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in

Gibon J. (ed.), Lasseur J. (ed.), Manrique E. (ed.), Masson P. (ed.), Pluvinage J. (ed.), Revilla R. (ed.).
Systèmes d'élevage et gestion de l'espace en montagnes et collines méditerranéennes

Zaragoza : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 27

1999
pages 139-154

The primary production and vegetation characteristics of some Pyrenean Aragonese meadows and their relationship with climate and management

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SUMMARY – Livestock production in the Spanish Pyrenees is of reduced importance in economic terms compared with tourism and enjoyment of nature. To identify the potential for sustainable livestock production systems within a landscape where the primary aim is to create/maintain an attractive landscape rich in biodiversity, some studies were carried out in the Pyrenean Aragonese meadows. Studies on soil and vegetation related with climatic events were carried out in the private meadows of the village of Fragen (Broto valley). The floristic composition allows us to classify them into three management groups: (i) two cuts and grazing with irrigation; (ii) a single cut and grazing without irrigation; and (iii) grazing only. The number of species diminishes with intensification, the proportion of grasses increases as does the production of forage. The mineral content of the hay is significantly related to the proportion of grasses and the group "other species". Quality is positively related to grasses, and negatively related to the group "other species" and to diversity. The leguminous contribute principally N, Ca and Mg while the "others" are negatively related to the P content. The traditional method of irrigation would have to be improved by shortening the weekly periods or reducing the applied dose. The importance of topographical position can be emphasized in terms of whether or not it permits the maintenance of the fine elements of the soil; greater water efficiency is obtained when fine elements are present.

Key words: Agricultural practices, primary production, topographic influences, floristic composition, water use efficiency.

RESUME – *"Les caratéristiques de la production et de la végétation dans quelques prairies des Pyrénees aragonaises et leur rapport avec le climat et la gestion". L'élevage dans les Pyrénées espagnoles a diminué en importance quantitative mais coincide avec les nouvelles demandes du tourisme et la valorisation du paysage. Pour bien identifier le potentiel des systèmes durables de production animale dans un paysage où l'objectif principal est de créer/maintenir un paysage attractif et riche en biodiversité, divers types d'étude ont été effectués dans les prairies des Pyrénées aragonaises. On étudie dans des parcelles de propriété privée du village de Fragen (vallée de Broto) les sols et la végétation en relation avec les variations climatiques. La composition floristique nous permet d'effectuer une classification des prés en trois groupes de conduite : (i) deux coupes et un pâturage avec irrigation ; (ii) une coupe et un pâturage sans irrigation ; et (iii) pâturage uniquement. Le nombre d'espèces diminue avec l'intensification, la proportion de graminées augmente ainsi que la production. Les contenus minéraux du foin présentent une relation significative avec la proportion de graminées et avec le groupe des "autres espèces". La qualité est liée positivement avec les graminées et négativement avec le groupe des "autres espèces" et la diversité. Les légumineuses apportent principalement N, Ca et Mg, tandis que les "autres espèces" ont une relation négative avec le contenu en P. La méthode traditionnelle d'irrigation peut être améliorée en raccourcissant les périodes hebdomadaires ou la dose appliquée. La situation topographique de la prairie est très importante parce qu'elle conditionne le maintien des éléments fins du sol. L'efficience de l'eau d'irrigation est plus grande en leur présence.*

Mots-clés : *Pratiques agricoles, production végétale, influences topographiques, composition floristique, efficience de l'utilisation de l'eau.*

Introduction

The Spanish Pyrenees are a southern European mountain area with mostly south-facing slopes, thus making the economising of water resources an important issue. Furthermore the general layout of the tributaries of the Ebro in transverse valleys running from north to south, provides an important barrier for the rain from the Atlantic creating a small continental nucleus in the central area of the Pyrenees.

The livestock production has been of greater importance than the arable agriculture since the Neolitic period (Bahn, 1983), except during periods of over-population when there was a need to increase production per unit area (Cohen, 1981). Two such periods took place, during the first few centuries of the Reconquest (9th-11th centuries) (Bonnassie, 1988), and before the European Industrial Revolution (19th century) (Lasanta, 1989). The techniques employed in the growing of cereal crops, which dated back to Roman times, were developed and continued by the medieval monasteries till the last century. Towards 1917 the demand for animal traction increased and during the industrialisation period in Spain (around 1950) the demand for meat increased; in both cases these novelties implied a change in a large proportion of the cultivation, from cereal crops to meadows for mowing. New demands of tourism and enjoyment of nature increase the possibilities of complementary issues.

To take these changes into consideration some studies on the traditional management of San Juan de Plan (Gistain valley) and Fragen (Broto valley) meadowland, related with the ecological constraints, were carried out. The objective was to identify the potential for sustainable livestock production systems within a landscape where the primary aim is to create/maintain an attractive landscape rich in biodiversity

Materials and methods

Study areas

The village of Fragen (Broto valley) was chosen because it displays intermediate characteristics, both in terms of meadow intensification, and in terms of the possibilities of complementing these activities with the demand generated by the nearby National Park of Ordesa and Monte Perdido. Some initial comparisons with the village of San Juan de Plan serve to enable a better understanding of the traditional management methods; sheep migrations to the Ebro depression continue from San Juan de Plan and have disappeared in Fragen, but in both cases the high mountain pastures continue to be used during the summer (Lucio, 1982), and these communal rhythms directly influence the management of private meadowlands and those close to villages. Besides, taken in consideration the general climatic west-central part gradient, Fragen enjoys a greater relative proximity to the ocean and this position allows it to bring forward springtime activities, and by way of compensation, the summer rains in the central area facilitate a good recovery for autumnal regrowth in San Juan de Plan.

The characteristics of the three types of pastures (irrigated only in summer, unirrigated and grazed only) in terms of floristic composition, diversity, production and mineral content of the hay, summarise present methods and foreseeable methods in the coming years, and the impact that the various forms of management may have on the floristic diversity of the different plots. Glacial deposits and the maintaining or not of fine elements in the soil layers above them, constitute an important factor in the control of ground humidity and condition the production of the meadows in accordance with their topographical position.

Studies on soil and vegetation have been carried out, and records of climactic variations have been kept, in the pastures of Fragen, on the private plots of stockbreeders who, for many years, have collaborated closely.

Climatic and edaphic factors

These have been measured at three levels: valley, village and plot. For the valley, the daily pluviometric data from the five stations closest to the study area (Fragen, Linás de Broto, Torla, Broto and Sarvisé) have been gathered for the last twenty-nine years (1964-92, Iberdrola, hydroelectric company). For the village of Fragen, we have relied on the automatic daily recording of temperature and air humidity by the standard meteorological station (National Meteorological Service, 1.2 metres above the ground), through weekly changes of the graphic records. In the plots, temperature and soil humidity are automatically controlled at −10, 25 and 50 cm by data loggers (Unidata 6003B) with hourly records and a capacity for storing several months of information. The three-monthly extraction of data is carried out using a portable computer and these are processed at the Institute. The Weilbull formula, which is recommended by the FAO (Doorenbos and Pruitt, 1976), is used for calculating

probabilities of rainfall. In order to find out the distribution of humidity within the soil profile, two batteries with three ceramic capsule and mercury capillary tensiometers were installed in the plot at depths of 20, 40 and 60 cm, during the irrigation season. A daily reading of the tensiometers was carried out from the first day of irrigation, totalling 39 readings (7 weekly irrigations, from the 16th July to the 23rd August). Using the Richter method (Igelmo and Cuadrado, 1986), the characteristic humidity curve for 0 to 100 cbar of pressure was worked out, using a mixed soil sample of 51 sub-samples collected along the length of the meadow. The volume of water of the irrigation canal was measured using a digital flowmeter (Model 2030-CF, General Oceanics) and the time taken to irrigate was measured using a stopwatch. The evapotranspiration of the meadow (ETc) was calculated according to the Blaney and Criddle method. The amount of water needed for irrigation (Ar) was calculated as the intermediate value between the mean and the maximum requirement (Urbano, 1992) and was considered 60% efficient (blanket irrigation; Domínguez, 1971) in order to calculate the water to be provided (Nr). The amount of irrigation (D) was calculated for an irrigation depth of 30 cm. The minimum soil humidity fixed corresponded to the 50 cbar reading on the tensiometers (Urbano, 1972), in other words, 20% in volume.

In order to determine the texture of the soils, samplings at five depths with two repetitions per meadow (and in two meadows) were carried out. The analysis of granulometry for discontinuous sedimentation were applied, and the USDA classification criteria were followed (in Porta *et al.*, 1986).

Floristic composition and production

In order to compare the three types of meadows in terms of floristic composition, the point quadrat technique was employed; thirty one meadows were selected on the Fragen meadowland (between 900 and 1200 m asl) in 1993: ten were pastured, ten cut and non irrigated, ten cut and irrigated and one alfalfa (lucerne) plot kept as a control plot (Fig. 1). The characteristics of these three types of meadows are defined by the number of species, Shannon diversity index, equitability index, biomass and biomass of every species. The point quadrat method over a 20 m transect was used to evaluate the vegetation. On the basis of abundance data of identified species, a correspondence analysis was applied and a similarity cluster with the factorial coordinates was made.

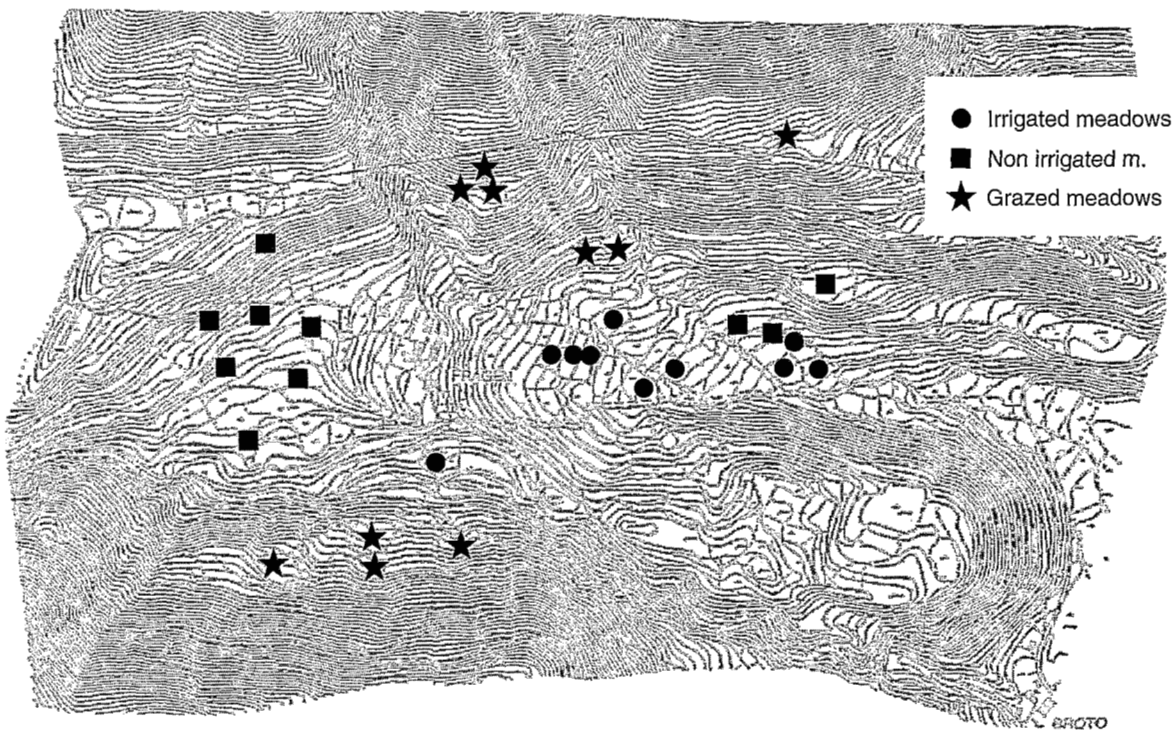


Fig. 1. Sampling meadows within Fragen meadowland. The three different levels of intensification.

The annual production of 31 meadows was determined. In the irrigated meadows it consisted of two cuts and one autumnal grazing period, in the unirrigated, one cut and one grazing period and in grazed meadows only one grazing period. In this last case one cut was simulated at the moment of maximum production in order to make a comparison with the other meadows. The production was obtained from the cutting of plots of 0.5 × 0.5 m, with four repetitions per plot. The cut grass was dried and production was expressed in terms of dry matter. The mineral composition (N, P, K, Ca and Mg) of 30 meadows (10 of each 3 types and 4 repetitions) was determined at the IPE-Jaca and the mineralisation was carried out following the method proposed by Lachica (1990) using pressure reactors and a microwave oven. The calculations were made by means of atomic absorption and emission spectrometry (K, Ca and Mg) and flame photometry (P). The N was calculated as total nitrogen K (Kjeldhal).

One quality index was calculated by the "complex" method with the species biomass data from the 31 samplings of the first cut of 1993. Forage quality "complex" is a method for determining the mean quality (feeding value) and the summary value of grassland and leys, through the synthesis of the botanical (weight-rate) analysis (Sostaric and Kovacevic, 1974a,b).

The follow-up of production was compared with rainfall in 1989 (irrigated meadow) and in 1992 (non-irrigated and irrigated) by cutting micro-plots of 0.5 × 0.5 m and carrying out 9 repetitions for each of the meadows. The number of samples, the dates and the productions are given in the corresponding charts. Production is expressed in grams of dry matter per square metre.

The general data on the different types of agricultural surfaces have been taken from the publications of the Ministry of Agriculture, Fisheries and Food (MAPA), and although they are from the year 1974, there have been few changes at a municipal level (MAPA, 1979, 1982, 1989).

Results and discussion

Climate and general calendars

Livestock calendars have been compared in San Juan de Plan (Gistain valley) (Garrapiz, 1992) and Fragen (Broto valley) (Bernués, 1992) and rainfall and thermal features have been observed at both localities (Fig. 2; Table 1). In the more traditional system of San Juan de Plan there are two types of livestock (cows and sheep) whereas at Fragen there used to be very few sheep. The area layout at San Juan de Plan creates a more complicated simultaneous use of common pastureland near the village and of private fields. In Fragen the low number of sheep prevents the organization of communal flocks. Neither of them have a large area of pastureland (13% in the former and 3.5% in the latter) but a large proportion of meadows is given over to grazing (45% in San Juan de Plan and 48% in Fragen). This co-existence of two kinds of areas, one that is extensive and communally used (woodland and supraforestal pastures) and another that is intensive and privately owned (meadows), with different degrees of management (grazing or grazing and mowing), makes it necessary to separate them into different sets with different methodological approaches. On the whole, both the villages use the summer rangeland for a similar amount of time but in Fragen spring time activities begin a little earlier, resulting in a shorter winter stabling than in San Juan de Plan.

Both localities (Table1) receive similar amounts of rainfall but with seasonal distribution differences: the highest rainfall is in autumn in both of them, although in the more westerly location of Fragen winter continues to be of importance whereas in San Juan de Plan, close to the central nucleus of the Pyrenees, winter is the driest season followed by summer. The autumn-winter rains at Fragen compensate for the winter temperatures and enable spring vegetation to come early. Both localities also display similar thermal integrals with a small advantage for Fragen.

Primary production and quality

The classification of intensive zone and other meadows, allows the establishment of production as well as quality grading. In the case of Fragen, as far as production is concerned, the greatest differences are seen between the mowing meadows (irrigated and not irrigated) and the grazing meadows (Table 2). In the case of San Juan de Plan, a greater difference in production in the irrigated

meadows exists compared to the other types of meadows. This can be explained by the fact that in Fragen the unirrigated meadows are located on soils with fine elements (moraine deposits), which have a higher water retention capacity than the irrigated meadows. As a whole, the mowing meadows of Fragen are quite similar to the ones close to the village and their management is relatively intensive. At San Juan de Plan, the highest production is obtained in the irrigated meadows close to the village. The unirrigated meadows are located on the slope and their production is comparable with that of grazed meadows. As a whole, there is a gradual decline in production with an increase in distance from the village, which nevertheless is less pronounced than in the case of Fragen.

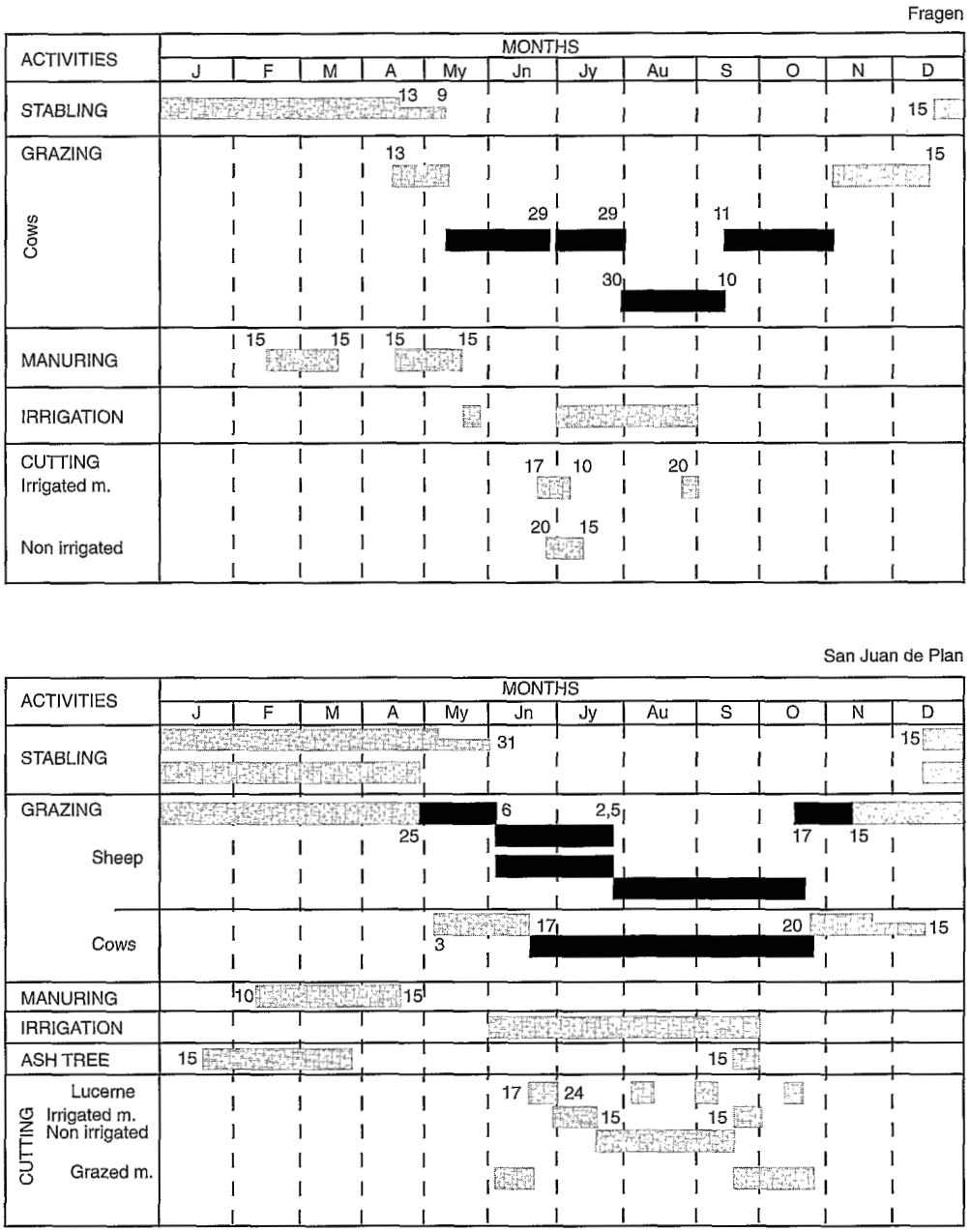


Fig. 2. Fragen and San Juan de Plan comparisons of livestock calendars. In black, the grazing periods in summer pastures.

As far as quality is concerned, it is confirmed that on the slopes of San Juan de Plan exists a clear gradient from the irrigated meadows to the only pastured ones. In Fragen, the highest decrease is seen in the grazing meadows. Given the importance of grazing in spring and autumn for cows and in winter for sheep, their increasing could be one of the main factors in reducing wintering costs.

Table 1. Rainfall and thermal features of San Juan de Plan (Plandescún meteorological station) and Fragen

	Rainfall		Monthly average temperature (°C)			
	Annual avg. (mm)	Seasonal distribution (%)				
Plandescún		Aut-Sum-Spr-Win	Jan=–0.3	Apr=7.6	Jul=19.1	Oct=10.0
	1207.9	Spr=25.3 Sum=26.9	Feb=1.1	May=9.7	Aug=18.7	Nov=4.3
1060 m asl		Aut=28.6 Win=19.2	Mar=4.6	Jun=15.3	Sep=16.4	Dec=0.0
Fragen		Aut-Sum-Spr-Win	Jan=0.88	Apr=7.14	Jul=18.49	Oct=6.89
	1253.1	Spr=24.7 Sum=19.4	Feb=1.26	May=12.56	Aug=19.84	Nov=5.98
1100 m asl		Aut=29.4 Win=26.5	Mar=6.32	Jun=13.4	Sep=13.7	Dec=2.72

Table 2. Primary production and quality of the meadowlands in the Fragen and San Juan de Plan villages (July 1993 values, at the period of maximum development)

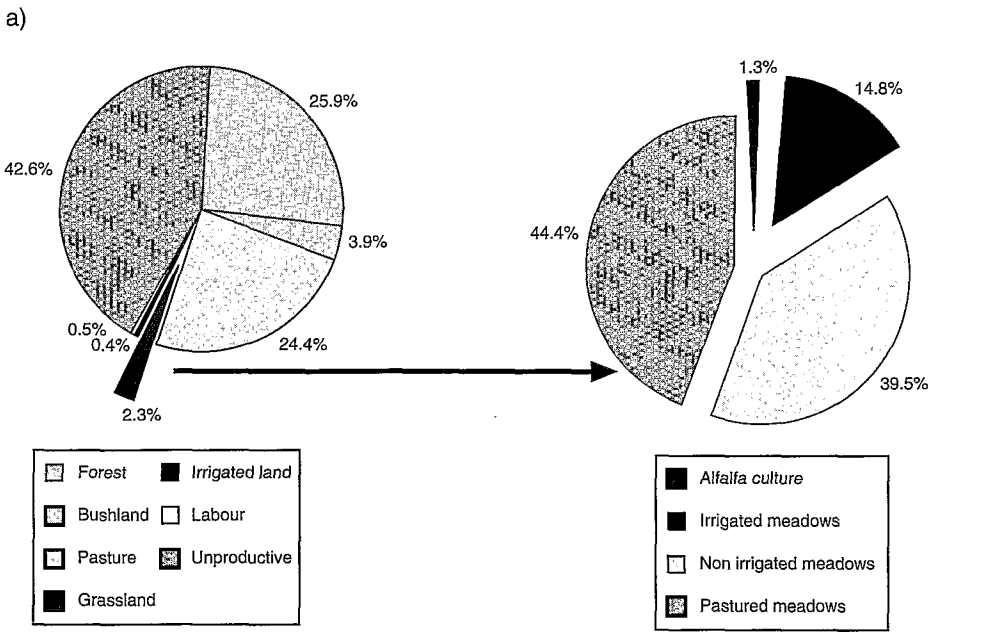
	Fragen		San Juan de Plan	
Production	kg/ha	Std. err.	kg/ha	Std. err.
1 irrigated meadows	4489	992	5212	66
2 unirrigated meadows	4270	485	3950	278
3 meadows only grazed	2332	132	3192	352
Quality "Complex"	t/ha	Std. err.	t/ha	Std. err.
1 irrigated meadows	3.025	0.826	2.601	0.182
2 unirrigated meadows	2.107	0.277	1.506	0.191
3 meadows only grazed	0.854	0.205	0.837	0.150

The importance of extensive zones and topographical situations

The classification as "Unproductive" of large supraforestal areas is frequent in the Spanish Pyrenees (Agriculture Ministry classification; MAPA, 1979 and 1989; MAPA, 1982) but actually these are grazed in summer by domestic herds (cows, sheep, goats, horses) and by the wild fauna (chamois, wild boar, marmot, etc.). In the Torla municipality, for example, if we add these types of surfaces to the "Pasture", the surface area becomes 70% of the total surface (Fig. 3a). Seen another way, the meadowland ("Grassland" in Fig. 3a) makes up 2.3% of the total in that zone and in general in the Aragonese Pyrenees it does not go beyond 5%. Also, if we classify these meadows in four different management groups (alfalfa cultures, irrigated meadows, non-irrigated meadows and grazed ones) according to the Finances Ministry classification, we can clearly note the importance of grazed meadows. These points show the great importance of the large surfaces in the Spanish Pyrenees (summer supraforestal pasture zones and village altitudes) where it is necessary to improve the extensive techniques to establish a correct management, balanced between productive and sustainable aspects, according to the EU Policy.

The main limiting factor for grass production is the annual scarce rainfall, due to the meridional and south-facing slopes of the Spanish Pyrenean range. The amounts of 900-1000 mm, necessary for permanent meadow production, are only present near the mountains and thus, the topographical aspects become an indirect limiting factor: for example the village of Fragen is the highest village where it is possible to have irrigation within the area studied. The rainfall amount in different villages of the Broto valley follows an altitudinal sequence, that is common to all mountainous zones. However, the average number of rainy days in a year in each village depend on their relative position respect to

the rainfall entry ways (see Fig. 3b, where overriding importance of the North way can be seen). The higher precipitation does not corresponds to the places with higher number of rainy days, because in these places precipitations of less than 10 mm are more frequent. These differences may only be noticed during the summer drought. All of these points show that the intermediate situation of Fragen inside the valley means that the differences between irrigated and not irrigated zones form a good representation of the general conditions of the southern Pyrenees.



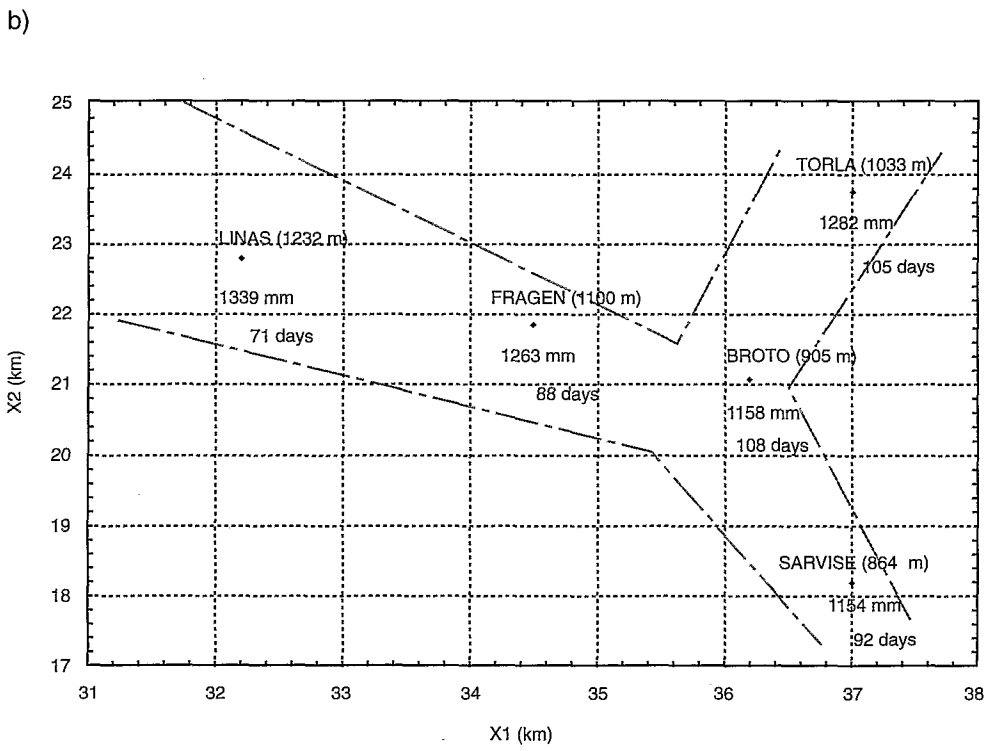


Fig. 3. (a) Agricultural classification of Torla municipal territories and meadowland distribution of Fragen village. (b) Geographic position of the villages in the Broto valley. Annual rainfall (mm) and number of rainy days. In brackets, altitude in m above sea level.

Characterisation of the meadow's vegetation: floristic composition, production and quality

The first factorial axis (Fig. 4a) corresponds to a management gradient with a separation of cut meadows in the positive part and pastured meadows in the negative one. The second factorial axis separates the open communities versus the more organized ones. The similarity cluster of factorial coordinates (Fig. 4b) shows a clear separation of the three types of management on the basis of their floristic composition.

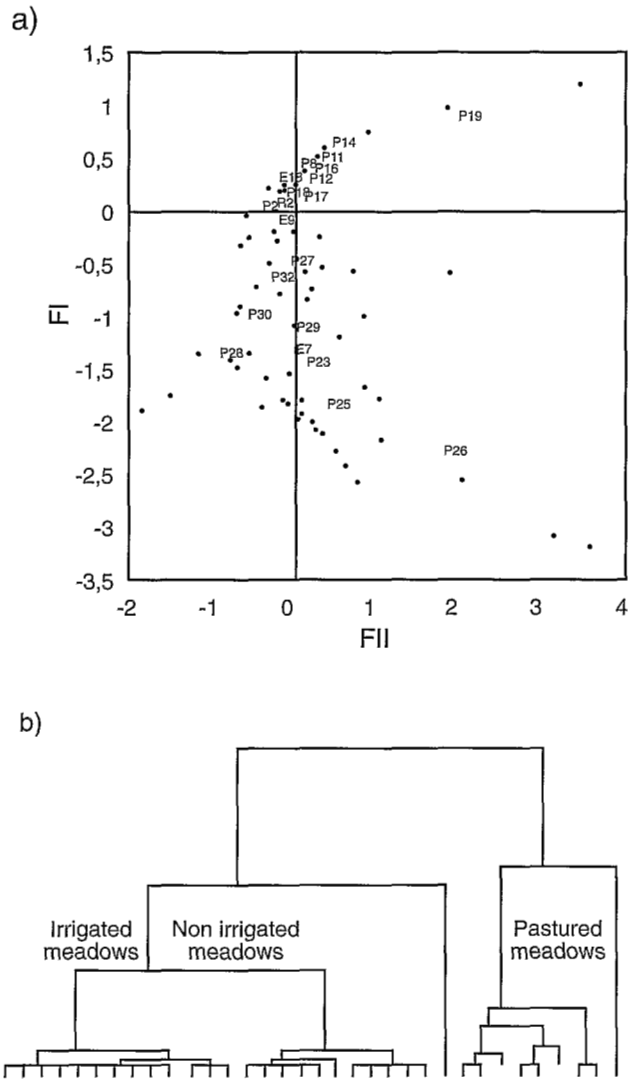


Fig. 4. (a) Correspondence analysis of abundance vegetation species data. Letters and numbers are sampling plots identification and points without identification are the species localisation in the coordinate axis. (b) Similarity cluster with the factorial coordinates. The three management groups are clearly isolated.

According to number of species, percentage of grasses, legumes and other species biomass and biomass of every species (Fig. 5a) we can say that the grazed sward maintains a high number of different species (80 different species identified) as compared to the cut sward (56 in non irrigated meadows and 47 in irrigated meadows). There is also a higher inter-meadows variability in the grazed communities and a lower one in the irrigated meadows. The average number of species per square metre in every meadow is higher in the grazed ones, intermediate in the irrigated and lower in non-irrigated meadows.

The biomass (Fig. 5b) from grasses is higher in cut sward (more than 65% of the first cut biomass) while in grazed ones there is a balanced proportion of grasses and other species. The proportion of leguminous is similar in the three types of meadow. *Dactylis glomerata* makes a more important contribution in the cut sward and *Festuca rubra* in the grazed ones. The 85% of the first cut biomass was contributed by 24 species in the grazed meadows, 16 in the irrigated and 13 in the non irrigated meadow. Therefore, the grazed sward favours greater equitability of community species while the cut sward favours only a few species, and of these the following stand out: *Dactylis glomerata, Lolium perenne, Poa pratensis, Festuca pratensis.*

The annual production of the 31 aforementioned meadows was determined (Fig. 5c). The second cut in summer is only possible with the contribution of irrigation and therefore the annual production of the irrigated meadows is higher than that of the other types of meadow (43% of the total production of the three types). The first cut in the unirrigated meadows is higher than in the irrigated ones but the annual production represents 33% of the total. The general lower production of grazed meadows would correspond to 23% of the total.

The average data of the quality "complex" index of every type of meadow are shown in Fig. 5d. A difference of nearly 25% exists between grazed meadows and cut ones and there are no differences between the two types of cut meadows.

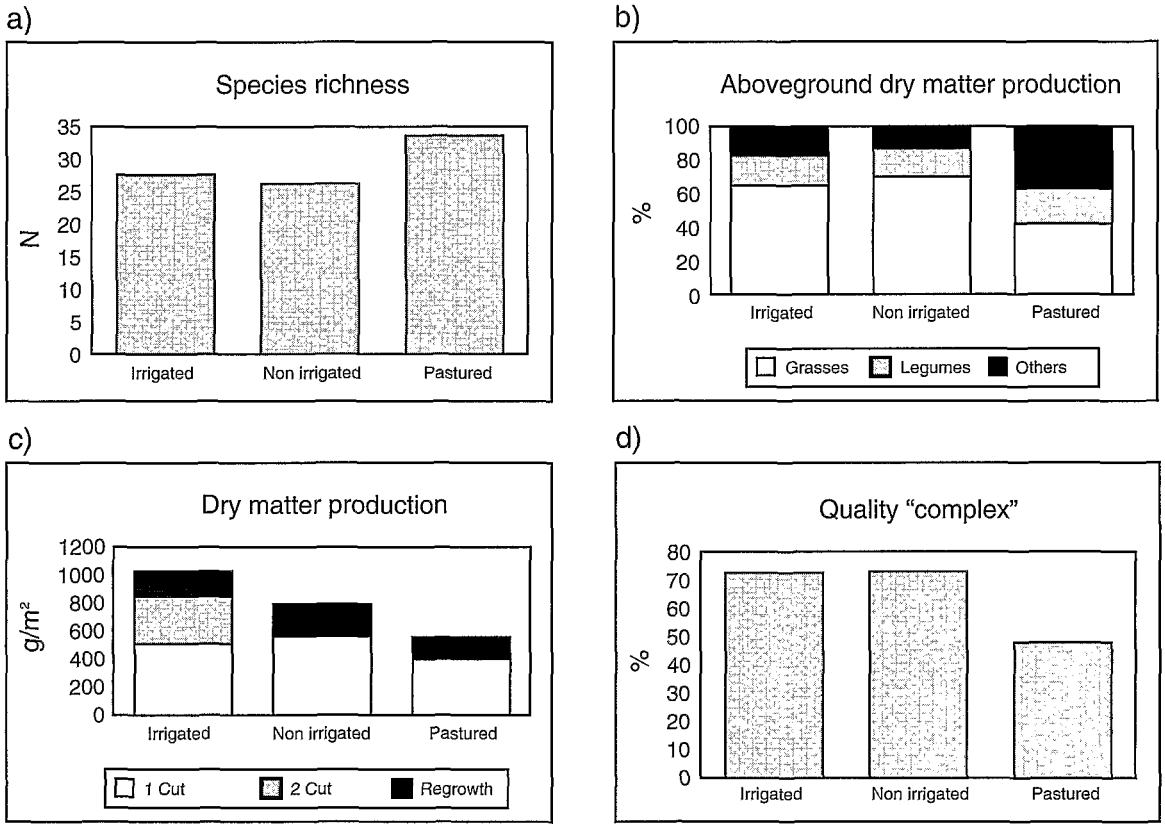


Fig. 5. The characteristics of three types of meadows. (a) Number of species/m^2. (b) Aboveground dry matter contribution of grasses, legumes and other families. (c) Dry matter production. (d) Quality "complex" index.

Correlations between the different characteristics

Through the botanical composition, three different types of managed meadows were identified: (i) irrigated ones; (ii) unirrigated; and (iii) pastured meadows; and averages in characteristics of every type were calculated. A first statistical analysis of comparisons of group means by the t-test for

independent samples (P<0.001), shows that the groups had not been separated in terms of Mg and N contents. However, the content in Ca, clearly separates the group of pastured meadows from the group of harvested meadows. Also, P and K contents differ significantly between irrigated and non-irrigated harvested groups (Table 3).

Table 3. Mineral contents (N, P, K, Ca, and Mg) of herbage in the three types of meadows (July 1993 samples)

	n	Mean	Min.	Max.	Std. err.
N (%)					
Irrigated meadows	39	1.605	1.240	2.520	0.378
Unirrigated meadows	40	1.738	1.320	2.530	0.046
Meadows only grazed	28	1.606	1.100	2.330	0.516
P (%)					
Irrigated meadows	39	0.251	0.407	0.011	0.011
Unirrigated meadows	40	0.316	0.481	0.009	0.009
Meadows only grazed	28	0.235	0.304	0.005	0.005
K (%)					
Irrigated meadows	39	2.043	1.339	2.595	0.571
Unirrigated meadows	40	2.468	1.418	3.575	0.083
Meadows only grazed	28	2.165	1.192	2.985	0.736
Ca (%)					
Irrigated meadows	39	0.805	0.435	1.424	0.034
Unirrigated meadows	40	0.745	0.356	1.434	0.416
Meadows only grazed	28	1.525	0.727	2.465	0.073
Mg (%)					
Irrigated meadows	39	0.200	0.131	0.284	0.006
Unirrigated meadows	40	0.182	0.129	0.286	0.006
Meadows only grazed	28	0.196	0.149	0.290	0.007

All the variables studied for 30 plots (dry matter production, diversity, "complex" quality, mineral contents, contents in grasses, leguminous and "other") have been compared and the following can be summarised from the obtained correlations.

The dry matter production is very significantly related to the content in grasses and related to the content of the group "other" species. The specific richness and the Shannon diversity index are positively related to the content of "other" species while this relationship is reduced with an increase in the incidence of the grasses. This fact indicates that the biomass distribution in the group "other" species is found more evenly distributed among the species, while in grasses it is restricted to one or two species. The "complex" quality index decreases significantly with the number of species and with the contents of the group "other" species; on the other hand, it is positively related (P<0.01) to grasses. The leguminous species are directly related to contents in N, Ca and Mg. The P is only negatively related (P>0.01) to the content of the "other" species group. Ca is related to the rest of the parameters and its relationship to the diversity (number of species and Shannon diversity index), the content of the "other" species group and the leguminous is positive, while it is negative to production, grasses contents and to "complex" quality index.

The meadowland of Fragen, with a traditional management typical of the Pyrenees, presents a high production and mineral content. The N, P and K contents are higher than those found in all meadow types (irrigated, unirrigated and grazed) in the Central Pyrenees (Ferrer *et al.*, 1990; Maestre *et al.*, 1990) and in the Cantabrian Mountains (Pérez Pinto, 1989). At the time of the first cut (June) the irrigated meadows do not reflect a greater degree of intensification than unirrigated meadows either in increased production, reduced diversity or greater mineral content.

Influence of the rainfall regime in the harvested meadows. Production cycle

The irrigation characteristics were studied in an irrigated meadow during the summer of 1991. The traditional techniques of irrigation were observed and soil humidity and its development through the summer were controlled. The humidity control was made by using two groups of tensiometers at three soil depths (20, 40 and 60 cm). Other observations were made during 1992 and 1993. The results show the necessity of irrigation between May and August despite it does not appear a dry period in the climate diagram. The comparison between the necessary irrigation doses (60 l/m^2) and those managed by the farmer (131 l/m^2), shows that he uses 118% more than is necessary with the traditional irrigation technique (Table 4). The soil humidity control (Fig. 6) shows that the depth most sensitive to variations is 20 cm and that the traditional irrigation periods of 8 days are too high considering the dose applied, and it would be necessary to increase the periods between irrigations or to diminish the doses.

Table 4. Calculated irrigation water (dose and frequency)[†] (from 1990 and 1991 data)

	ETC avg	ETC max	Ar	Nr	F (days)
May	104.88	148.71	60.04	100.07	12
June	107.88	159.90	49.83	83.05	14-15
July	127.37	178.77	103.50	172.75	7
August	121.76	163.42	100.03	166.71	7-8

[†]ETC: evapotranspiration; Ar: necessary water; Nr: irrigation water. Calculated irrigation dose: 60 mm for a supposed depth of 30 cm. F (days): frequency

The comparisons of dry matter production between 1989 and 1992 are achieved using the results on samplings in an irrigated meadow. The evolution of aboveground biomass is represented in Fig. 7a,b for the two studied years. The same standard spring growth can be observed in both years; it consists of a typical sigmoid curve followed by a final increase of the production just before the cut. The first part of the curve would be interpreted as a continuous vegetation growth until its maximum development (ripening), from that moment a regrowth is produced and joins the already mature material, which supposes an increase of the final production. Between the spring of 1989 and 1992 there is a difference in the yield and the cutting date (375 g DM/m^2 the 16-06-89 and 337 g DM/m^2 the 25-06-92) and it is possible to see from the development curve an earlier beginning of growth in 1989 compared to 1992. The increase in the production as earlier beginning can be interpreted observing the rainfall graphics in the Fig. 7c,d. While in 1989 the spring rains were distributed homogeneously, 251.0 mm over 27 rainy days from the 30th of March to the 2nd of June, in 1992, 267.9 mm fall in only 18 days at the end of the same period.

The increase in biomass due to the new vegetative regrowth at the end of the spring period, could justify the late cutting date, as an attempt of obtain this production increase. The probability of attaining the same end spring rains reached in 1989 is 60%, which helps to justify a late cutting date. In the summer development, the growth curves are clearly different: in 1989 the summer regrowth started ten days before than in 1992 and an additional water supply was given by means of irrigation (in 1992 irrigation was not supplied because this summer rainfall was very high), and finally, the cutting date in 1989 coincided with the maximum canopy development whereas in 1992 the harvest was in a growth state previous to maximum development.

The rainfall in the summer of 1989 was of 193.8 mm in 15 rainy days, from 26th of June to 26th of August. It was supplemented with 6 irrigations with a dose of 131 l/m^2, due to the irrigation system employed (60% of efficiency), it means 471.6 l/m^2, which added to the rainfall gives a total of 664.6 mm in the summer. Whereas in 1992 the only water contribution was 338.7 mm of rain in 19 days of the same period. The yield obtained in 1989 was 375.03 g DM/m^2 and in 1992 was 272.92 g DM/m^2. That means that the production of the second cut is always conditioned to the possibility of applying irrigation, even in 1992 with a very high precipitation (the probability of a summer rainfall equal or superior to that registered in this year is less than 20%) it was not possible to obtain a yield similar to that obtained with irrigation.

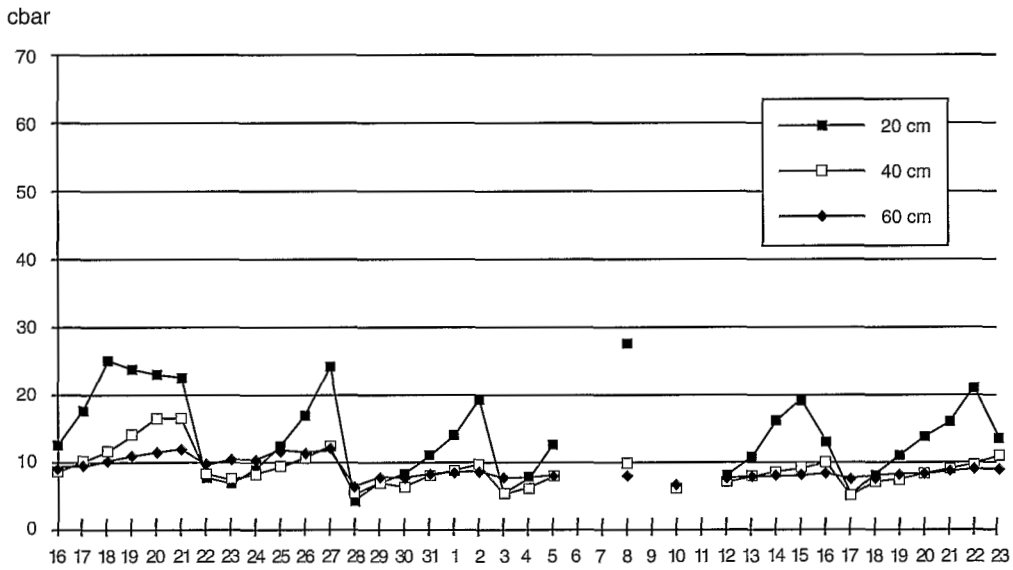


Fig. 6. Soil humidity control by tensiometers at three depths (20, 40, 60 cm) in an irrigated meadow in 1991.

Comparing the results in 1992, in both meadows (irrigated and unirrigated) (Fig. 7b), we observe a clear difference during the spring growth. Compared with the already commented tendency in the irrigated meadow, the development in the unirrigated meadow experiences a strong increase in the first days. These differences could be explained by the different types of soil of both meadows. In the summer regrowth, there is not much difference, since the rainfall is quite regular throughout that period, as explained in the previous paragraph. However, the irrigated meadow always presents a higher production than the non-irrigated, possibly due to the higher content in leguminous and its floristic composition. Assuming that the spring production depends narrowly on the availability of water stored in the soil, given that the meadows are in a morrenic substrata with great heterogeneity in the distribution of the clays, such production is conditioned by the position of each meadow in the meadowland.

Conclusions

Comparisons between valleys and role of the location of each village within the valley

The characteristics of stockbreeding in the village of Fragen (Broto valley, Aragonese Pyrenees) can be considered intermediate in terms of intensification level. These, compared with the characteristics of San Juan de Plan (Gistain valley), which are more traditional and therefore have a lower intensification level, allow us to summarise the following points: both villages continue to use the supra-forestal pastures, which allows the stockbreeders greater freedom from tending their animals in order to dedicate the summer months to the care and harvest of the grass from the meadows. From the beginning of May to the beginning of November (six months) the animals do not graze on the mowing meadows.

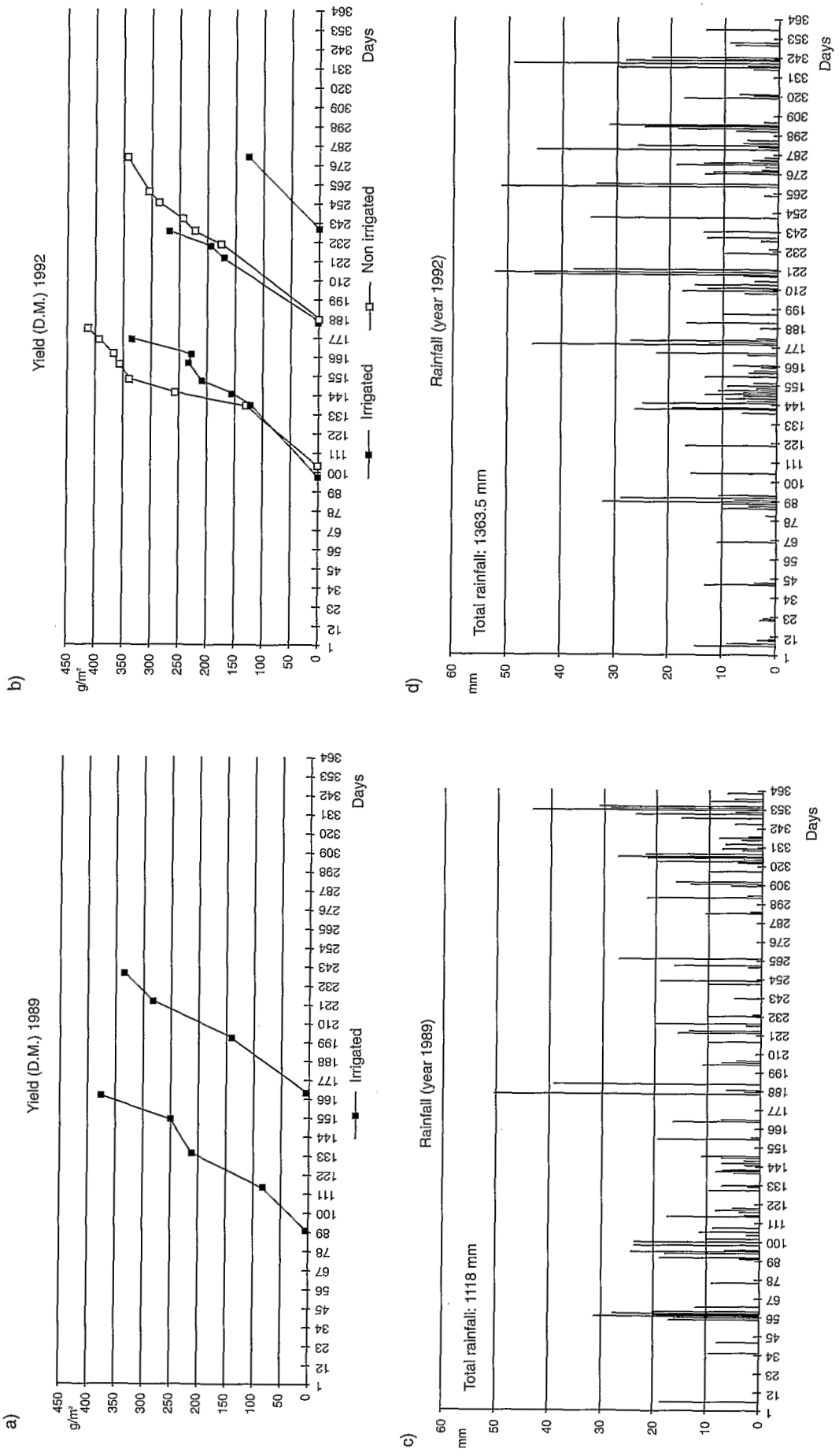


Fig. 7. Comparisons of dry matter production between 1989 and 1992 and yearly rainfall distribution: (a) dry matter yield in an irrigated meadow in 1989; (b) dry matter yield in both irrigated and non-irrigated meadows in 1992; (c) yearly rainfall in 1989; (d) yearly rainfall in 1992.

The differences between the valleys of the western and the eastern areas point out the greater Atlantic influence in the village of Fragen in comparison with the predominantly continental influence in San Juan de Plan. A slightly earlier spring in the case of Fragen allows a shortening of the winter feeding of cattle.

The persistence of communal grazing rights both in the supra-forestal pastures and in the lower areas is evidence of the double situation of stockbreeders who have private rights over the plots next to the village and communal rights over the common grazing grounds. All this implies an interaction between the intensification interests of the private area with other more extensive interests in the common grazing area. The grazing areas must be considered as a considerable complement for these Pyrenean villages. The greatest intensification in the mown meadows of Fragen compared with those which are only grazed, allows a greater production in the mown area. However, in the case of San Juan de Plan, intensification is only concentrated in the irrigated area while the non-irrigated and grazed meadows have very similar production levels. With regard to quality, the differences are more marked.

The annual rainfall, inferior to 900-1000 mm, limits the extension of the meadowland towards the south of the Pyrenees. Such rainfall corresponds to the villages above altitudes of 800-900 m in Spain. Meadowlands are typically in the mountains and the rainfall they benefit is conditioned by their topographical distribution. The intermediate situation of Fragen, between the other villages of the valley, allows it to receive the disturbances which arrive directly from the north and northwest.

Characteristics of Fragen meadowlands

With regard to the characteristics of the vegetation, the floristic composition of the various meadows of Fragen allows us to classify them into three management groups: (i) two cuts and grazing with summer irrigation; (ii) a single cut and grazing without irrigation; and (iii) grazing only. In the comparison of these three intensities of exploitation, it has been observed that the number of species diminishes with intensification, the proportion of grasses increases as does the production of forage; as for species, *Dactylis glomerata* is clearly dominant, and *Lolium perenne*, *Poa pratensis* and *Festuca pratensis* are also important.

The mineral content of the hay, in relation to the other variables, shows that production, expressed in dry matter, is significantly related to the proportion of grasses and the group "other species". Quality is positively related to grasses, and negatively related to the group "other species" and to diversity. The leguminous contribute principally N, Ca and Mg while the "others" are negatively related to the P content.

On the influence of the rainfall regime and the production cycle, it is worth considering that with the traditional method of irrigation (great quantities of water in a short time), the stockbreeder uses more than 100% of the necessary dose and therefore it would have to be improved by cutting down the weekly periods or reducing the dose applied. In any case, even in apparently rainy summers (as in 1992), irrigation is necessary at the second cut. With regard to the date of the first cut, despite being seemingly late for the hay harvest, it allows the capturing of the rains before the cut and thus, a regrowth of tender leaves is incorporated into the harvest. These are rains which may appear in 60% of the years. As to the situation of the plots within each exploitation, the importance of topographical position can be emphasized in terms of whether or not it permits the maintenance of the fine elements of the soil; greater water efficiency is obtained when fine elements are present.

Perspectives

The need for manpower and economising on machinery is facilitating the union of stockbreeders for the communal management of the mowing meadows and the grazing areas close to the village. Therefore, the grouping of plots into large homogenous areas, is an urgent requirement for stockbreeders in terms of ecological and management factors.

The new ideas of promotion of diversity and sustainable development demand a double-sided plan with regard to the global management of stockbreeding territory: (i) development of new techniques of

extensive stockbreeding and updating of the traditional ones in order to achieve a level of intensification which is compatible with the diversity of these meadows and pastures species richness; and (ii) control of the present most-intensified areas in order not to increase their area or their intensification.

The possibility of integrating the young in mixed stockbreeding-environmental education-cultural development programmes seems to be welcomed by young stockbreeders who have decided to continue in the village and are thinking of new opportunities for their children.

Acknowledgement

We are grateful to Mrs. E. Ubieto, J. Azorín and R. Galindo for the laboratory analysis. The accurate observations of the anonymous referees was a useful contribution to improve the first version of this paper. This work was funded by the EU CAMAR Project (No. 8001-CT90-002).

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