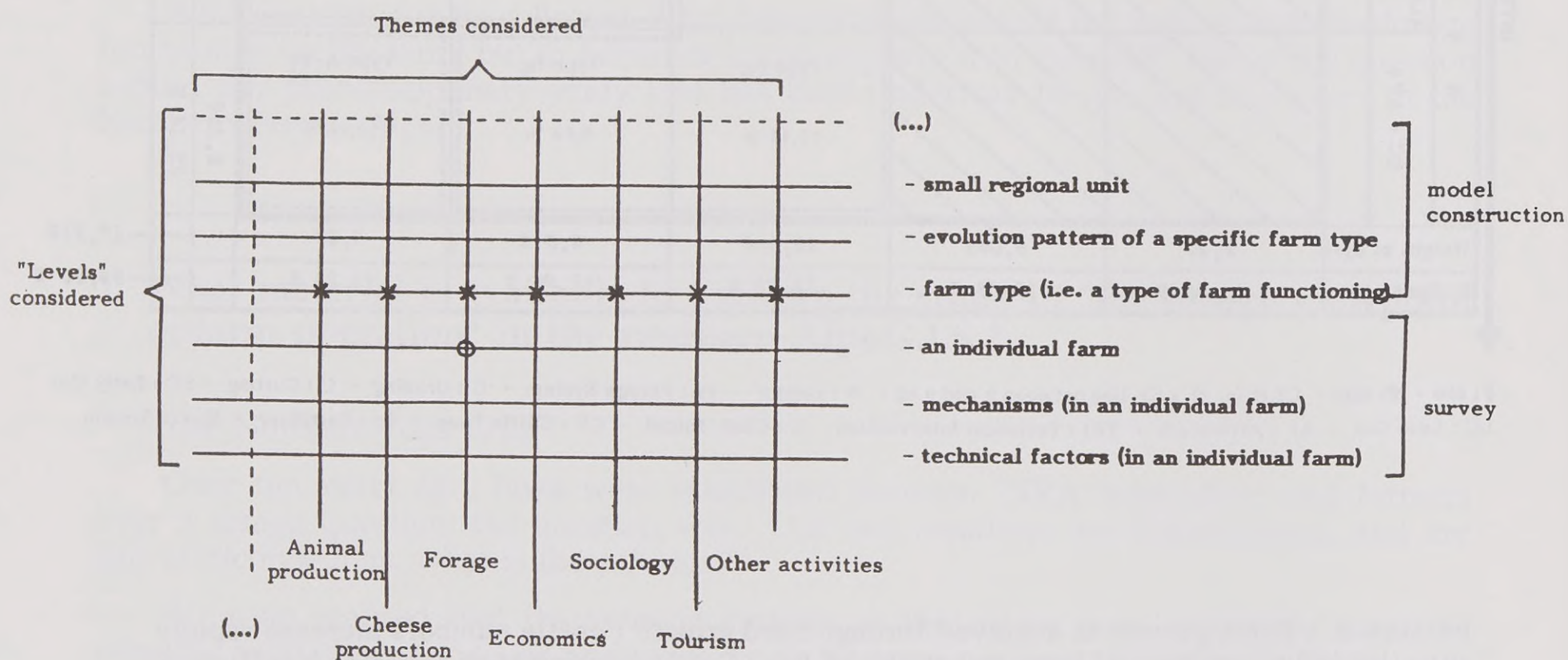


Figure 2 — The systems approach, a multi-level, multi-theme approach.

Our partners have confirmed that these models already provide a framework for valuable back-up to the farms in the region because they are tailored to the context and they give guidelines for the definition of more sectoral research, but each intersection also merits further work by specialist teams, particularly on the intersections between the level of types of farm and each different discipline (marked x).

Collaboration with the forage research team has been established for some time along these lines and for historical but also methodological reasons, working together on this theme is more delicate than with other disciplines or institutions. It is relatively easy and

extremely rewarding for both sides to add specialized information from such sources as Milk Recording Surveys or the Management and Accountancy Centres onto our typological table, since they work on individual farm files. A priori, it is however difficult to add to this same typological model, which is based on types of farm, data from a sample of fields or land parcels which do not claim to be representative of individual farm units (because of experimental costs) but which only represent the diversity of real-life situations (farming practices x environment).

Data collected by the "forage approach"

The forage researchers working on the Northern Alps project worked under special conditions:

- they worked hand in hand with professional farming bodies who from the outset raised the pertinent questions on grasslands (and particularly on hay meadows) and required pertinent answers as soon as possible.

- they worked hand in hand with researchers dealing with farming systems which has made them aware of the variability of farmers' practices in their forage areas and has helped them to identify the most typical among them.

It therefore seemed essential to explore the data on the spot in order to throw further light on the operation and main states of equilibrium of forage areas subject both to the effects of the physical environment and to farming practices. This information was obtained, on the regional level, thanks to a network of combined complementary research operations:

- definition of the area of validity for the references collected: circumscription of geographical areas with similar physical characteristics and similar use of permanent grassland areas;

- carrying out of technical surveys on a large number of fields to describe and order the factors (environment and practices) conditioning the development of grasslands;

- building up of a typology based on these dominant factors;

- monitoring of experimental designs for the measurement of growth kinetics and qualitative evolution (stages, feed value, etc.) of the main types of meadows.

- observation of the features of the forage during the monitoring process (phenology, but especially morphology and structure of plant cover).

Due to its all-embracing nature, this physiognomical approach to vegetation proved basic to the definition of "a use value". The actual use value of a meadow in a farming system cannot be limited to the notion of productivity however sophisticated this may be. It also integrates features such as evolutionary dynamics in response to changing agricultural practice, suitability for hay production, for grazing, sensitivity to random external factors etc.

Moreover, this approach means that operational recognition criteria can be elaborated for the types of grassland mentioned above and relevant back-up can therefore be given to agricultural advisors concerning each land parcel.

The forage team started from observed farming practices in order to forge yardsticks of the "use value" of meadows, on the farm and has been accumulating and summarizing a series of data and references which will hopefully lead to the detailed description of this particular "forage viewpoint" on farm operation.

2. Initial interaction between the two approaches

A first fairly simple step towards this idea of the "forage functioning" on the various types of farm is to refer back to the typological operations table (of the "systems approach")

and fill in the details on forage with the help of specialised complementary surveys or experimental procedures suited to the farming practice encountered.

A second avenue, currently being explored, is rapidly mentioned in the conclusions of this paper. It is an attempt to link up, not elementary knowledge, but the models of the forage research team (especially the meadow typology which integrates a vast amount of data) with the farming systems research team's models (micro-regional typologies of farming methods).

Work on the first step is typified by an initial study ((2) DAMBRICOURT, 1982) which attempted to fill in a typological model on farming systems in the Canton of Beaufort (Savoie) with particular reference to "manuring techniques in the Beaufort region".

The problem of slurry spreading is crucial to the question raised ("Our hay meadows are overgrown with dicotyledons"). The type of manure produced (dry or semi-liquid slurry) depends on options chosen for stabling, especially when buildings housing animals are renovated. Not all farms can afford to refit their stabling and build a slurry pit, whilst others are obliged to do so due to the increase in herd size. But slurry pit capacity sometimes requires emptying three or four times a year. Liquid slurry is easier to pump and spray, but requires repeated transport from farm to field. Not all farms have comparable fields either in terms of proximity or slope of plots, or accessibility from the road where the slurry tank can reach; labour-force availability is not always comparable, and is not present at the same times of year for all types of farms; lastly, some farms purchase most of their hay.

This means that some fields are manured with 80 to 120 m³ slurry, including spring spraying of grazing land, which leads to refused herbage; other fields are never or very rarely manured. How can any clear picture of these systems be obtained in order to provide finely-tailored realistic advice to the various different farms in the area?

The typology of the farming systems in the Canton of Beaufort should provide a tool for the understanding of this complex phenomenon which affects a great many factors within the farming system: the type of manure produced and its use which were in fact correctly classified for the types of farm as defined in the typological table.

Moreover, experimental data accumulated at the same time on the type of hay meadows were also sufficient to support analysis of the main consequences of farming practices as concerns slurry management. ((3) FLEURY et al., 1985).

Thus, thanks to this twofold simplification/clarification provided by the typology of meadows, which was underway at the time, and the typology of farming systems which expressed the whole context of the farming operations, it was possible to give finely-tuned user-relevant back-up on slurry.

We shall however illustrate another more systematic study carried out in the Thônes region ((5) GRANGER, 1986): it is an initial approach to the question of climatic risk related to hay-making on farms in the upper valleys of the Northern Alps. As shown in Figure 3 this is a typical situation where the two approaches (representing the forage "viewpoint" on the farm and the farming system) must be combined to really circumscribe the risks for individual farms. The result is a combination of information on climate, on the hay meadows (physical environment and exploitation practices) and the farms.

A hay drying model developed in Switzerland by W. LÜDER ((6) GRANGER et al., 1987) was adapted to the region. Using past statistics, this estimates the climatic availability of S.S.Ds (daily Sum of screen recorded air Saturation Deficits) for the various hay-making periods in a given area (Pays de Thônes in Haute Savoie) on the basis of climatic data recorded at a representative meteorological station. Furthermore, the S.S.Ds required for full on-field drying of forage or for post-drying it by ventilation were assessed. This climatic and forage approach enables us to compare the required and available S.S.Ds and

provides as a result an estimate of the number of harvesting opportunities available to farmers for the hay-making operations (Fig. 3).

At the same time, the integration of data collected from the typology of farm functioning in the Thônes region, and additions to it, thanks to rapid finely-focused complementary surveys on hay-making, provided information for each box on the farm typology table, on the area to be mown, the equipment used for forage harvesting as well as on the strategy chosen by each farmer for his hay harvest (level of intensification of fields; early or late cutting; second cut if any) as well as their tactics for carrying out harvesting operations (maximum area cut and harvested during a single sequence of harvesting operations; satisfactory or unsatisfactory tedding practices; taking advantage of favorable weather periods ...). This means that we can estimate the required harvesting opportunities per category of farm.

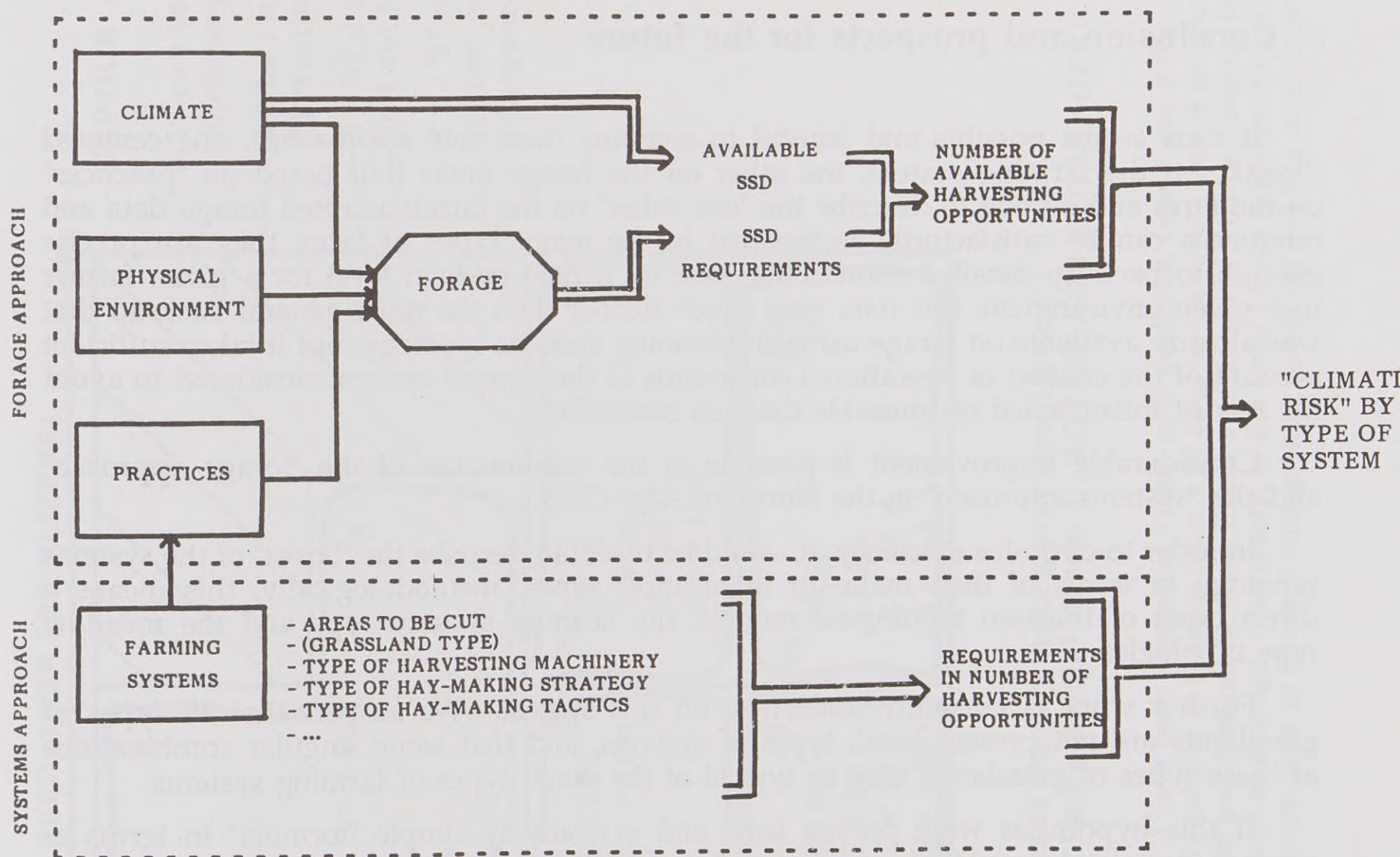


Figure 3 — How the approaches may be articulated: a practical example for determining climatic risk at hay-making time at farm level.

Adding details to existing knowledge of how farmers in each box of the typology table make their hay is an interesting exercise per se; it confirms the relevance of this type of typology for the working of farms. The Thônes typology, like the Beaufort table has "boxes" (on the working of farms) which are each fairly homogeneous for the set of factors affecting forage production including tactical factors as detailed as readiness to mow on a Sunday. A series of typological tables has been established on mowing dates, aftermath percentages, harvesting machinery etc.; the series demonstrates a high level of

coherence inside the boxes as regards the concept of the "forage viewpoint on farm operation". Figure 4 gives just some of the results on hay-making practices in each group of farmers.

The attempt to associate two levels of study (the bioclimatic, field level on one hand, and the "systems" approach on the other) enabled us to get a finer understanding of the way the hay-making part of forage management operates on individual farms. As a result, we were then able to produce a diagnosis and advice on the forage resource at the higher systems level. By comparing the number of required and available harvesting opportunities during the hay-making period, it is possible to assess the degree to which these requirements are met, i.e. the climatic risk at hay-making, for each farm type. An example of climatic risk is given in Figure 5 as assessed for the current management of hay meadows and for an "ideal" management of fields and hay-making in this type of environment (minimal climatic risk).

3. Conclusion and prospects for the future

It thus seems possible and fruitful to combine these two approaches, one centered directly on the farming system, the other on the forage areas (but based on "practices" on the farm and aiming to describe the "use value" on the farm): adapted forage data and references can be satisfactorily reclassified in the major types of farm; they are precise enough to back up detailed counselling even on a field-by-field level for a given farmer in a given environment; this data goes much further than the more general back-up that was already available on forage using the farming systems typology, but it takes sufficient account of the context of operational constraints of the type of system considered to avoid the risk of mismatched or unusable detailed counselling.

Considerable improvement is possible in the combination of the "forage approach" and the "systems approach" in the Northern Alps G.I.S.

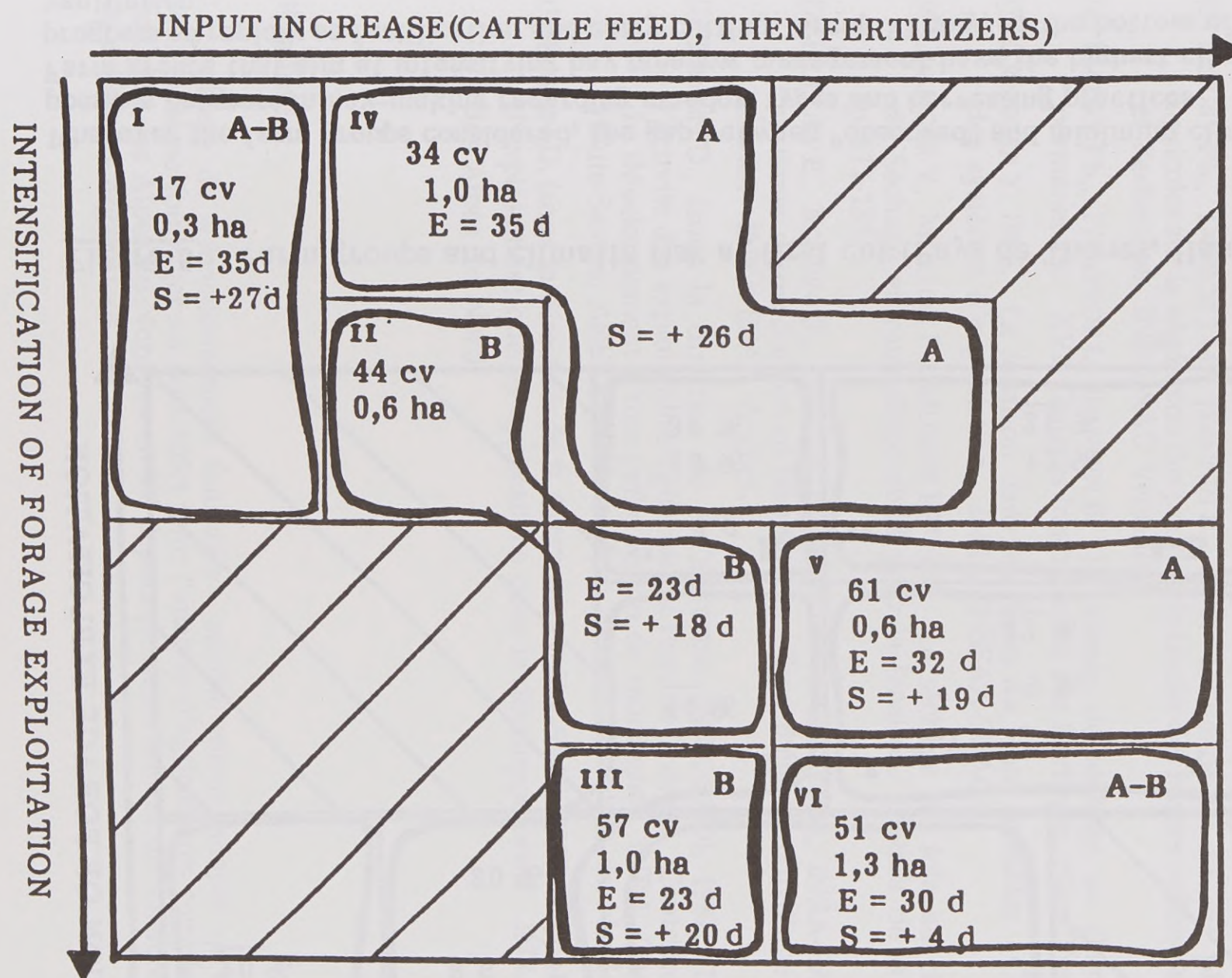
In order to optimize efficiency, it would be useful to describe the "boxes" of the systems typology in terms of their make-up in meadow types; methodologically, this means a direct cross of the two typological models, the farming systems type and the meadow type typologies.

Further work is currently underway on this subject. We suspect that all types of grasslands are not present in all types of systems, and that some singular combinations of these types of grasslands may be typical of the major types of farming systems.

If this hypothesis were proven true, and a relatively simple "formula" in terms of type of grasslands could be put forward for each box of the systems typology, great progress would be made in the matching of counselling to needs and in precision of results in this key question of the control of hay-making. In particular, the requirements in S.S.Ds., on one hand, and the need for the number of harvesting opportunities per type of system, on the other hand (Fig. 3), could be studied in much greater detail. We already have available the data behind the requirements in SSDs for the different meadow types as well as for the different types of hay-making ((4) FLEURY et al., 1989).

As an example, requirements for drying expressed as S.S.Ds for full on-field drying of forage from a grass and a grass-dicotyledon meadow are 230 and 300 respectively at the beginning of *Dactylis glomerata* ear emergence and 140 and 210 at mid-fructification.

Inversely, if opposite each type in the meadow typology we add the names of the major types of farming systems where it is found, and the main uses to which this type of meadow is put, we could probably give a definitive meaning to the idea of "use value"

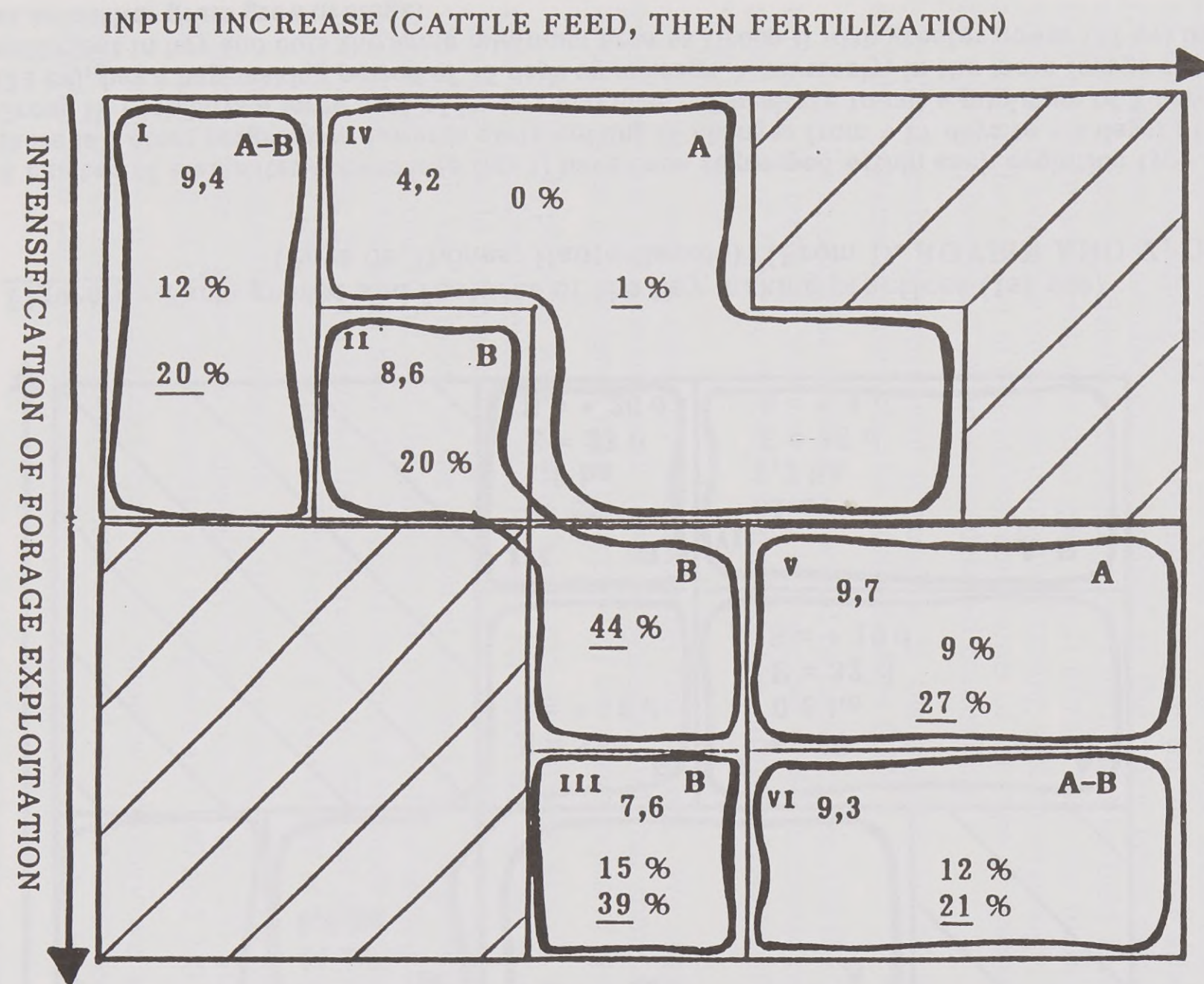


CAPTION :

- 17 cv : total horse power of harvesting machinery (cv)
- 0,3 ha : minimum area cut per day of cutting (harvesting capacity)
- E = 35 d : average duration of cutting period at first cut (days)
- S = + 27 d : average development stage of grass at start of first cut (days after Cocksfoot ear emergence).

Figure 4 : Farm groups and features of the hay making practices (1st cut)
(Pays de Thônes, Haute-Savoie) (From D. ROYBIN AND Y. GRANGER)

A number of elementary boxes (see fig. 1) have been regrouped within each evolution type A and B (Groups I, II...). In both types there is a clear progression towards early cutting (S changes from + 27 days to + 4 days) ; type B progresses more rapidly. Group IV which buys a large part of its hay and does not hesitate to cut a minimum of 1 ha/day despite low harvesting power (34 cv), has a hay-making period of 35 days on average. Conversely, in the more forage orientated type B, Group II is self-sufficient in hay and cuts the same minimum area as Group B with greater power (57 cv) in a much shorter period of 23 days at an earlier grass growth stage.



CAPTION :

9,4 Requirements in number of harvesting opportunities for the first cut

12% : "Minimum climatic risk" (simulation based on the mowing of grass meadows, on frequent teddings and on the use by farmers of all available harvesting opportunities)

20% : "Observed" climatic risk based on mowing of dicotyledon rich meadows and on hay-making practices observed in each farm group (more or less frequent tedding and more or less good use of opportunities)

Figure 5 : Farm groups and climatic risk at first cut (Pays de Thônes, Haute-Savoie)

Whatever the farm groups considered, the gap between "observed" and minimum climatic risks shows, for each one, the range of possible progress in hay-making regarding meadow types and harvesting practices.

Farm groups that aim at intensifying hay meadow management have the highest climatic risks ! Hay-making practices do not progress as rapidly as fertilization and early cutting. Group VI only, at the bottom of the figure, reverses this trend by implementing ventilation.

of these types and considerably simplify the back-up and the range of experiments required in order to prescribe feasible improvement of the meadows.

Acknowledgements:

This paper is based on studies carried out by the various participants in the research program "Alpes du Nord" G.I.S., particularly on those of P. FLEURY and D. ROYBIN, Research-Development engineers, and of Y. GRANGER, a trainee at E.N.S.S.A.A.

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Résumé :

Le concept de « fonctionnement fourrager » semble mieux adapté qu'une vision en terme de sous-système fourrager au sens strict pour l'analyse d'agricultures complexes. Le G.I.S. des Alpes du Nord rassemble depuis plusieurs années des chercheurs et des professionnels de différents organismes.

Le « volet système » de ce programme a réalisé des modèles de fonctionnement des différents types d'exploitation, tandis que le « volet fourrage » accumulait références et modèles adaptés aux pratiques régionales.

L'article décrit quelques interactions entre les deux approches, et les perspectives en la matière, concrétisant l'intérêt du concept de fonctionnement fourrager pour le développement.

1. The first step in the process of developing a business plan is to conduct a thorough market research. This involves identifying the target market, understanding the needs and preferences of the customers, and analyzing the competitive landscape. The market research should provide valuable insights into the opportunities and challenges of the business environment.

S. Grassland resource management:
level and modelling of farm level

Forage system modelling: the changing approach of a team of economists

Jean Marie ATTONATY, Marie-Hélène CHATELIN

Summary:

This article relates the different approaches of a team of economists in forage system modelling within conception of decision support systems. This sub-system representation has followed the same evolution as the representation of the farm as a whole. Thus, after implementing optimisation approaches in order to propose global systems, then budgeting systems to quantify the planned decisions, the authors now consider the management of the forage system modelling in order to apprehend the management process and propose strategies when facing climatical events. These approaches renewal was linked to the evolution of the perceived stakes and the economical theory of management. However, without desavowing the previous experience, the authors tried to extend and enhance the field of their problematics.

It was back in the 1960s that a team of economists at the Grignon INRA ESR research station first started working on matters relating to farm management, and decision support in particular. During the course of its work since then, the team has been obliged to combine global approaches to farming with sectorial approaches, and economic approaches with technical approaches, in order to be able to provide farmers and their advisors with usable methods and instruments.

The term "forage system" embraces all the means of production, techniques and processes used on a given piece of land to match the crop system(s) to the animal husbandry system(s) (Attonaty et al., 1980). For our purposes, however, the forage system is not an object of study per se, but part of the broader context of the farm itself. Thus, in our work in designing decision support instruments, forage system modelling has developed in parallel with modelling for the farm as a whole.

The first management studies produced were based on results obtained from group analysis: the farms making the highest profits were simply held up as models to the other farmers. The ease with which this type of model could be used, and the concrete nature of the example it provided led to widespread use of this approach, which is still used today by many farm management consultancies. Two main weaknesses of this method

soon became apparent: firstly, there was the difficulty in drawing up homogeneous groups of farms often, which often meant that the user was offered models which differed too greatly from his own situation; and secondly, who was to say that the farms put forward as models could not themselves be improved?

At the same time, an analytical approach based on cost prices quickly showed its limitations as an aid to decision-making for the user; it did, however, lead to the realisation that the farm had to be considered as a whole. We thus consider the farm to be the only level at which the economic and technical consequences of a decision can be fully appreciated, and feel that building models of the way farms operate is the best means of assessing and quantifying the consequences of the decisions studied.

The manner of representing the farm has changed in tune with the needs of the farmers and new developments in economic theory, modelling techniques and computer technology. We went through three main stages in our attempts to model decision-making processes:

— First of all, an attempt was made to model both the production systems and the selection procedure. Here, linear programming provides an ideal framework in which to work, at the cost of drastic oversimplification; it also opens the way to utopian dreams of optimum systems.

— Next, in response to the problems encountered in trying to represent the decision-making steps and their logical progression, all important decisions were removed from the equation, and the models simply become specialised calculation tools under the user's control. We then fell back on using budgetary techniques to quantify the decisions.

— Lastly, sets of decision rules were incorporated, and the models become ways of forecasting the consequences of altering both the component parts of the system and the rules used to run the system, contributing in this way to an understanding of the management methods used by the farmers.

1. The search for optimum systems

Between 1960-70, the neo-classical movement in economics provided a logical framework for analysis; operational research was flourishing, and supplied techniques in harmony with economic analysis. Finally, we were beginning to have access to computers and to the first few linear programming codes. This is how a major body of research grew up around modelling techniques based on linear programming. This approach matched our expectations of the time: it provided the framework for a global analysis of the workings of a rational system whose sole aim was, in the final analysis, the optimisation of a function. One of the first attempts was aimed at establishing optimum levels for livestock numbers and the feed and forage and non-forage cropping plans for a mixed farming and dairy enterprise. The inclusion of the forage system soon proved a source of complication, and the question of references soon cropped up. These difficulties proved an obstacle to the use of such models at farm level.

Nowadays, linear programming has become a tool for the researcher to use at a global level (farm or region) to investigate the effects of technical innovations, shrinking markets, fluctuations in relative prices, etc. A team of micro-economists at Grignon led by P. Cordonnier is using linear programming as the basis on which to model cattle farms.

An attempt was recently made (P. Leroy, 1986) to build a model for winter feed, in which all winter feed requirements were taken into account. The problem was stated in the following manner: we know the patterns of the requirements of some animals and the forage stocks in hand. How can we best use this knowledge to feed the herd? Practical

constraints such as the transition from one feedstuff to another and the rules for the opening of silos meant that a whole number multi-periodic model was required. The non-linearity of the substitution between concentrates and roughages was solved using an iterative procedure to stabilise the substitution coefficients. The limitation of this type of model is that extensive computer facilities and a large amount of time are required to solve the problem, thus making it difficult to use in development work.

Linear programming has left us with a wealth of methodological lessons, especially in the field of forage system modelling: it gave rise to the first attempts at modelling complex systems; it clearly showed that the forage system could not be examined in isolation; it was instrumental in establishing a dialogue between researchers from different fields, development planning officers and farmers; and, lastly, it clearly highlighted the different levels of interaction between model and data.

Conversely, attempts at taking unforeseen events into account lead to models which were difficult to handle; attempts to plan the transition between the starting situation and the objective led to multiperiodic matrices which were too large; and, lastly, the quantitative decision-making criterion used meant that qualitative decision-making criteria such as simplicity, safety, flexibility, and so on, could not be taken into account.

2. Using budgets to quantify the consequences of decisions

As linear programming was beginning to show its limitations, so requirements were changing. Production systems had been simplified to a certain extent, the systems which could be used on a farm were, in the main, known, and the number of different types available was small. The behaviourist movement and certain operational research techniques, such as multicriteria approaches in particular, led economists to question the very concept of "optimum" itself: rather than looking for the optimum solution, why not provide a set of logical solutions, from which the farmer could choose on the basis of his own implicit or explicit, quantifiable or unquantifiable, criteria. Two generations of instruments designed to achieve this aim followed one upon the other, the first consisting of medium-term (6 to 10 year) farm development models, and the second being used to draw up short-term forecasts for the year ahead.

2.1. Medium-term farm development models

The aim here was less to find the optimum solution than to cost the repercussions which the adoption of a system widely used in the region would have and, above all, to find out how to plan the transition between the current situation and the objective. This rekindled interest in the traditional technique of using budgets, since computers could take the tiresome part of the calculations off the advisor's shoulders. The first development plans appeared, under which financing was only forthcoming once technical and economic development planning study had been performed on the farm.

A software package was produced to satisfy the wide range of requirements involved. Each program in the package covered a specific sector of the farm and supplied the results which would be used as the input data for the other sectors (see Fig. 1). The package also provided an economic overview and, where necessary, an overview of work requirements. This set of programs was used in a large number of different applications.

With a few exceptions, the economic and financial forecasting program was the only one used at a development level. This was essentially due to material considerations: the banks and farm management consultancies were the only ones with a computer, with the

other organisations having to sub-contract all the processing, from punching the cards to running them on the computer. In short, the whole business meant a lot of coming and going around a computer, and the time it took to finally produce the results proved a real obstacle.

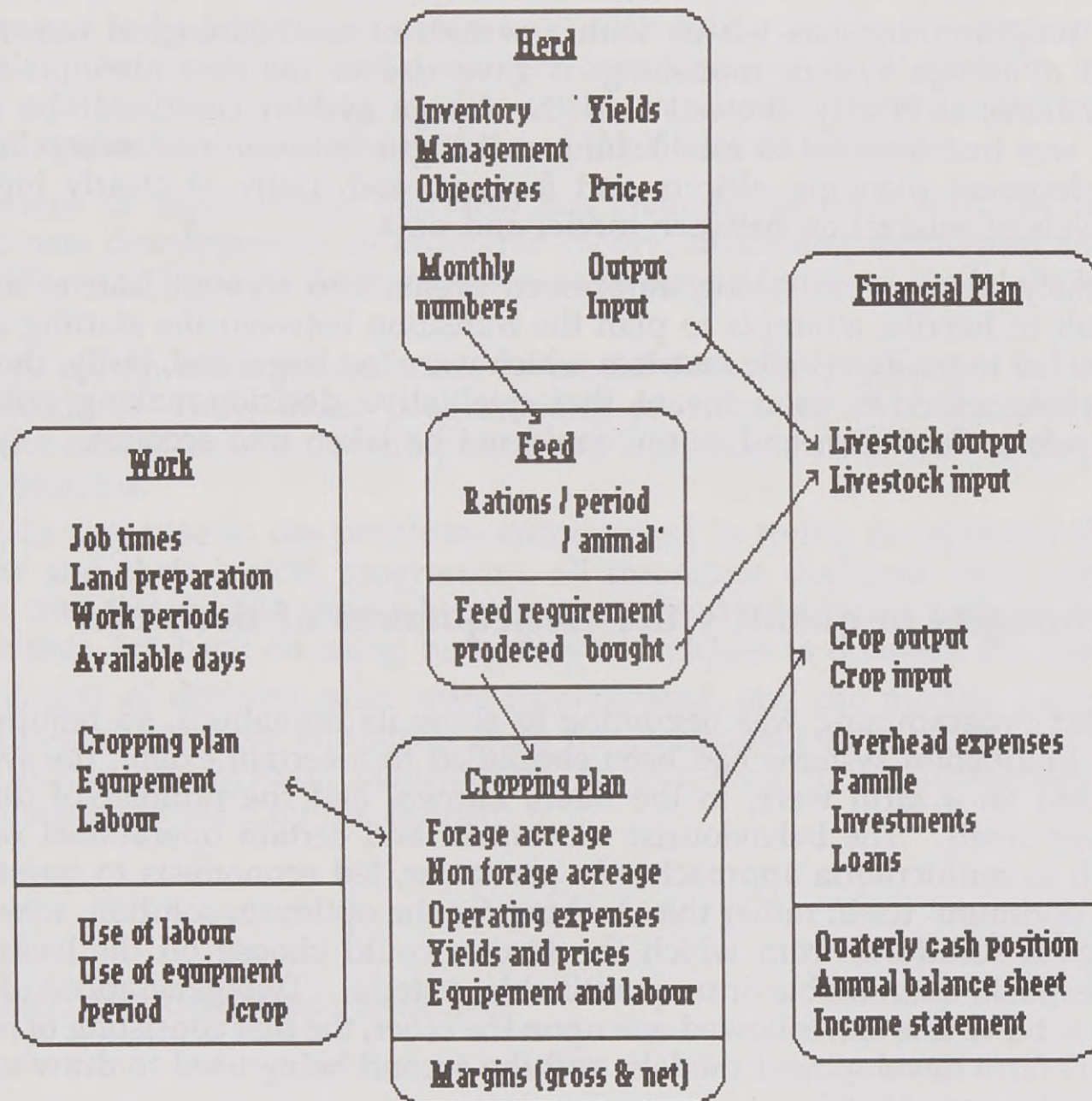


Figure 1 — Computerised budgets

As far as studies and research were concerned, however, this series of programs served as a framework in the construction of a number of global models designed to be used to investigate the economic consequences of technical changes in model farms. The pilot experiment aimed at improving fodder plants in the Lustignan region conducted at the INRA station is the archetypal example of this family of approaches (Attonaty, Bureau 1973).

The research station had a series of analytical references for various species and varieties of forage and were considering how to make use of this data to offer logical solutions to the region's livestock farmers. A model farm was defined in collaboration with the local development bodies: it was not, strictly speaking, a representative farm but rather, according to expert opinion, a commonly-encountered type of farm, and one which was suitable for further development. A number of variants were studied for this 40 ha farm: three herd sizes; two levels of production; two types of grasses; two levels of forage intensification. In all, 24 models were built on the basis of the same process: the calculation of livestock requirements per period; the manual determination of forage cropping plans and the placing of the remaining land under maize and wheat for grain; and then the calculation of the economic results in the form of an earnings report. The forage cropping

plans were drawn up to include, as far as was possible, safety stocks to allow for variations in yield and the dates on which the forage became available. Whilst we were far from certain that we had found the best solution, this approach had a number of advantages, and we drew many lessons from the results. For example:

— With an identical herd size and forage intensification level, the results were very similar for all the variants. The economic criterion was thus not relevant, and the analysis could only be taken further by considering other criteria such as the safety of the seedlings and resistance to drought.

— With the same degree of intensification, income increased as the herd size increased. The difference was, however, relatively small, whence the need for an additional study to assess the profitability of this growth, and go into the conditions required for such growth to be possible in more detail (such as whether the increase should be in leased or bought livestock).

Generally speaking, all those taking part in the study appreciated having summarised results for all the models rather than just a single solution, however "optimum" it may be; all understood the need for a global approach. The role played by the market price of grain cash crops in the choice of herd size and production level was just one factor which clearly showed the significance of the interaction between the various elements.

Computerised budgets, which at the time were dependent upon access to central computers, were no great problem to a team of researchers, but presented more of a problem for farm management consultants, since the inequality of access to computer facilities and the cumbersome processes involved meant that such tools were only ever used at farm level in connection with administrative concerns, such as Development Plans. It was not until the advent of the microcomputer around 1980 that many of these material obstacles could be overcome. Today, whilst the instruments which we have touched on above have become obsolete thanks to advances in computer technology, other more recent instruments built outside the research world are based on the same guiding principles.

2.2. The short-term models aimed at controlling the existing systems

From the outset, we saw the microcomputer as the long-awaited opportunity to branch out towards new horizons for decision support tools. On the basis of the assumption that the microcomputer would be a tool used by the farm advisor in his work with farmers, we directed our research towards a set of forecasting modules which were centred around the coming "campaign" (a period of 12 to 18 months), rather than medium term concerns and structural alterations to the farm. The economic situation was deteriorating at the time, and the main problem appeared in many cases to be how to achieve proper control over the existing systems. In addition to reducing the scope of our forecasts, this new concern also led us to examining more carefully the numerous unforeseen events involved in farming, using study and research models.

The concept behind the creation of computerised budgets (which combine analytical and global, technical and economic approaches) formed the basis for the construction of a set of short-term technical and economic forecasting modules (Fig. 2). This "set" is made up of the same elements as the computerised budgets: herd size planning (the dairy herd only in this case); feeding; the choice of a cropping plan, and the cash position. However, the shrinking of the time scale involved and access to interactive processing totally changed the style of these programs and the way in which they were used. The package was designed in close collaboration with the development planning officials, who tried out both the programs themselves and the different approaches to using this new tool with the farmers.

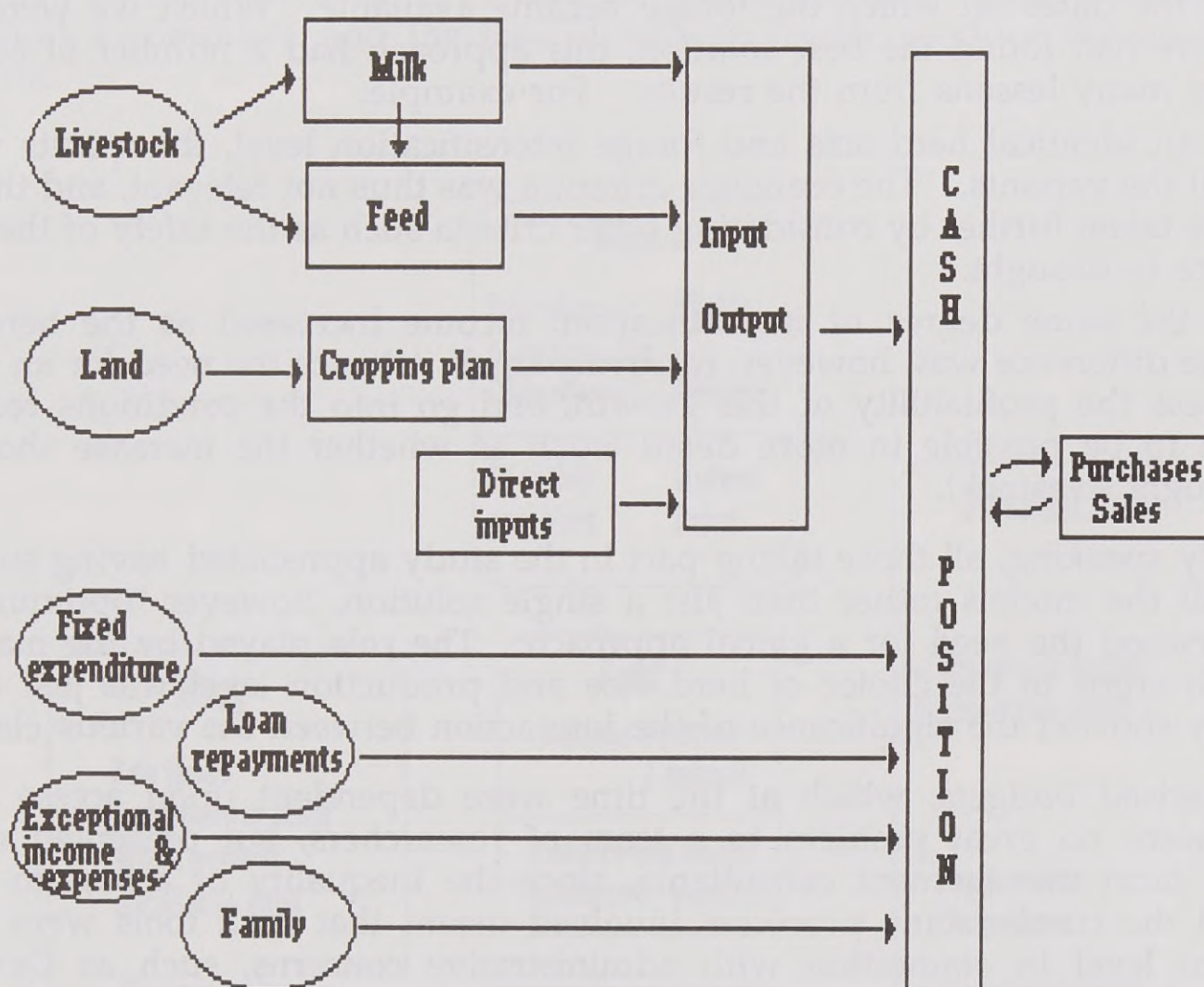


Figure 2 — The short-term forecasting chain

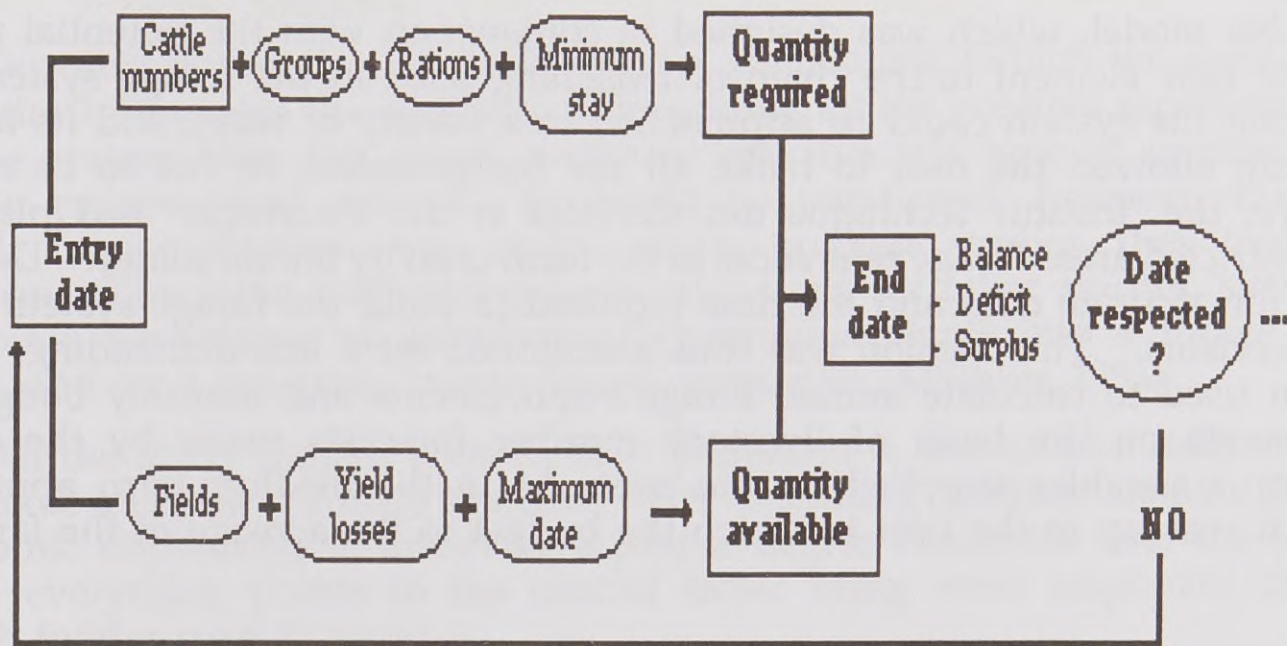
The model for the sector of the farm related to the forage system was a special case in the development of the set, in that two versions were designed. The first version covered both the use of the parcels of land and the livestock rations. The aim of this module was to help the farmer and his advisor to draw up a forage timetable. The program was not designed to help find an optimum solution, nor to calculate one automatically on the basis of a set of decision rules; it was a simulator working on a day-to-day basis over a period equal to the length of the campaign (12 to 18 months), to be controlled by the user throughout the process of simulation. The idea at the time was to allow the user to choose which decisions were to be simulated and to relieve him of the need to make long calculations, rather than including in the program the whole gamut of decisions possible, along with the context in which they would be implemented. The program contained the following four simulation functions:

- Feeding by grazing (Fig. 3: this module is used to simulate on a day-to-day basis the grass consumed by the animals and to draw up a schedule for use of a block of parcels over a given period and for given groups of animals;

- Forage stock build-up: the user chooses a parcel or a set of parcels, determines the type and yield of the stock built-up, and the simulator then controls the turnover of the stock by storing the dates at which it can be consumed;

- Feeding from forage stocks (Fig. 4: this module can be used in two ways — either to forecast forage requirements, or to simulate the consumption of existing stocks;

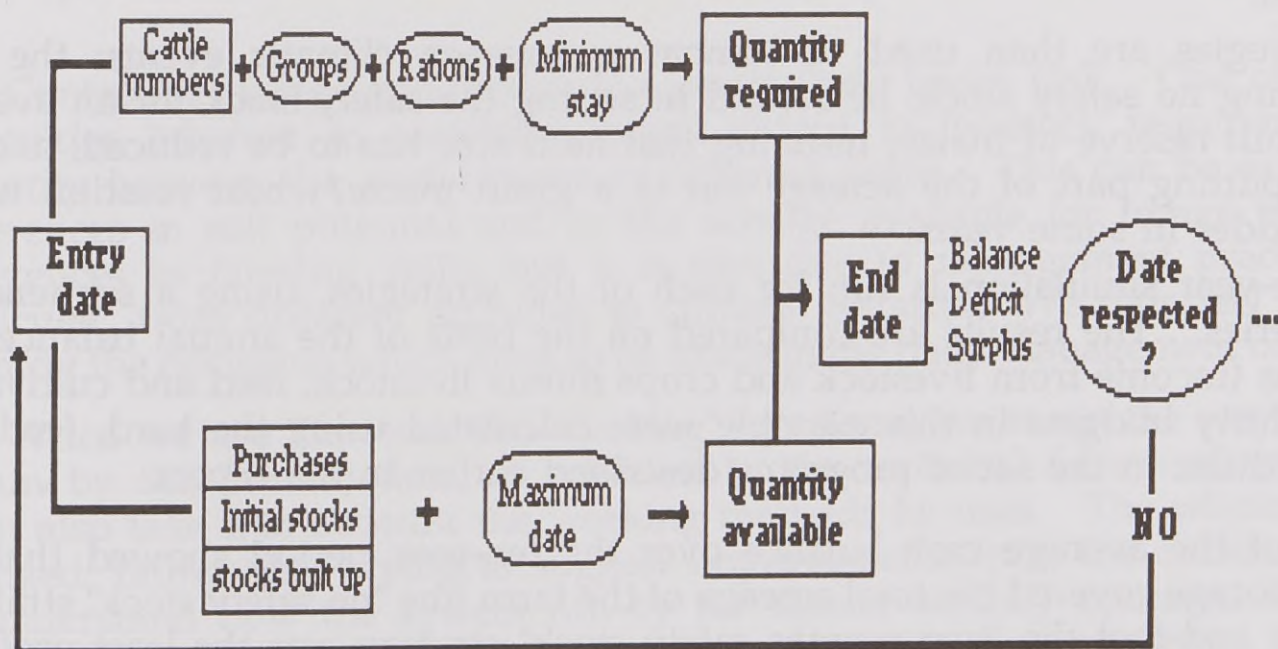
- Calculating concentrate requirements: once the simulation for the use of the parcels and the rationing timetable for roughage has been run, the concentrate requirements are calculated on the basis of the monthly production forecasts.



This module simulates the scheduled use of a block of fields over a given period for given groups of animals. It works as follows : the user chooses a list of fields, assigns them a yield and a loss rate and, where required, sets a maximum stay date (e.g : because he plans not to stay too long on these fields since grass, yield and quality are only adequate at this period; at the same times, he chooses the groups of animals which are to be put out to graze and assigns them a ration; and lastly, if he wishes, he enters a minimum date (i.e . the date up to which he wants the animals to remain on this block. The programme then simulates the daily grass intake by the animals.

At the end of the period, there are three possible outcomes : the simulateur has not encountered a date limit and the end date for the stay animals on the block is the date at which the ressources are used up; or one of the stay period limits has come into operation, and the end date proposed is either the maximum date (in which case usable acreage still remains) or the minimum date (in which case, a percentage of the animals' requirements has not been met). The user decides either to accept the end date, which thus becomes the new entry date, or to simulate the period again. To allow for the working methods of some farm advisors, the references have also been entered in the form of an acreage per animal per day, rather than as a quantity of dry matter.

Figure 3 — Grazing



This module can be used in two way : either to forecast forage requirements, or simulate the consumption of existing stocks. It works in the same way as the grazing module; in this case, however, the available quantity to be matched to the requirements is the product of initial stocks and the harvests simulated on the fields. If a minimum date is entered, the simulator will calculate the stocks of forage to be set aside to cover livestock requirements over a period, since rations are fixed.

○ User decision

□ Simulation data

Figure 4 — Feeding from stocks

We felt that this model, which was designed in conjunction with the potential users, brought a valuable new element to the chain of reasoning used in the forage system: its flexibility meant that the system could be approached in a variety of ways, and its highly interactive structure allowed the user to make all the compromises he felt to be necessary. Furthermore, the "Institut Technique des Céréales et des Fourrages" had planned to circulate over restricted areas forage references in the form used by the simulator. Despite this, the demand for accurate data and the time required to build the forage system soon discouraged the advisors. This version was thus abandoned for a less demanding, more traditional version used to calculate annual forage requirements and monthly bought-in feedstuff requirements on the basis of livestock number forecasts made by the dairy module, and ration timetables supplied by the user. As in the medium-term approach described earlier, it was up to the user to match the budget to the acreage of the farm in question.

Alongside the work on designing the forage system simulation model, a study group composed, in part, of the same people, was examining the problem of how to include the capacity of a forage system's to react to unforeseen events, from an economic viewpoint. As part of this research, an experiment was conducted in west France during the "Forum des fourrages de l'Ouest" meeting (Chatelin et al. 1982). The aim was to compare the different strategies which could be adopted to combat climatic variations (such as not having safety forage stocks or keeping reserves in stock, etc.). The example given below illustrates the methodology used in this experiment:

— We first place ourselves in a concrete pedological and climatic context, the Loire region of France, with its characteristic features of a high risk of drought in the summer and the ability to harvest maize for both grain and silage. In this context, we use phenological models to calculate the forage yield as a function of the climate on the harvest dates chosen, and the quality of the forage is estimated from the stage the forage has reached at harvest time.

— We then design a model farm, i.e: an acreage; a forage system which is "simple but typical" of the region (such as Italian rye-grass, and maize); a herd size; and a level of milk production.

— Three strategies are then used to combat unforeseen climatic events: the first consists in providing no safety stock; the second in setting the safety stock for an average year at a two-month reserve of maize, meaning that herd size has to be reduced; and the third consists in putting part of the acreage out to a grain maize/wheat rotation which can be used as fodder in some years.

— A multiple-year simulation is run for each of the strategies, using a sequence of known climatic series. The results are compared on the basis of the annual balances for the herd and crops (income from livestock and crops minus livestock, feed and cultivation expenses). The thirty budgets in this example were calculated using the herd, feed and cropping plan modules in the set of programs described earlier in the report.

An analysis of the average cash balance over the ten-year period showed that the strategy in which forage covered the total acreage of the farm (the "no safety stock" strategy) was not profitable and that the "two months safety stock" strategy was the least useful of the three. The differences between the strategies proved very small, however, and additional judgement criteria were required to analyse them in greater depth.

In addition to the studies on unforeseen climatic events, a number of technical troubles were simulated in these model systems. In the main, the results showed that troubles affecting the quantities of forage harvested were more damaging than those affecting the quality of the forage itself. It also transpired that, taken individually, the troubles were never catastrophic, provided that their consequences were properly identified and were not allowed to lead to under-feeding of the herd and a consequent drop in milk production. Conversely, a whole series of troubles would have serious economic repercussions.

Our surprise at the results of certain simulations (which we were able to explain a posteriori) illustrates the difficulty of imagining all the possible repercussions of a decision on the system from the outset, and how effective this type of approach is in dispelling certain preconceived notions. It should be mentioned, however, that since we were unable to computerise some of the stages in these studies, they took a long time to perform. The same methodology was also used for other studies, such as those on the economic advantages of introducing leguminous plants into a forage system (Mathieu 1982), and on a rye-grass/maize forage succession (Mathieu, 1986).

All the study models showed how important it was to take risks into account in any economic analysis of forage systems. The "operating troubles" models also showed us the economic importance of achieving a proper degree of control over the forage system at a farm: everything points to the control factor being more important than the choice of which fodder crop to grow.

Our experience with budgets — whether short or medium term, at farm level or in studies on specimen cases — showed us the need for a methodology for use of these budgets. The flexibility of budgets means that they can be used in a large number of different ways, which was felt to be an additional complication and an obstacle to effective assimilation by the user. In order to be able to control budgets and choose the right decisions, one must use an approach based upon an understanding of the working of the farm, and on a representation of this knowledge. Unless the user has a representation of the working of the farm in question, built to achieve a precise end, there is a great danger of him not being able to separate the essential from the non-essential and getting sidetracked into an endless search for perfection.

3. Understanding the farmer's management methods so as to be able to propose a solution

Controlling forage production is a particularly tricky task. One of the results of the difficulties inherent in matching forage output to livestock requirements is the great disparity between the performance of different farms. This can be explained in part by differences in soil potential and in the acreage available for forage production, and by differences in farming skills, but it is also due to management practices stemming, in particular, from different attitudes to climatic hazards. We thus feel it to be important to study the decisions which need to be made in the daily management of the forage system.

When we use the term "the working" of a farm, we mean the way in which the farm is run by the farmer; thus, in addition to the technical factors normally involved, we must also take into account the working methods he uses. The whole procedure is thus changed: rather than trying to suggest improvements from the outset, we must now try to understand how the system run by the farmer actually operates, so as to detect any weak points and, where possible, suggest appropriate improvements.

We felt that the construction of a computer model of how the working of the farm operates was a necessary step — however ambitious — and that it was certainly a viable proposition. We also felt that the knowledge gained from the research which had been going on for some time into farm work and equipment (Attonaty et al. 1986; Papy et al. 1988) could be used in the running of a forage campaign. We had the following expectations for this model:

— That it would provide the researcher with the means of checking that the working of the system had been correctly described; this involves comparing two sides of the same real — life situation — one using the model, and the other using the quantitative and qualitative data available; in the forage sector, which is particularly complex and rich in

interactions of all kinds, it should also provide a way of checking the consistency of the analytical data and their relevance to the running of the system;

— And that it should provide the farmer with a way of understanding the consequences that new practices will have on the working of the system.

We feel that such a model could now be viably developed, an opinion which receives confirmation from two branches of research into different areas.

Firstly, as far as understanding the farming practices used is concerned, the research conducted by our colleagues at SAD (Duru, 1988) established that, in order to manage his forage campaign, the farmer uses an adaptive forecasting program with a two-level structure consisting of, on the one hand, the division of time into periods and, on the other, the division of space into blocks of parcels. These divisions can be revised in response to unforeseen events, and things proceed as if the farmer at last had a series of rules guiding him in how to react to a series of situations which have been catered for more or less explicitly. Any forage system management model must thus use this two-level structure and contain this set of rules.

Secondly, the research we have conducted into expert systems has taught us a series of techniques which we can use in the field of modelling, to build simulation models. The first idea which we shall borrow is the separation of knowledge specific to an area of expertise and its use by an inference engine. By adding the time element (clock and calendar) and the unforeseen events, we feel it to be possible to design a general simulator or, rather, a specific simulator generator, on the condition that the case in question is covered by the formalism adopted (Fig. 5. Artificial intelligence techniques provide us with two broad ways of representing data when formalising the forage system. On the one hand, production rules (which fall into the field of logic) can be used to manipulate both quantitative and qualitative data, and will be used to describe the sets of decision rules for the farmer. On the other hand, "scenario" or "frame" type representations can be used to describe the structure of objects and the relationships between these objects. This second method seems a good way of representing the two-level structure (time in periods and space in parcel blocks) identified at forage system management level. Generally speaking, this will allow us to describe objects with properties and behavioural rules in the context of their environment. Lastly, in order to be able to describe the working of the forage system, we feel it to be important to define a language to describe the objects and concepts which need to be manipulated. The techniques now available for the processing of natural languages open the way to the construction of a specific computer language for each class of model.

Closely basing ourselves on the work simulation model, we outlined a language which could be used to describe the working of the forage system and to simulate its behaviour in different climatic years. This program is based on three broad families of objects: crops and their phenological model; structural data such as animals, parcels and forage stocks; and, lastly, three objects corresponding to three different decision levels — the periods, the conditions, and the rations. The periods are responsible for handling the allocation of the parcels to a block of use (grazing or stock build-up). The conditions control the farming conditions inside each unit (grazing speed, regrowth time, etc.), and the decision to move from one parcel to another. The rations contain the rules for the distribution of stored forage to complement the grazing. A common data system is used in the rules for these three objects, and it can use data on the state of the parcels (such as yield, stage, etc.), on stock levels, or from climatological models (rain, soil bearing capacity, etc.).

Current efforts are directed towards gathering data at a farm in collaboration with Alain Havet, an INRA SAD researcher. This is a new way of gathering data since it deals less with actual data than with the identification and formalisation of the decision rules used by the farmer to manage his forage system over the course of a campaign. We are using this work as a basis from which to list the type of information used by the

farmer, and then to design an appropriate way of representing it, which can be placed on computer.

The problem of vetting this multiform set of data still remains, however; it is likely to be resolved by estimating the consistency of actual simulations and identifying a posteriori the rules which proved to be most relevant.

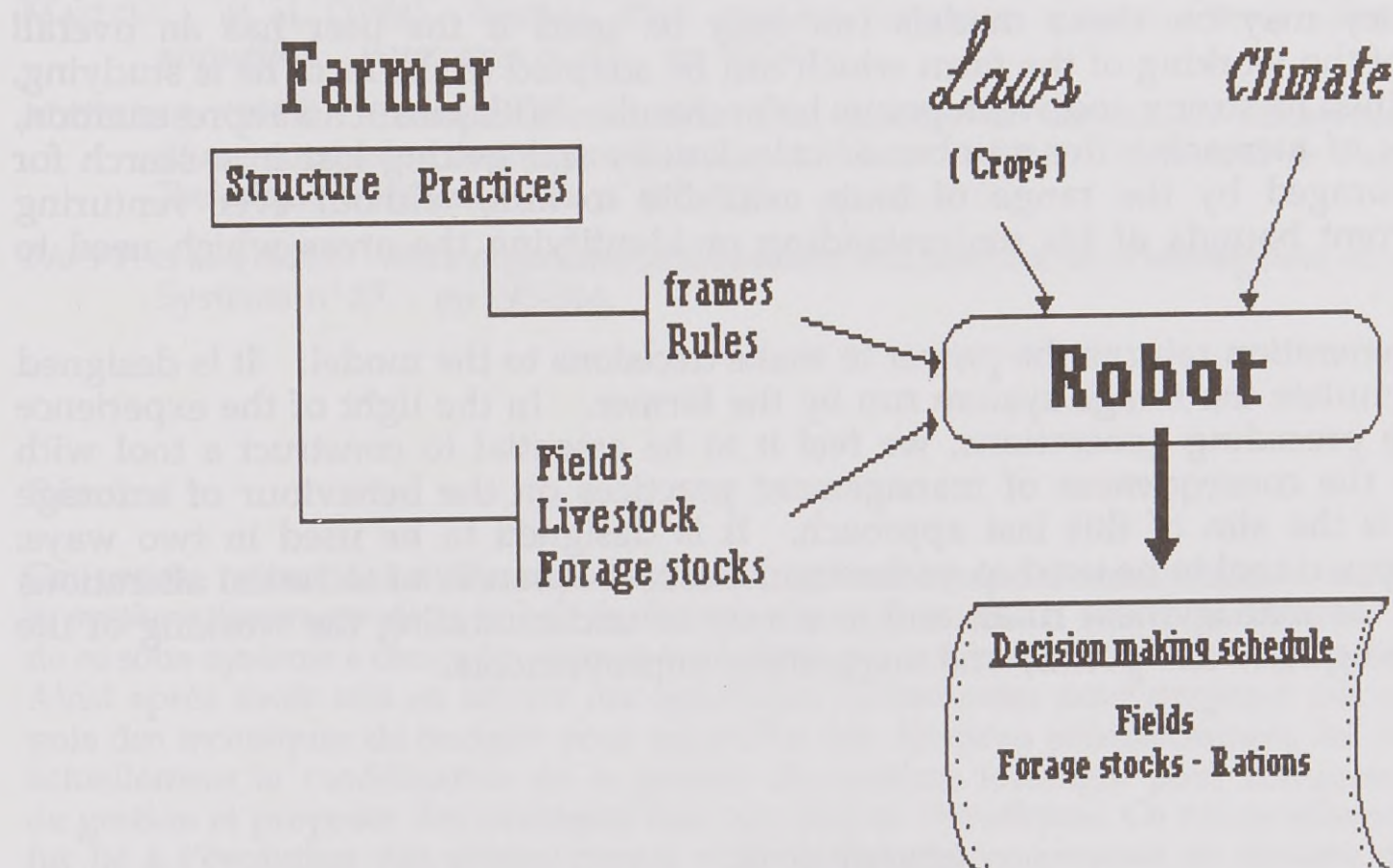


Figure 5 — Outline of a forage simulator

Conclusion

The first generation models used optimisation techniques aimed at providing the optimum solution for the farm as a whole. This approach is an attractive one, and would be suitable if the technical side and the objective function could be modelled in such a way as to help the farmer to make his decisions.

This approach supplies instruments able to cope with simple, clearly-defined problems. A linear program for the preparation of cattle feed will yield results which can be turned into action even if one does not know how the solution algorithm works nor how the matrix was written. It just means that the user must trust the nutritionists who built the model and accept the objective function chosen.

This does not, however, hold true for the farm as a whole: model building obliges one to make a lot of major simplifications, and the resulting objective function becomes something of a caricature of what it should be. It is thus not of much use to the farmer, and must be used in a different manner: the results are unusable unless one first looks at how they were arrived at, so as to find logical explanations for them and to assess whether they are still relevant to the real-life system. Now that linear programs can be

run on a microcomputer, there is likely to be a renewal of interest in this approach. But these models will always remain theoretical tools used by specialists for research and study purposes, and there will always be the danger of becoming sidetracked into analysing the mechanisms in the model rather than those involved in the real-life situation.

The second generation on the other hand, precludes the taking of any major decision by the model, thus turning them into specialised "calculators". Whilst, in the previous generation, the model would decide on the herd size and its feeding pattern, the user now has step-by-step control, simulating decisions and altering them on the basis of the quantifications supplied by the calculation tools, and on how he interprets them. However sophisticated they may be, these models can only be used if the user has an overall representation of the working of the farm which can be adapted to the farm he is studying, and has determined its strong and weak points beforehand. Without such a representation, he runs the risk of increasing the number of calculations and getting lost in a search for perfection encouraged by the range of tools available to him, without ever venturing beyond the current bounds of his understanding or identifying the areas which need to be analysed.

The third generation returns the power to make decisions to the model. It is designed to be used to simulate the forage system run by the farmer. In the light of the experience gained with the preceding generations, we feel it to be essential to construct a tool with which to study the consequences of management practices on the behaviour of a forage system — this is the aim of this last approach. It is designed to be used in two ways: as a decision support tool to be used to understand the consequences of technical alterations and changes to the management rules; and as a way of understanding the working of the system, diagnosing its weak points, and suggesting improvements.

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Résumé :

Cet article retrace les différentes approches qu'une équipe d'économistes a suivi pour modéliser le système fourrager dans le but de fournir des instruments d'aide à la décision. La représentation de ce sous-système a connu les mêmes évolutions que la représentation de l'ensemble de l'exploitation. Ainsi après avoir mis en oeuvre des approches optimisantes pour proposer des systèmes globaux, puis des techniques de budgets pour quantifier des décisions prédéterminées, les auteurs envisagent actuellement la modélisation de la gestion du système fourrager pour comprendre les processus de gestion et proposer des stratégies face aux risques climatiques. Ce renouvellement des approches fut lié à l'évolution des enjeux perçus et de la théorie économique en matière de gestion (et des instruments sous jacents). Toutefois, sans renier les acquis des étapes précédentes, les auteurs ont recherché à élargir et à enrichir le champ de leur problématique.

Modeling good field days for hay drying: an adaptation of Luder's method in France¹

Yves GRANGER, Pierre MORLON, Etienne MUNIER

Summary:

Based on the summation of screen water vapour saturation deficit, Luder's method models hay drying, and then suitable workdays for cutting. These depend on the climate, grass characteristics and the techniques applied. Comparing this "supply" with each farm's demand (which depends on areas, machinery and the farmer's strategies), it makes it possible to define and calculate the climatic risk for hay drying.

Introduction

We work in relatively cold and wet regions, where milk production (mainly for cheese) is dominant. Dairy cattle is fed in summer by grazing perennial pasture, and in winter from a hay or mixed hay/silage ration. Most agricultural operations are subject to climatic variability and risks. Hay making is frequently delayed to prevent rain from spoiling the hay. But it modifies regrowth time, and a higher proportion of stalks reduces forage quality. Characterization of production systems adequation to climatic risks and variability, requires an accurate evaluation of "good field days" or "field working days" for hay making. Such a day is defined as the first one of a sequence allowing grass to be cut, dried in the field, and gathered, without being spoiled by rain. Current approach by number of consecutive "non rainy days" or "fine weather days" (with so many arbitrary definitions as authors), are not sufficient, and it is necessary to use a climatic model for hay drying. For practical reasons, such a model should use exclusively easily available meteorological data, — i.e. recorded in meteorological network. In any case, an extreme sophistication in meteorological data would be of no use without the same precision in vegetal characterization, which can be obtained only in experimental stations, and not for regional studies. As was noted by THOMPSON (1984 : 18-19):

"A fairly rigorous model of swath drying was developed by THOMPSON (1981). He found it necessary to use a multi-layer formulation in order to include in a realistic way as many possible of the factors (...).

The model was complicated and used too much computer time to be useful in investigations of the climatology of haydrying: even then, it was not found possible to incorporate the important factor, swath architecture, which can probably only be treated rigorously (as an advection problem) by a higher-order turbulence closure method."

After a bibliographic review, and tests of other models, the method developed in Switzerland by Dr. Werner LUDER (1982) appeared to suit our purposes, after its calibration and adaptation to the features of the regions where we work: Lorraine and Savoy, in Eastern France.

1. A digest of Luder's method

1.1. The drying model gives an estimation of forage moisture at any time, as a function of its initial moisture, and of the summation of a climatic index since cutting. The climatic index used is the water vapour Saturation Deficit (SD) in air, i.e. the difference between the real amount of water vapour, and the saturation amount at the same temperature (both in meteorological screen). It is calculated in grams of water/cubic meter of air, at hourly intervals, by the BOSEN (1960) formula.

During the night, there is no drying: on the contrary, moistening by dew compensates late and early day drying, so that forage moisture is approximately the same at 8 a.m (T.U) as at 17 p.m the day before (SPATZ et al, 1970). So, S.D. is summed only during the "efficient drying period", from 8 a.m to 5 p.m (in Lorraine we found 6 p.m as a better limit in June, when day is very long). The sum of hourly saturation deficits (SDS) during this period is closely related to daily ETP (calculated by PENMAN's formula); in Mirecourt in Southern Lorraine:

$$\text{ETP (Penman)} = 0,0239 \text{ DS} + 1,613 \quad r^2 = 0,73$$

n = 50 days, randomly chosen between May 15 and August 15, over 12 years.

The drying model is of exponential form:

$$W = a \exp (- b x + c x^2)$$

w is the moisture content (%) of hay, on a dry weight basis.

x is the sum of saturation deficits (hourly intervals) since cutting.

a, b, c are constant:

a is the calculated initial moisture

b expresses the ability of forage to loose water.

Comparing predicted and observed moisture contents of hay all along the drying period gives excellent results; average correlation coefficients exceed 0,97 in LUDER works in Switzerland, as well as in ours in Lorraine (MUNIER, 1986) and Savoy (GRANGER, 1986) — but correlation coefficients are always high when relating accumulative values of variables.

1.2. The “need of Saturation Deficit Sum” (SDS need) to achieve drying of hay, is determined by the intersection of the drying curve (drying model), and the line representing the moisture making it possible to gather in the hay (75 % dry matter for total field drying, and 60 % DM for complementary barn drying) (fig. 1). As the angle is very acute, uncertainty is high for one curve intersection point. But the purpose is not to model drying of individual plots, but to determine the average needs of a limited number of cases defined by altitude (in mountain areas), botanical composition, maturity, yield of vegetation, techniques used for cutting, conditioning and tedding. Consequently, the intersection is determined, graphically, for a family of curves (fig. 1).

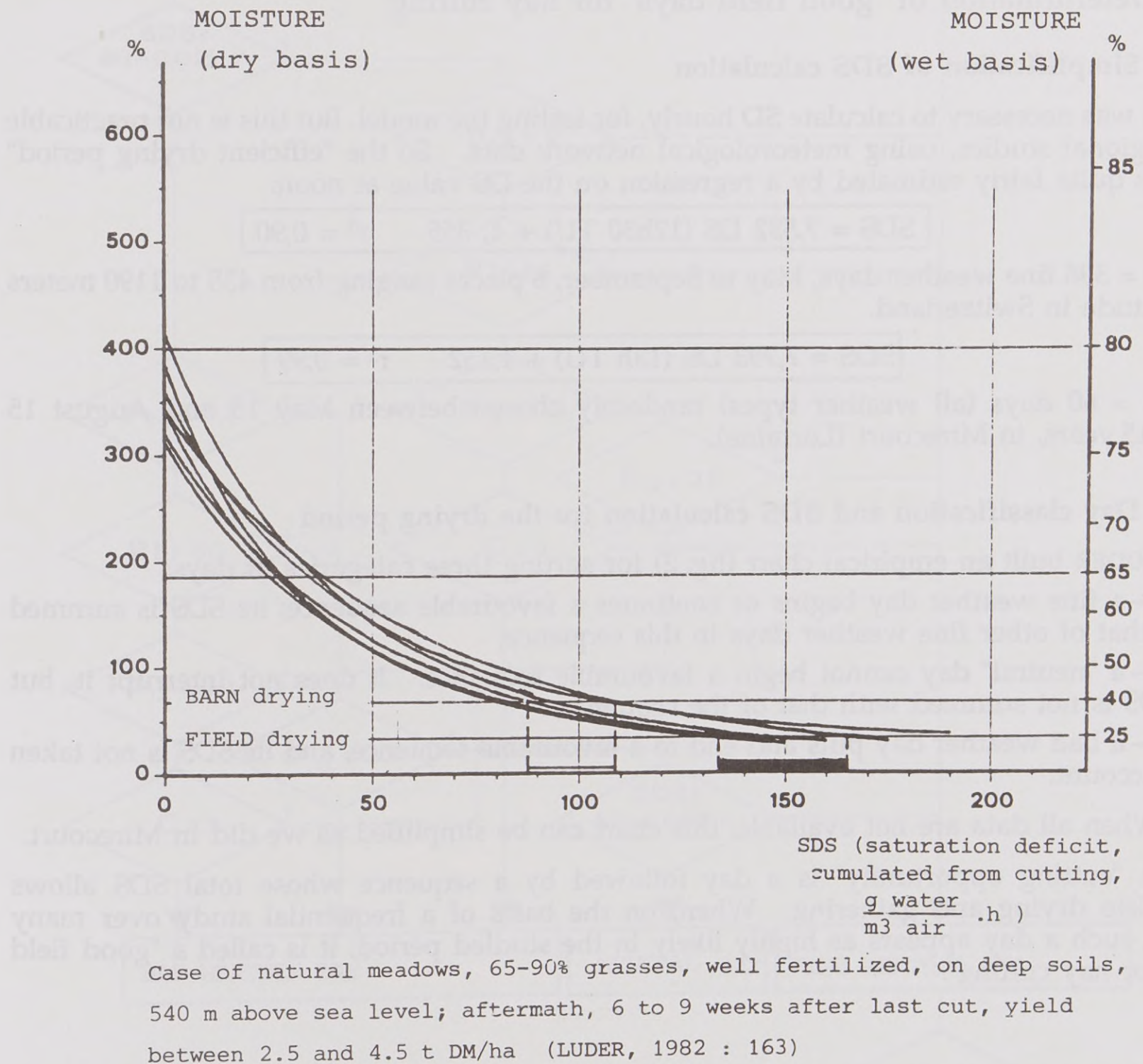


Figure 1 — Graphical determination of drying needs by grouping adjusted drying curves

In LUDER's experiments in Switzerland, SDS needs varied as follows:

- decreased by 4 % for each 100 m increase in altitude;
- increased with yield (8 % for each ton DM over 3 t at the first cut in spring)
- maturity and yield were not separated in order to approach agricultural reality in the region;

— were lower at 2d and 3d than at 1st cut, at the same altitude and for the same yield (different morphological composition of plants, with fewer stalks — and perhaps soil temperature and moisture influence);

— were reduced by conditioning (30 % in SDS, i.e. 25 % in time; in Mirecourt in Lorraine, it corresponds to some hours to 1 day);

— the difference between needs for total field drying, and for barn complementary drying, was highest for lower yields and altitudes (28 % for 3 t DM/ha at 400 m), and decreased as these increased.

1.3. Determination of "good field days" for hay cutting

1.3.1. Simplification of SDS calculation

It was necessary to calculate SD hourly, for testing the model. But this is not practicable for regional studies, using meteorological network data. So the "efficient drying period" SDS is quite fairly estimated by a regression on the DS value at noon:

$$\text{SDS} = 7,532 \text{ DS (12h30 TU)} + 4,355 \quad r^2 = 0,90$$

n = 398 fine weather days, May to September, 6 places ranging from 435 to 1190 meters of altitude in Switzerland.

$$\text{SDS} = 7,793 \text{ DS (13h TU)} + 1,152 \quad r^2 = 0,99$$

n = 60 days (all weather types) randomly chosen between May 15 and August 15 over 15 years, in Mirecourt (Lorraine).

1.3.2. Day classification and SDS calculation for the drying period

LUDER built an empirical chart (fig. 2) for sorting three categories of days:

— a fine weather day begins or continues a favourable sequence; its SDS is summed with that of other fine weather days in this sequence;

— a "neutral" day cannot begin a favourable sequence. It does not interrupt it, but its SDS is not summed with that of the sequence;

— a bad weather day puts and end to a favourable sequence, and its SDS is not taken into account.

When all data are not available, this chart can be simplified as we did in Mirecourt.

A "cutting opportunity" is a day followed by a sequence whose total SDS allows complete drying and gathering. When, on the basis of a frequential study over many years, such a day appears as highly likely in the studied period, it is called a "good field day for hay cutting".

1.4. Definition of climatic chance and risk

As climate is variable from year to year, it is usual to take a threshold of good working conditions frequency (i.e. clear weather before forage becomes too mature), v.g. 8 years out of ten. LUDER considers that the worst two years, disregarded in this approach, can be very important to determine the breeding system and the machinery. For each farm, and each hay making period in the year, he calculates the ratio: cutting opportunities demand/supply. The demand (number of days required to cut all hay on the farm) depends on the total area to be cut; machinery, manpower and organization. The supply depends on meteorology, vegetal characteristics and the techniques applied (tedding frequency, conditioning).

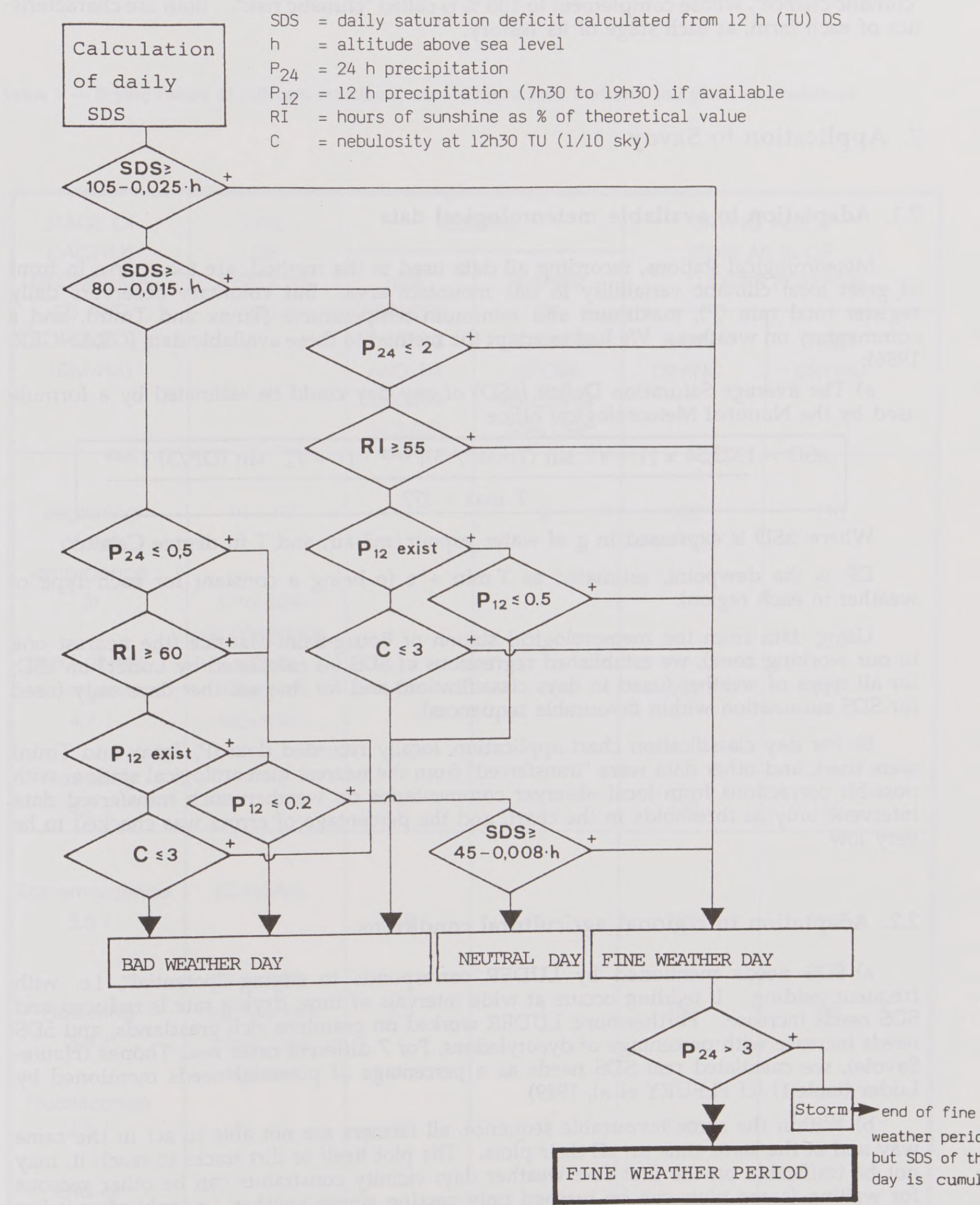


Figure 2 — Day sorting chart (LUDER, pers. com., 1986)
This chart can be simplified when all data are not available (MUNIER, 1986)

Limiting, each year, this ratio to 100 %, and averaging it on several years, gives the "climatic chance", whose complement to 100 % is called "climatic risk". Both are characteristics of each farm, at each stage of its history.

2. Application to Savoy

2.1. Adaptation to available meteorological data

Meteorological stations, recording all data used in the method, are too sparse in front of great local climatic variability in this mountain area. But voluntary observers daily register total rain (P), maximum and minimum temperatures (Tmax and Tmin), and a commentary on weather. We had to adapt the method to these available data (GRANGER, 1986):

a) The average Saturation Deficit (aSD) of any day could be estimated by a formula used by the National Meteorological office:

$$\text{aSD} = \frac{1323,54 \times [1 + \sqrt{2} \sin (T_{\max} / 3)]^{8,827} - [1 + \sqrt{2} \sin (DP/3)]^{8,837}}{T_{\max} + 273}$$

Where: aSD is expressed in g of water vapour/m³ air, and T in degree Celsius.

DP is the dewpoint, estimated as T min + e (e being a constant for each type of weather in each region).

Using data from the meteorological station of Bourg-Saint-Maurice (the nearest one to our working zone), we established regressions of SDS (as calculated by Luder) on aSD, for all types of weather (used in days classification) and for fine weather days only (used for SDS summation within favourable sequences).

b) For day classification chart application, locally recorded data (P, Tmax and Tmin) were used, and other data were "transferred" from the nearest meteorological station, with possible corrections from local observer commentaries on weather: such transferred data intervene only as thresholds in the chart, and the percentage of errors was checked to be very low.

2.2. Adaptation to regional agricultural conditions

a) SDS needs mentioned by LUDER corresponds to drying "potential", i.e. with frequent tedding. If tedding occurs at wide intervals of time, drying rate is reduced and SDS needs increase. Furthermore, LUDER worked on graminea rich grasslands, and SDS needs increase with percentage of dycotyledons. For 7 different cases near Thônes (Haute-Savoie), we calculated real SDS needs as a percentage of potential needs mentioned by Luder (table 1) (cf FLEURY et al, 1989).

b) Within the same favourable sequence, all farmers are not able to act in the same way and at the same time on all their plots. The plot itself or dirt tracks to reach it, may not be trafficable on the first fine weather day; vicinity constraints can be other reasons for waiting (some plots can be reached only passing across another, i.e. only after it has been cut). Furthermore, farm organization (available machinery, availability of neighbours's help), family preferences (v.g. working on Sunday, or not), or risk aversion, create other differences between farmers.

Table 1 — Drying needs of different meadows, according to their maturity and yield, and teddings

STAGE OF DACTYLIS GLOMERATA (2) AND YIELD (DM/HA)	TYPE OF MEADOW (3)	TEDDING		DRYING NEEDS (SDS) AS % OF LUDER'S POTENTIAL	
		TIME BETWEEN CUTTING AND 1st TEDDING (HOURS)	NUMBER OF TEDDINGS BEFORE REACHING 60% DM	BARN DRYING	FIELD DRYING
Beginning of ear emergence 3t	P1 - P2 0 to 30% dicotyledons other than legumes	2	2	120	110
end of ear emergence 4,7 t		18	1	197	171
Flowering 4,2 t		5	1	110	176
Ear emergence 3,5 t	B2-M1-M3 20 to 90% dicotyledons other than legumes	3,5	3	120	120
Flowering 3,8 t		8,5	3	165	165
Fructification 4,5 t		5	1	140	157
End of fructification 4 t		3,5	2	137	128

c) For the a) and b) reasons, individual cases are very different. In a first stage of our study, we regrouped them, crossing two levels of SDS needs (100% and 150% of Luder's potential) and three levels of farmer's abilities :

level 1: farmer seizes all opportunities

level 2: farmer doesn't work on Sundays, and cannot increase cutting capacity

level 3: same as 2, plus: farmer has to wait 1 day after last rain, and doesn't seize isolated opportunities.

2.3. First results

As was said above, climatic "chance" and "risk" characterize each farm. But it is possible to choose, a priori, an acceptable risk level, and calculate for it the average number of cutting opportunities according to climate. For a regional preliminary study, it makes it possible to compare:

- different times in the year, or different climatic zones;
- vegetal characteristics (botanical composition, maturity, yield);
- the techniques applied;
- farmers' abilities to seize cutting opportunities.

For example, at Arèches (a village at an altitude of 1000 m. in Savoy), for the 20% risk, the results in fig. 4 shows that:

- the number of cutting opportunities increases from May to the end of July, with a less favourable period in the second half of June;
- compared to Luder's potential, dicotyledon rich meadows, unfrequently tedded, offer cutting opportunities reduced by 30-35 % in July and August, and 55-60 % in May and June;
- barn complementary drying adds two cutting opportunities per month; allowing farmer to increase hay area, or to have higher security in his system;
- differences are high according to farmers'abilities to seize opportunities.

On the whole, the farmers' strategies and the characteristics of their production systems appear as being as important — or even more so — as the climate itself.

POTENTIAL

meadows with high proportion
of grasses, frequently teded
or conditioned

ADAPTATION

high proportion of dicotyledons,
1 or 2 teddings

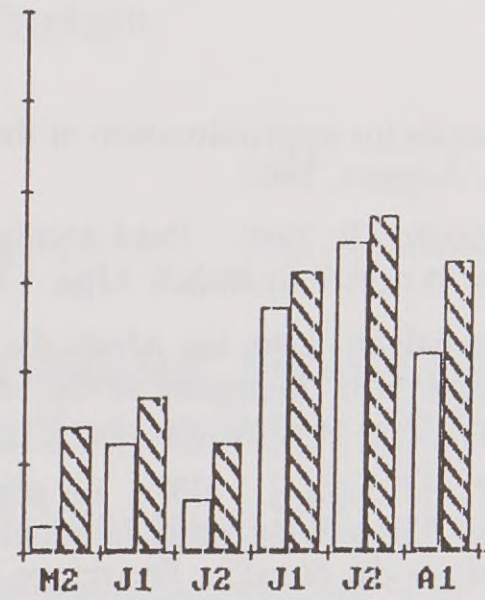
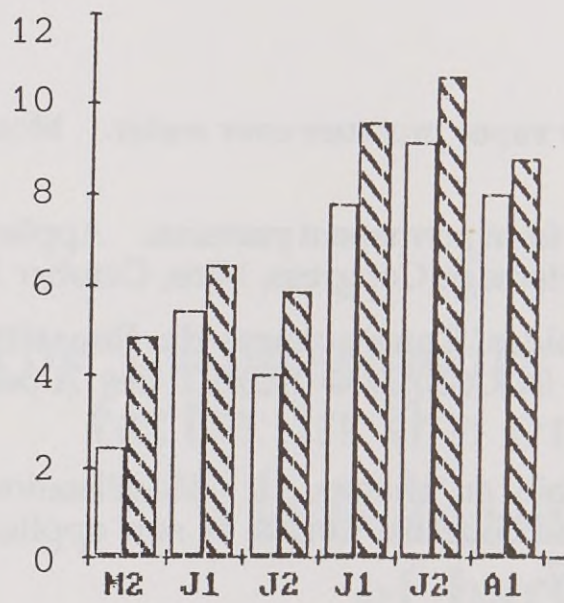
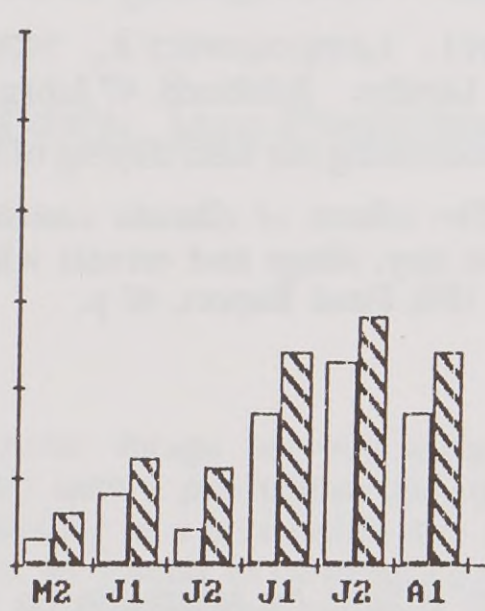
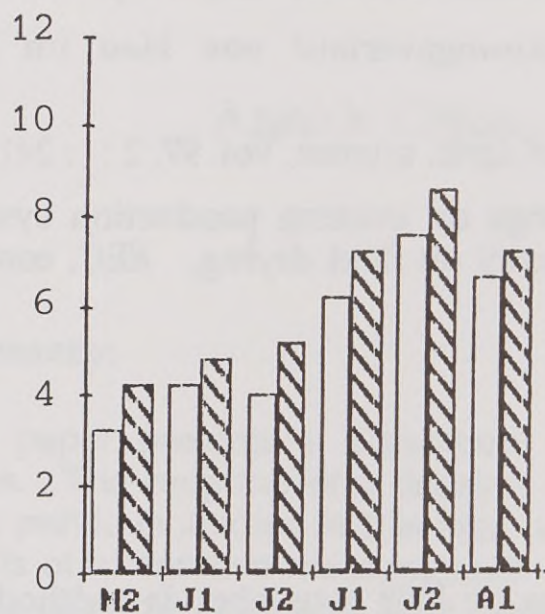
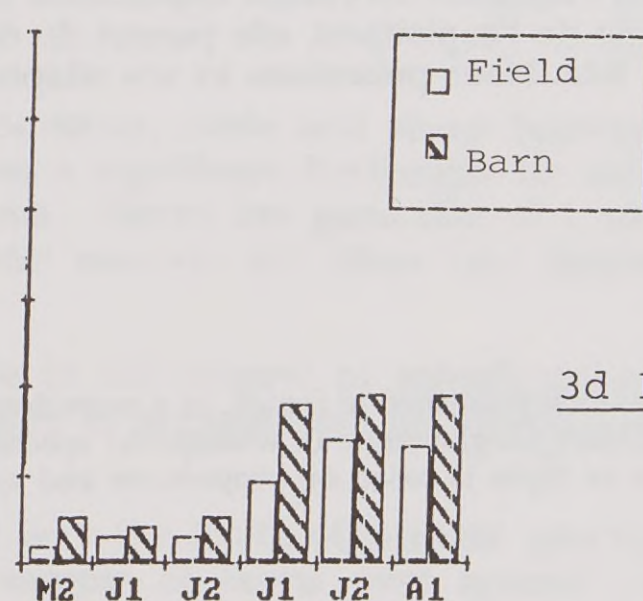
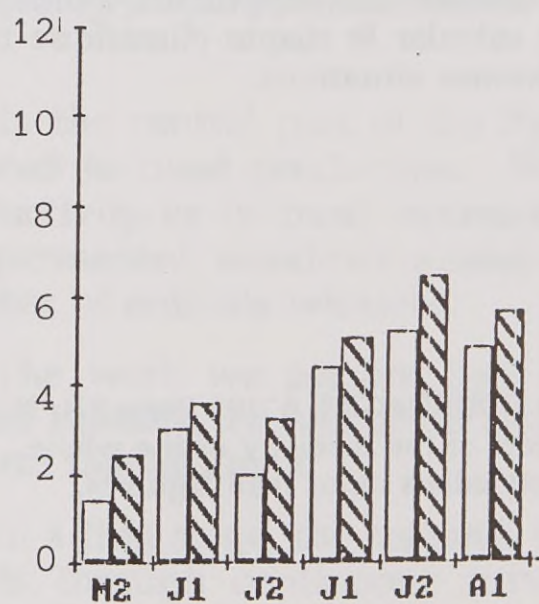
1st LEVEL2d LEVEL3d LEVEL

Figure 4 — Number of cutting possibilities at the 20 % risk 1st cut, 1st fortnight to May to 1st fortnight of August (1962-1985); village of Arèches in Savoy

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Résumé :

Basée sur le cumul des déficits de saturation en vapeur d'eau de l'air sous abri, la méthode de LUDER modélise le séchage du foin, et à partir de là les jours disponibles pour la fauche, qui dépendent du climat, de la végétation fauchée et des techniques appliquées. En comparant cette « offre » avec les « besoins » de chaque exploitation (eux-mêmes fonction des superficies, du matériel, et de la stratégie de l'exploitant), elle permet de définir et de calculer le risque climatique relatif au séchage du foin. Nous présentons ici son adaptation à différentes situations.

NOTES:

1. This study was first published in french, in a more detailed form, in *FOURRAGES*, n° 101 (June 87): 111-137.
2. The stages of *Dactylis glomerata* (a widespread species) are indicators of the maturity of the whole.
3. The definition of types is based on proportions and species of Dicotyledons other than legumes.

The heterogeneity of grassland fields as a limiting factor in the organization of forage systems

Development of a simulation tool of harvests management in the Central Pyrénées

Annick GIBON, Sylvie LARDON, Jean-Pierre RELIER

Summary:

This paper presents a simulation project of winter forage harvests management on pyrenean farms. The coupling of a decision process model with a production process model, both derived from previous studies in this area, allows the building of a simulation tool in order to predict the results of alternative managements. In this work we intend to consider changes in farm structure (fields characteristics and farm equipment) and in management practices. The main objective is to give an account of the role of the heterogeneity of the meadows fields as a constraint for organizing forage systems. We discuss the choices made during the building of this model and of a prototype computer-simulation tool.

In the central part of the Pyrenean mountains, cattle and sheep farming are mainly devoted to meat production. Winter causes a significant bottleneck for animal farming productivity as in most mountainous regions. Farms are generally of a small size and the permanent meadows available for winter reserves are often very limited given the number of animals wintered.

The work we present here takes place in the context of interdisciplinary research started towards the end of the seventies in order to prepare basis for technical improvement of farm management.

In a first stage, the research effort dealt with the study of farmers' practices and farm results through continuous surveys of a sample of farms over several years (Gibon, 1981). These works led to the conclusion that it was possible to improve the production of meadows (Duru, 1981). They also underlined the importance of climatic uncertainty in the operation of forage systems. A simulation model of farm structure and management

showed the importance not only of the overall design of a forage system, but also of the results of tactical management practices in reaction to weather variations (Charpentreau et Duru, 1983).

Further studies led to the modelling of grassland production according to climatic conditions. They showed important differences in forage yield and quality, according to the fields' fertility and the harvests management (Duru, 1985, Duru & Gibon, 1988). It is now possible to have a clear idea of the expected average results for any meadow under a wide range of management practices and of differences between years, according to the way climatic conditions interact with the field's aptitudes and the technical operations' calendar. With the help of simplified diagnostic tools for the evaluation of field fertility (Balent et Duru, 1984), they now offer advisory support to farmers concerning improvement of meadow management.

However, it remains difficult to answer farmers who question the efficiency of improvements at the overall farm level. The effect of the fields' heterogeneity is one aspect of the forage system about which little is known up to now. It may be assumed that this heterogeneity is a significant factor when organizing and managing the forage system.

In order to increase our knowledge of this question, we undertook construction of a model for simulating the management and results of the winter feed storage process.

When starting this approach, we decided on a double objective for future use of the tool. First, research into farmers' practices (bases for the analysis of the practices and their results) and second, the advisory purpose (furnishing of estimated results for alternative organization and management).

This paper deals with the adjustment of an overall conceptual framework for representing the creation of forage reserves in order to develop a prototype computer-simulation tool.

1. Conceiving a model for constitution of winter forage reserves

1.1. Description of the system and simulation objectives

The creation of forage stocks is considered here as a sub-system of the forage system which is relatively easy to isolate: the farmlands where the reserves are made are mainly devoted to this use, and the stocks are the main purpose of their use. The interest in working on a well-identified sub-system is to be able to limit the range of the subject to be treated without losing sight of the desired overall approach (Melèse, 1982; Le Moigne, 1984).

The system elements consist of 1) fields farmed for harvesting, 2) equipment and labour necessary for harvesting and fertilizing the fields, and 3) places for storing harvested forage. Its functioning is structured around the farmer's interventions on the fields, and the biological processes of the grass growth and evolution after cutting. System input consists of climate parameters, and output of stocks achieved.

The operations of fertilizing done before the harvesting period and those of spring grazing are here considered as data. They are used in defining the initial state of the fields. Grazing operations on the fields after first harvesting of stocks, relatively rare in the region considered, are taken into account as restrictions imposed from the outside.

The goal is to find a tool for achieving on the one hand intervention dates similar to those of the farmer on all of the fields, and on the other hand, results close to the stocks harvested. In order to simulate the farmer's interventions, it is necessary to be able to

imitate his decisions on a day by day basis in relation to the system state and the climatic conditions. So as to do this and also to evaluate the stocks laid up, it will also be necessary to simulate evolution of the state of grass covers.

The simulation should also enable comparison of variations in crop management and/or in the farm structure (characteristics of field, equipment and labour).

For evaluating the sensitivity of results to climate, the simulation will be done with a series of "climatic years". This technique is now widely used for evaluating strategies of agricultural management, for example in overall management of the forage system (Charpentreau & Duru, 1983), or of the organization of work (Attonaty et al, 1987) to give only French examples.

1.2. Representation of the farmer's decision process

1.2.1. General bases

Recent studies of forage systems in our country and in particular those done in our research group, refer to the adaptive and sequential character of the farmer's decision process in managing the balance between forage offer and need, and to the sensitivity of results to climatic variations (cf for example Duru & al., 1988 a). We have insisted on the existence of key periods when the state of certain variables has an important effect on results of the whole, and which constitute a reference for making adjustment decisions when necessary (Gibon and Duru, 1987). With a similar conception, Duru & al. (1988 b) discussed the existence of a "general model" of farm management. This includes "one or several general objectives which define the end towards which the farmer's decisions converge, and a forecasting program based on the time period concerned". This program includes "intermediary objective states which define decision moments at which the farmer might take stock of the progress in order to know where he stands in relation to his general objectives. A set of rules defines the nature of the decisions to be taken in order to achieve the fixed objectives. The rules are used to trigger practices for adapting to the recognized variation range and to choose between several operations if necessary".

This overall view of the decisions and of their linking in time is indispensable in the context of uncertainty surrounding technical management.

Another aspect of forage system is relatively poorly explained in the works mentioned: the manner in which the decisions are interlinked in a system with several levels of organization. We were thus driven to look for other concepts.

The notion of "technical operation" constitutes the basic element for our reflection. Agronomists define it at the scale of the elementary management unit, the field, as a limited set of practices which cause it go from a state a to a state b (Gras et al, 1985). Figure 1, inspired by these authors, illustrates the way in which this concept, with the associated ideas of "field operations schedule" and "management practice" may be used to approach the organization of the farmer's interventions in its spatial and temporal dimension relating to the level of a land unit, made of a set of fields devoted to a specific main use.

The idea of a field technical pathway (Sebillotte, 1978) describes the logic which controls the succession of operations at the field level during the campaign, with a view to reach a yield objective. In terms of a decision system, going from the single technical operation to the sequence of operations for a particular field brings into play a set of rules depending on a "forecasting program" in the meaning of the preceding definition: we then talk of a "field operations schedule".

The idea of "management practice" is proposed to describe the logic relative to the implementation of a given technical operation on all of the fields involved. Going from

the single technical operation to the management practice therefore brings into play rules relative to the organization of interventions on the space of fields, in such a way as to respect the given objectives (quality of hays, or external calendar constraints for example).

FIELDS	TECHNICAL OPERATIONS						
	Manuring	winter & spring grazing	Silage cut	Hay harvesting 1		2 nd Aftermath harvesting	
Field N°1		T O ^G ₁	--	T O ^{H1} ₁			F.O.S. 1
Field N°2	T O ^M ₁	T O ^G ₂	T O ^S ₁				F.O.S. 2
Field N°3							F.O.S. 3
Field N°n	T O ^M _k	T O ^G _n					F.O.S. n
	Manuring practice	winter & spring grazing practice	Silage making practice	Hay making practice 1		2 nd Aftermath practice	

Legend: T.O.: Technical operation; F.O.S.: Field operations schedule

Figure 1 — Organization of technical operations in the hay fields at the farm level (adaptated from Gras et al., 1985)

We may also pose the existence of organization rules at a higher overall level, by considering both the scale of the whole campaign and the set of fields level (Figure 2).

Studies of the farmers practices show that they usually define a field operations schedule for each field within the set. All these schedules are chosen according to a global pattern taking into account the different field potentials and the spatial characteristics of the farmland.

Parallely, other rules enable the overall organization of the series of management practices. It is at this level that the global work schedule is organized and that competition between different sets of operations is resolved (finish the hays before starting the 2nd cutting for instance).

Overall, as shown by figure 2, the decisions are part of 3 levels of organization according to two interlinked guiding themes: the one relating to the logic of exploiting the fields in accordance with production objectives and constraints, and the other relative to the consistency of implementing practices in relation to scheduling restrictions (maturing of grass, work time resource, etc.).

These different levels of spatio-temporal organization are useful to represent the succession of decisions over time according to a scenario permitting the simulation.

To take into account the interdependant nature of the decision levels, we suggest the idea that the progress of the campaign is marked by a hierarchy of "reference-states". Each reference-state is associated with a set of rules for action. A reference-state relative to a higher level define a framework of action which will remain valid as long as another reference-state of the same level has not been reached, even if in the meantime reference-

states of a lower level have occurred. We shall illustrate this in the following part of the paper.

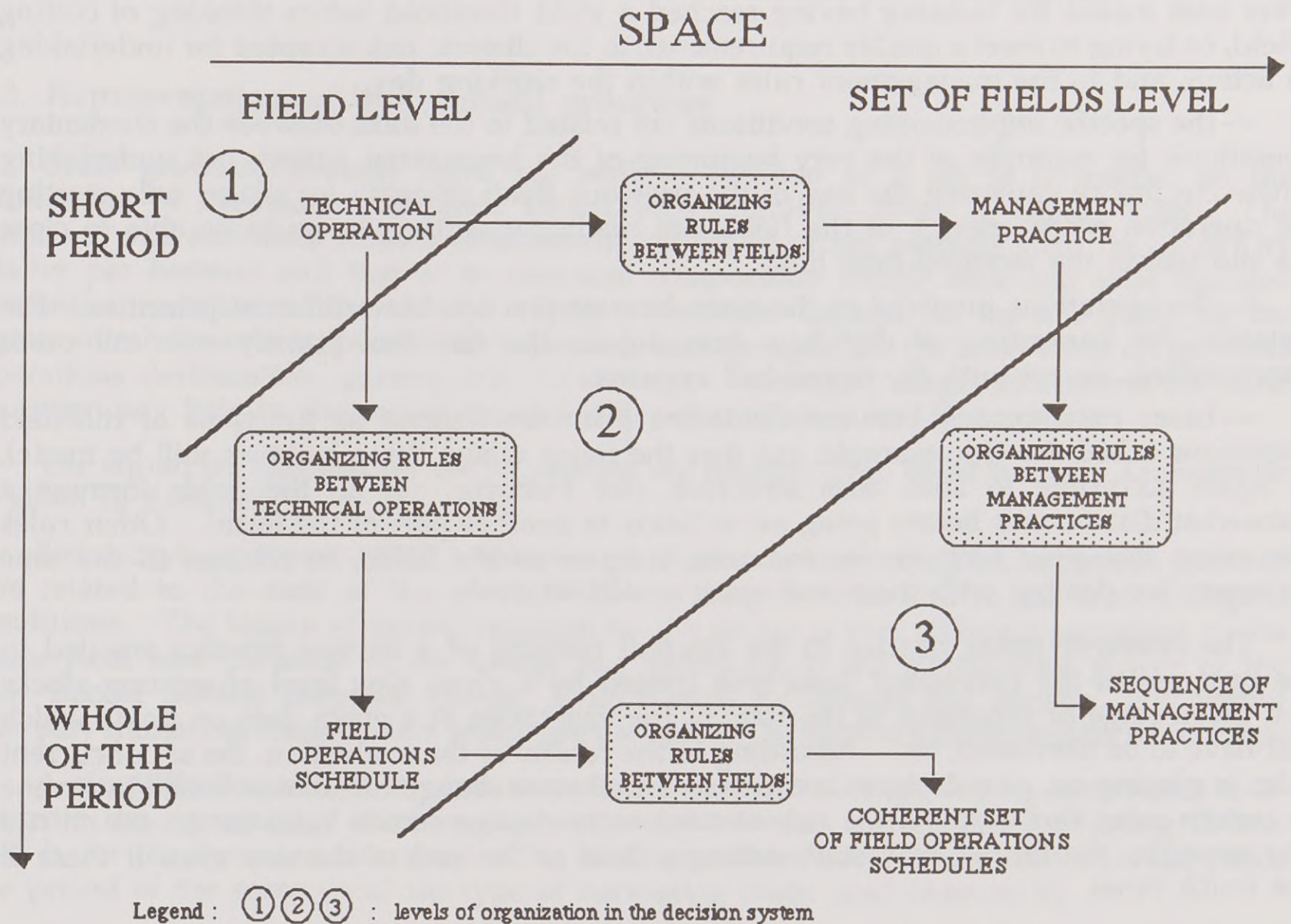


Figure 2 — Organization of decision system for the management of technical operations

At the same time, the set of field operations schedules represents the overall space-use decisions. It should be noted that in forage production, it frequently happens that the farmer assigns a few fields as buffers. In case of need, their field operations schedules are readjusted during the campaign (fields which are only to be cut in the event of drought or lack of grass, etc.).

1.2.2. Decisions relating to forage harvesting

Management practices are identified according to the nature of the harvest operations done (silage, hay, etc.), to the growth cycle (1st growth, 1st aftermath, 2nd aftermath, etc.) and to the type of harvesting chain used. We group together several types of elementary technical operations when their achievement is closely linked over a short space of time: for hay dried on the ground for example, the same "operation" includes the cutting, which puts an end to the grass growth, starts the next cycle of growth as well as the hay drying process, and the harvest itself, with gathering of the hay at the end of the drying process.

In addition, the fertilizing operations have been treated here as elementary techniques accompanying such and such a harvest practice (for example, nitrogen supply after silage of the first growth) and are therefore treated according to the corresponding management practice.

1.2.3. Internal organization of a harvest practice

Between two reference-states, a given set of rules is used to start action on a given day.

— the general conditions for starting a given operation refer to the state of the grass cover (this means for instance having reached a yield threshold before thinking of cutting a field, or trying to meet a quality requirement), to the climatic risk accepted for undertaking an action, and to the management rules within the working day.

— the specific implementing conditions are related to the links between the elementary operations: for example, at the very beginning of the haymaking period, not undertaking a new cut before gathering the hay in the previous field; or again for silage, only starting the operation when enough of the fields are ready for cutting, so as to be able to close the silo within the required time limit.

— the operations involved in the same harvest practice have different priorities. For instance, for harvesting of dry hay, bringing in the hay has priority over all other interventions, except with the round-ball systems.

— bases for choosing between fields are priorities defined as functions of the field operations schedules (for example, cut first the fields where three harvests will be made), or again according to land farm structure, (for example, cut all the fields forming a somewhat distant unit before going on to fields in another part of the farm). Other rules also come into play such as, for example, the size of the fields, in relation to the time necessary for dealing with them and work availability.

The reference-states relative to the internal running of a harvest practice are tied to the progress of the harvesting (land area treated by a given day; level of existing stocks at a given stage of progress), to the state of the vegetation at a given date on fields which still have to be harvested, etc. According to the results of the evaluation, the set of current rules is playing on, or a decision is made on whether to change thresholds which intervene in certain rules (for example the risk of rain) or to change certain rules in the set on use (for example, the farmer may start cutting a field at the end of the day even if there is not much time).

1.2.4. Overall organization of harvest practices

The reference-states at this level concern mainly the beginning and end of the periods relative to each of the harvest practices, as well as the global management of periods in which there might be competition between them. The set of rules at that level enable adapting the overall organization to the campaign conditions.

Some of the reference-states are constituted by scheduled dates for the beginning of a harvest practice. When such a date is reached, the state of grass growth is reviewed in relation to the year's conditions. According to the results, the thresholds relative to the state of the grass will or will not be modified in the different rules involved (for example poor growth meaning that a lower than normal yield threshold is fixed). The field operations schedule for the buffer fields may be readjusted at that moment.

Likewise, the reference-states corresponding to the end of a harvest practice (relative to the date or the state of the stocks made at the moment when the set of operations finish) may lead to revisions of some field operations schedules, or to changes in the set of rules which will be implemented in the following period: if, for example, there are too few stocks following the normal harvest because a lot of hay got wet, a decision may be taken to do the first cut on the buffer fields which are not normally cut, or else to change the management rules for aftermath in order to try and cut a larger land area.

1.2.5. The climatic risk and the farmer's behaviour

The objective of the simulation requires a representation of day-by-day risk management, which is an important basis for the farmer's decision. The weather forecast for the

following days made by the farmer in the real situation is represented in our model by an estimation of the probability of the sequence of rain-free days necessary for the operations envisaged (derived from a weather years series). His attitude towards risk is represented by a threshold beyond which action is considered to be possible.

1.3. Representation of biotechnical processes

Grass growth: Previous work has enabled creation of a set of references on the production of Pyrenean grasslands (Duru, 1985; 1986; 1987; Duru & Gibon, 1988). The empirical and statistical models estimate the evolution of the herbage yield (in kg of Dry Matter per hectare) and that of its chemical composition (crude fibre and total nitrogen content) in relation to the climate. Their parameters depend on the one hand on the agronomical characteristics of fields expressed in classes and on the other hand on previous operations (fertilization, grazing and harvesting). Simplified diagnostic criteria are used to assign any field in the region into a fertility class (Balent and Duru, 1984).

The equations retained for the simulation are derived from these works. An example is given in Annexe I.

Grass drying process: this is a complex phenomenon, dependent on numerous parameters related to the state of the plant, to the techniques used and to the meteorological conditions. The length of drying required by the forage is very different according to the grass yield and the state of the forage and according to the evaporating power of the air. Recent models proposed (Luder, 1982) quoted by Munier and Morlon, 1987) bring into play numerous climatic data which are not part of the normal meteorological recordings.

A simplification which is often done to represent the forage drying constraints is to estimate the sequence of rainfree days necessary between cutting and harvesting (Duru, 1987 b, for the Pyrenean situation). The set of norms we have chosen draws on the yield, the period of the season and the type of harvesting chain used (Annexe II).

Changes in forage between cutting and gathering: manipulations and transformations of forage during the harvest (and during conservation in so far as silage is concerned) cause quantitative and qualitative losses which vary according to situations (harvest procedure and climatic conditions). We have taken them into account in the form of sets of norms suggested by the bibliography. The quantitative losses (in %) are related to specifications of standard chains (from Dulphy, 1985). The qualitative losses depend on harvest chains and conditions and are evaluated by means of equations relating the chemical composition of dry forage to that of green forage (Demarquilly, 1985).

The state of the standing grass crop is estimated using the models for growth and evolution of quality. The indicators they provide are very far removed from those used in a real situation by farmers: this leads to translate through these criteria the farmer's decision rules relating to different grass states, by referring to some examples.

2. Construction of the computer-simulation tool

The simulation tool includes a control program which manages progress over time and calls on different modules.

— Farm data base: each farm is described by its fields (with their agronomic and structural characteristics and with their field operations schedules), its harvesting chains and its storage facilities.

The stocks made (results of calculations) are registered following achievement of technical operations in a field and by place of storage. An overall report is done in terms of each type of forage (silage stocks, hay, aftermath) and quality class (3 to 4 according to the type of forage).

—Climate data base: this is used to record a series of climatic years for each meteorological station present in the area for which the model is valid.

—Modules for calculating biological states: the state of the standing grass and the quantitative and qualitative losses after cutting are treated by two distinct calculation modules.

2.1. Control program operating

It runs from day to day using the campaign's climatic data. It operates with three structures:

—The diary is used for noting obligatory appointments: gathering in hay as soon as it is dry, for instance. If the appointments do not take place when scheduled, because it is raining or because the working time is not long enough, they are postponed to a later date.

Each day, the control program checks whether it is raining or not. It triggers operations written in the diary according to their priority. Achievement of an operation either leads to recording of an appointment in the diary (hay cutting), or updating of fields and stocks (silage operation or gathering of hay). If any working time remains available for the day, the control program studies the possibility of starting another operation. When a working day is complete, it goes to the following day and so on until the date on which the campaign ends.

—The reference-state automata routine: The organization of reference-states was translated by an automata routine program. As long as a new reference-state is not reached, the same set of current rules is active. Each day, the control program determines if the conditions for reaching a new reference-state are satisfied. This leads to changing of the threshold values (grass state, risks accepted with respect to climate) and potential activating of new rules. The new set of rules thus constituted will remain in force until another reference-state is reached.

Reaching a reference-state used for overall organization of management practices can also lead to modification of the field operations schedule for the buffer fields.

—The rules base: All the rules are grouped in a general rule-base. Only some of them are in force for the period between two successive reference-states. These latter are used by the control program in a hierarchical way in order to successively:

- determine the set of fields which may be harvested. These are "active" fields (following a harvest, a field is inactive for a certain period of time, to allow the grass to regrow), which fulfil conditions of quantity/quality of growing grass (intervals defined by threshold values).

- check whether implementation of the technical operation is possible in relation to the day's climatic conditions. This involves checking whether the probability of the number of consecutive rain-free days required for the operations envisaged is sufficient with respect to the risk threshold in force.

- choose the field to be harvested according to an order of priority based on the grass state (age, quantity, etc.) and the characteristics of the fields (surface area, field operations schedule).

2.2. Choice of programming language

The oldest choices dealt with the biotechnical sub-system. Pascal, a structured programming language, was chosen to encode the well identified functions of this system: growth of grass, drying, qualitative and quantitative losses, harvesting and storing operations.

The choice of a Relational Data Base Management System enabled simple and reliable coding of data, structured according to their attributes: fields with their characteristics, days with climatic variables, etc.

As far as the decision system is concerned, it consists of a multiple knowledge base: reactions when a reference-state is reached (in programming terms these are conditional instructions), field operations schedules (attributes linked to fields), management practices (rules for choosing between competing operations for a given day). We decided not to use an expert systems tool to build and manage this knowledge base. A preliminary study showed the unwieldiness of this type of procedure in this situation. On the one hand, the reasoning leading to choice of an operation is relatively simple and the number of rules brought into play is rather limited. On the other hand very frequent connections have to be made between the biotechnical and decision system models. In addition these models had to be controlled by a master program, the control program, which manages the time, (sequencing of days, management of the diary) which contains the user interface (validation of choices, trace of operations done, final output) and the interface with the data base management system (loading of data).

In order to integrate these different aspects, we kept the Pascal language: the "records" make a model of the fields (with the field operations schedule as a particular attribute), the storage places, the harvesting chains. IF/THEN structures modelize the changes in reference-state and the decision rules (implemented in a program way, i.e. without calling on the chaining algorithms characteristic of inference engines).

3. Discussion — conclusions

When choosing our models for harvesting and its management, it was necessary to make a tool satisfying the technical specifications which interested us, thus:

— allowing representation of the farmer's decision process on a basis which is sufficiently general to easily simulate different scenarios which might be encountered (or imagined) in the organization of harvests for the model's area of validity.

From this point of view, our approach to the decision process offers both a methodological approach to harvesting strategies (analysis of decision bases, elicitation of action rules for each level of organization) and a general framework for computer representation adapted to the objective (reference-state automata routine structure and associated rule sets).

We thus have available bases for constructing a "class-model", in the sense of a model adapted to a type of decision support problem (Rellier and Marcaillou, unpublished), in this case harvesting of forage in Pyrenean farms with a permanent grasslands base. Even if the contents of the reference-states have to be specified for each "instance-model" (a program for a given farm), the general structure is valid for different farms and different programs. Given the structure and the computer language chosen, the addition of new reference-states drawing on the same knowledge base is simple: it consists uniquely of completing the list of achievement conditions and of indicating the modified threshold values and activated rules. However it is not easy to modify this structure for adding new rules: these have to be checked for consistency with the pre-existing rules, and the

different branches of the decision tree have to be explicitly and completely described according to the new rule.

— allowing representation of the biotechnical processes which covers the whole range of phenomenon explored.

An indispensable condition of this approach is the use of models of grasslands production in relation to climatic conditions. This is only possible if there are local references for the production aptitudes of fields and for the productivity of grass covers adapted for this use, i.e. covering a wide range of situations and allowing the simulation of the dynamics of evolutions.

A first problem concerns the limits of existing knowledge when faced with the range of phenomena to be simulated, in particular phenomena which are difficult to predict or which have not been studied very much. Another level of questions refers to the design of production models in a form which can be used by such a tool: validity of the simplifications of hypotheses done, and especially overall coherence of the set of hypotheses. In particular one significant question has to do with limits to the degree of simplification to be respected for some phenomena (forage drying needs for example) given the sensitivity required of the simulation tool. This aspect is doubled here by the need to find solutions which enable extended use of the model by using current climatic recordings of standard meteorological stations. These questions helped stimulate research into some aspects which are relatively poorly known at the local level, such as the drying needs of forage in the Pyrenean situation, or at the general level, the evolution of the biomass and of the quality of late harvests (Duru and Colombani, current research; Duru and Gibon, 1989).

— allowing representation of the way in which the farmer checks the state of the system and the environmental climatic conditions, on bases compatible with the criteria used in the biotechnical models available.

In order to link farmer practices with biotechnical results, we emphasized agronomic criteria which might enable us to modelize the biotechnical processes. This meant translating the farmer's decision rules through these criteria by referring to examples. It is evident that in this approach, as other authors before us have mentioned for similar subjects (Attonaty et al., 1987), we are not trying to reproduce the farmer's behaviour nor to update his thorough reasoning, but only to reproduce the consequences in a realistic way, even though this is a reduction.

Our general objective is to test scenarios resulting from modifications in harvest management, so as to forecast the results of these modifications (land areas and levels of productivity, practices such as spring grazing or fertilization, types of equipment for the harvest, etc.).

The tool being developed is limited to simulating a modified management model, and does not permit its creation. Design of a correct management model for a given situation will come from another field of research, that of the generation of an action plan. The problem is being formalized and a proposition for resolving it has been undertaken. For the moment, modifications in structure and management whose results are to be tested, may only be validated by expertise or by trial and error, using the results of simulations.

The construction of a simulation model always involves questioning the conceptual bases used. The problem we chose to deal with by means of an example limited to a sub-system is that of evaluating the role of fields heterogeneity in management choices and restrictions of the forage system. By completing this with the use of previously gleaned knowledge on the operation of the system with respect to climatic hazards, we were led to study in depth representation of the decision making process and of its link with the biotechnical process in a way that was sufficiently complete and structured to enable simulation. This caused us to complete the existing modelling bases for the decision-making system so as to take into account different levels of its spatio-temporal organization.

APPENDIX I: EXAMPLES OF EQUATIONS USED TO MODEL GRASS GROWTH AND QUALITY CHANGES

Grass Yield (adaptated from Duru, 1985; 1987a)

First growth: $DM = a (\Sigma \theta - b)$ before the flowering date of *Dactylis glomerata*

$\Delta DM = \alpha \Sigma ETR$ during 3 weeks after flowering date of *dactylis*.

$\Delta DM = 0$ after

$\Sigma \theta$: growing degree days with a 0° C base temperature from february, the 15th (without winter and spring grazing) or from the end of winter and spring grazing. Flowering of *dactylis* is evaluated as a function of altitude.

ΣETR : Evapotranspiration according to 3 classes of water storage capacity of the soils.

Coefficients a , b , α depend upon PK fertility classes, N supply and, for b , upon winter and spring grazing.

Values of the equation (1) coefficients
for the extreme nitrogen supply situations

	PK Fertility	without grazing		after grazing	
		a	b	a	b
no N limi- tation	B	10.0	50	10.0	0
	M	7.5	100	7.5	0
	C	7.0	150	7.0	0
	P	5.5	200	5.5	0
no N supply	B	7.5	100	6.5	50
	M	6.5	150	6.0	100
	C	7.0	200	5.5	150
	P	5.5	500	3.5	200

(B, M, C, P are the different classes for soil fertility decreasing from B good, to P very poor)

Grass quality: (adaptated from Duru & Gibon, 1988)

For first growth:

Nitrogen content: $N(\% DM) = 22 J^{-0,6}$ with J = age expressed as the number of days of growth

Crude fiber content: $CF(\% OM) = 8,9 \log \Sigma \theta - 26$ before the flowering date of *Dactylis glomerata*

$\Delta CF = 0$ after

APPENDIX II: HARVEST CHAINS AND ESTIMATION BASES OF WEATHER CONDITIONS REQUIREMENTS FOR HAY DRYING IN FIELD

A chain is characterized by the type of herbage reserves it process, the surface it can harvest within one day, the sequence of rainfree days it necessitates for hay drying, and the overall level of quantitative and qualitative losses it induces. Each real chain is attached to a standard one, which defines its specifications, according to the machinery and the number of men involved.

examples of chains specifications:

	weather conditions requirements (consecutive days without rain)			Capacity ha day ⁻¹
	(a)	(b)	(c)	
N°1 Silage	1	1	1	3,0
N°6 Hay	4	3	2	0,5
N°10 Hay	3	2	2	1,5

(a) first growth before the flowering of *dactylis* with grass crop yield $\geq 4,0$ t DM ha⁻¹ and all cuts after September the 1st.

(b) first growth before the flowering of *dactylis* with grass crop yield $< 4,0$ t DM ha⁻¹; all cuts during the 3 first weeks after flowering and regrowth cuts before September the 1st.

(c) first growth cuts more than 3 weeks after flowering and before September the 1st.

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Résumé :

Nous présentons ici un projet de simulation de la constitution des réserves fourragères hivernales dans les exploitations d'élevage des Pyrénées Centrales. Nous utilisons conjointement un modèle du processus de décision et un modèle du système biotechnique, tous deux inspirés de travaux antérieurs dans cette région, pour construire un outil de simulation afin de réaliser une évaluation prévisionnelle de modifications de conduite. Dans ce travail nous nous intéressons à des modifications de structure de l'exploitation (caractéristiques du parcellaire et équipements de récolte) et de pratiques de gestion de la sole récoltée, et notre principal objectif est d'évaluer le rôle de l'hétérogénéité des parcelles comme contrainte d'organisation des systèmes fourragers. Nous discutons les choix effectués pour représenter le système de constitution des stocks et pour élaborer un prototype de l'outil de simulation.

