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Mediterranean dryland mixed sheep-cereal systems

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Abstract

In dryland areas of Spain and in other similar areas of the Mediterranean Basin, mixed agro-pastoral systems where sheep rearing is associated with cereal-fallow crops are very common.
The present review analyses first the history and origin of the mixed sheep-cereal system; secondly describes the system in Spain and other Mediterranean countries; thirdly, compares it with other arable and livestock systems and finally, makes proposals to improve the sheep-cereal system in the context of sustainable rural development and nature conservation.
The historical analysis suggests that after several millennia of independent development in the Mediterranean Basin, sheep and cereal systems merged probably during the Middle Age, as a risk reduction strategy, because mixed sheep-cereal systems are more productive, diversified, reliable and better adapted to fluctuating climatic and social environments. Economic globalization and intensification of crop and livestock systems are threatening the viability of the Mediterranean sheep-cereal systems, but compensatory payments for public services such as protection of rural life, environment, biodiversity, landscapes, and traditional food production systems (organic farming), are some of the justifications to maintain and integrate extensive sheep rearing in association with low-intensity cereal crops in marginal drylands.

Key words: sheep-cereal systems, barley, stubbles, fallow weeds, steppe-birds, rural life.

1. History and origin of mixed sheep-cereal systems

Agriculture was a prerequisite for any high civilization, like those of Mesopotamia and Egypt, because city dwellers are consumers, not food producers. The bulk of the food produced and consumed came from four domesticates: wheat, barley, sheep, and goats (Harlan, 1975). However, goat and sheep domestication (pastoralism) started before cereal cultivation.
According to mitochondrial DNA analysis, there were at least three geographically and temporally separate captures of founder female bezoar goats (*Capra aegagrus*) during the formation of early domestic populations. Fossil records suggest that the three goat lineages (Asia, Fertile Crescent and Europe) diverged much earlier (200,000 BC) than its domestication (c. 13,000-9,000 BC) (MacHugh and Bradley, 2001: Luikart *et al.*, 2001). In the case of sheep, mtDNA indicates they derived from two different maternal lineages, and that some of the modern domestic sheep (*Ovis aries*) and European mouflon (Hiendleder *et al.*, 2001) derive from one of these two common ancestors. These recent genetic discoveries indicate that goats and sheep could have been domesticated in Europe and North Africa (di Lernia, 2001), independently from its domestication in the Near Eastern Centre, and under different forms of pastoralism.
According to archaeological records, goat domestication started in the Eastern Mediterranean ca. 7200 BC, but size reduction, an indicator of domestication, began later in sheep, ca. 6500 BC. Cereal cultivation appeared about a millennium after caprine husbandry. By 5500 BC, domestic goats and sheep are found at Neolithic sites throughout Southwest Asia, frequently associated with evidence of cereals. Therefore we can expect that agriculture and pastoralism became the dominant mode of subsistence across much of the region between the 7th and 5th millennium (Bar-Gal *et al.*, 2003).
Initially, herders and cultivators of lands surrounding villages coexisted, but as populations increased, and with it the demand of foodstuffs, both activities dissociated and finally shepherds became nomads

who only contacted sedentary village cultivators to trade animals and animal products (Abdi, 2003; Johnson, 1983). Mixed cereal-sheep husbandry is a relatively modern type of pastoralism, not identified as such among the early types of prehistoric pastoralism in the Near East.
The globalization process in the Roman period led to large scale cereal production in the so-called Rome's granaries, scattered around the Mediterranean (Syria, Turkey, Egypt, Cyrenaica, North Algeria, Tunisia, Morocco, Sicily, and the Iberian Peninsula). These granaries may have offered the optimal conditions for the origins of sheep-cereal mixed systems during the fall and disintegration of the Roman Empire, and with the social changes associated to the beginnings of the medieval period. Since then, the convergence of sheep pastoralism with cereal agriculture became a common practice around the Mediterranean, especially in its more marginal areas, as a strategy to reduce risk and diversify production.
During the Middle Ages, as populations increased, more forest was cleared and converted to farmland and pastures with livestock excreta being the main source of fertilizer. As livestock numbers increased and due to the seasonality of Mediterranean climate and pasture resources, livestock rearing demanded seasonal movement of animals along networks of drove roads connecting summer and winter pastures (Bignal and Cracken, 2000).
In Spain, this transhumant pastoral system was well developed by the 8th century, and by the year 1273 the king Alfonso X had established a national livestock association, the 'Honrado Concejo de la Mesta', which defended the rights of livestock raisers undertaking transhumance across Spain, until its abolition in 1836. The Mesta maintained large numbers of Merino flocks moving towards regions where natural conditions provided green pastures (highland and mountains in summer, plains and coastal areas in winter) or to cropping areas like winter cereals to graze stubbles and weedy fallows. During the last decades, old agrosilvopastoral sheep rearing systems have evolved towards more intensive and economically efficient agro-pastoral systems, where use of concentrates and agricultural by-products make up the largest part of the animals feed. However, in marginal environments, like those prevailing in semi-arid Mediterranean basin countries, agriculture and livestock are still associated, and sometimes integrated.

2. The sheep-cereal mixed farming system

In Mediterranean countries, low-intensity arable systems are mainly confined to drylands (non-irrigated) which are particularly significant in the Southern European Union (Spain, Portugal, Italy and Greece), Middle East and North Africa (Syria, Tunisia, Morocco, etc). Very often, winter cereals use fallowing to maintain soil fertility, and associated with them, sheep rearing; animals graze stubbles in summer and weedy fallows in autumn-winter. The proportion of fallow (30-80%) and the importance of livestock increases as rainfall decreases. The number of fallow years also increases in poor soils (2-3 years). The components of the sheep-cereal/stubble/fallow systems are described below.

2.1 Cereal year

In Spain, winter cereals occupy around 6 mill ha (35% of arable land), and in summer, the majority of cereal stubbles are grazed by livestock, as well as nearly 3 million hectares of fallow land in the autumn-winter. During the last 20 years, the area cultivated with wheat has been maintained around 2.2 mill. ha, while the area of barley has been reduced from 4.3 mill. ha in the period 1985/92, to 3.1 mill. ha in 1999/2004. EU subsidies to increase arable land under fallow in marginal areas are probably the main cause of the reduction of barley cultivation. Oats and rye occupy small areas (391.000 ha and 161.000 ha respectively). During the decade 1995-2004, mean barley production in Spain was 9 mill. tons of grain (ranging from 5 to 11 mill. tons) and average yields 2400 kg ha^{-1}. Spanish barley production represents about 20% of EU barley production and 6% of world production.
The amount of straw produced by each unit of grain is 0.60 for wheat, 0.72 for barley, 0.78 for oats and 1.20 for rye (Kossila, 1984). In the barley straw, 35% corresponds to leaves, 58% to stems and 7% to awns and axis of spikes. Straw quality in Mediterranean semi-arid and marginal areas is generally better than in temperate zones (Rihani, 2001). Barley grain and straw are the most important livestock supplements during seasonal feed scarcity periods in dry Mediterranean areas (providing up to 50% of

animal nutritional requirements with 70% in the Middle East). When cereal yields are very low, as in dry years, grain is not harvested and animals graze cereals directly, maintaining their nutritional requirements during summer.

2.2 Stubble

After cereal harvesting, livestock enter the fields to graze the stubbles, which supply the remaining straw, weeds and the fallen grains. Sheep graze selectively; first the spikes and grains, secondly dry leaves, thirdly cut and fallen stems, and finally, standing stems. Summer weeds, such as *Polygonum, Cynodon, Amaranthus, Salsola, Chenopodium*, can be present in cereal stubbles, especially in areas where summer rains are relatively frequent. Some of these weeds are positively selected by sheep and contribute a fundamental part of their stubble diet. The biomass available in the stubbles ranges from 0.8 t ha^{-1} in dry years, to 4.5 t ha^{-1} in wet years. The quantity of fallen grain is highly variable, being around 200 kg ha^{-1} (Robledo, 1991), and it is related to spike density, soil topography, and soil stone content. According to Caballero *et al.* (1992), cereal stubbles represent a regular and important source of nutrients during the summer season for the Spanish sheep population –a mean of 24 million ewes during the last 15 years-.The capacity of stubbles to maintain sheep is limited because grain is consumed soon and the other stubble fractions cannot satisfy the nutritional requirements of gestating ewes (Guessous *et al.*, 1989). In such cases, animals are supplemented with concentrates. Sometimes, summer weeds represent an important fraction of stubbles: in North Greece, 33% of stubble biomass was made of weeds contributing up to 78% of the total diet (Yiakoulaki & Papanastasis, 2003).

2.3 Fallow year

The cycle of the fallow year starts with the autumn rains, which induce the germination of fallen cereal grains and other spontaneous plants. The biomass produced is highly dependant on rainfall and winter temperatures. Species of the Gramineae are the dominant fallow 'weeds', barley being the most important, followed by *Lolium, Bromus, Avena*, Leguminosae (*Vicia, Lathyrus, Medicago, Trigonella, Melilotus, Coronilla*), Cruciferae (*Eruca, Biscutella, Sisymbrium,Diplotaxis*), Papaveraceae (*Papaver, Hypecoum, Roemeria, Fumaria*) and others (*Centaurea, Bupleurum, Orlaya, Bifora, Silene, Vaccaria, Cerastium, Anchusa, Galium, Linaria, Consolida, Muscari*, etc.). At the end of spring, summer species germinate (*Salsola, Chenopodium, Polygonum, Hypericum* and *Amaranthus*).
Surprisingly, very few data are available on the biomass produced by cereal fallows, despite the important area they cover and the feed they provide to livestock. In SE Spain, Robledo (1991) and Robledo *et al.* (1989) estimated a mean production of 500-900 kg DM ha^{-1} during the period December-May; barley contributed 50% of the total biomass, followed by *Lolium rigidum* (19.3%), *Bromus diandrus* (11.3%), *Papaver rhoeas* (2,3%), *Vicia peregrina* (1.2%), *Trigonella polyceratia* (1.2 %) and others (77 species with a 14% contribution). It is so important that the yield contribution of Gramineae species during the fallow year could be consider as another cropping year, but one achieved without ploughing the soil and with the incorporation of manure from the grazing animals.

2.4 Sheep and herds

Sheep are the livestock species most related to cereal crops, with many races well adapted to different climatic and topographic conditions and able to convert cereal by-products into animal products. In 1995, a majority of Spanish livestock herds (60%) had less than 200 ewes, and very little economical future; 25% of total herds having 200-500 sheep made up one third of the census; however, herds with more than 500 sheep (13% of total) represented 50% of the national census and provide the best economic option for the future of the sheep-cereal system. Castilla-La Mancha and Aragón, two of the Spanish regions where sheep herds are larger (210-240 ewes/holding), are also regions where winter cereals are widely cultivated (Hoyos, 2003).

2.5 Climatic scenarios

The productivity of the system is very much related to rainfall; thus in Spain, during the last 20 years, mean barley yields oscillated from 1.4 t ha^{-1} in a dry year, to 3.4 t ha^{-1} in a wet year (mean yields 2.4 t ha^{-1}). In a mean year, the sheep-cereal system is well balanced, but during dry years, its components must be adjusted to get a minimal economic return that assures its continuity. Global climatic change scenarios open up new questions, but the versatility of the sheep-cereal system provides opportunities for adaptation to future climatic changes.
During dry years, production is reduced to 50% of a normal year (90% in lower rainfall regions) and in these occasions, cereal crops are fully grazed at the end of the spring Thus livestock are a fundamental tool to get an economic benefit from failed crops, a situation that can be prolonged during several years of drought, as occurs rather frequently in Mediterranean dryland regions. The price of cereal grains, straws and concentrates increases in dry years, what in turn increases the cost of animal feeding, because cereal products make up a large part of the animals diet.
During wet years, barley yields in Spain are 25% higher than in average years, and livestock feed resources are abundant; additionally, cereals are sometimes grazed during winter, with little reductions in grain yields. In wet years, weeds proliferate and compete with cereals, reducing the final grain yields, but in compensation, fallows are more productive.

2.6 Subsidy scenarios

EU subsidies to zones with environment or structural factors limiting development were initially used to increased sheep numbers and stocking rates in many regions of Mediterranean countries. In Spain, sheep numbers increased 52% during 1982-1993, and something similar happened to the area cultivated with cereals. With the new CAP starting in 1992, agriculture subsidies were given to producers instead of products. Since then, sheep numbers and cereal areas have stabilized or experienced a small reduction. In the case of livestock subsidies, they have not been used to improve forage production, infrastructure of farms, or to manage agrosilvopastoral territory, but have resulted in the intensification of farms and a movement of sheep from dryland to irrigated areas.
In Middle East and North African countries, governments offered subsidized grain to encourage the supplementation of grazing with cheap barley. This produced a rapid increase in the number of animals and the meat produced, but also meant more animals on less land, leading to degradation of rangelands to a generalized use of concentrate feeds and increased cost of meat production (feed costs represent more than 50% of livestock output; Nefzaoui and Ben Salem, 1999).
Fodder by-products from cereals represent the second largest resource in quantitative terms (after rangeland and natural pastures), but in terms of quality and seasonal availability, they represent the most reliable fodder resource for livestock during most of the year. Any future reduction of cereal area in economically marginal areas, due to reductions in subsidies, will diminish livestock feed resources and consequently, the stoking rate capacity of these areas.
In the near future, EU support to farmers must be linked to a double function: as producers of quality food, and as managers of a large territory with responsibilities for preservation of the environment. Future sustainable models for these territories should consider economic aspects, such as rural tourism, creation of second residences, winter sports, preservation and restoration of historical and cultural holdings, hunting activities, etc, as well as activities for the preservation and rehabilitation of the environment, such as reforestation, maintenance of natural parks, control of soil erosion, management of the territory, etc (Tió, 1996).

2.7 Maintenance of biodiversity

The cereal-fallow system maintains a pseudo-steppe landscape of great importance for nature conservation. The adventitious flora associated with cereal cropping represents about 20% of western Mediterranean flora, but also provides supplemental feeding and habitat for steppe wild birds such as partridges, quails, wood-pigeons, turtledoves, great bustard, etc, which are becoming under danger of extinction with the reduction of cereal-steppe habitats. Changes in the agricultural production systems in recent years (intensification, low-tillage, general use of herbicide, pesticide and chemical fertilizers, etc), loss of landraces and old crop varieties and abandonment of traditional field uses, have reduced the quantity and number of weeds to critical levels, resulting in some bird species becoming close to extinction in many European countries.

3. Comparison of sheep-cereal systems with other systems

Farming systems can be classified as extensive, semi-extensive or semi-intensive, and intensive, depending on the inputs, labour, capital and biodiversity involved.

3.1 Extensive-low input systems

According to Bignal and McCraken (2000), extensive systems can be classified as: livestock systems, arable systems, permanent crop systems and mixed systems, in which sheep-cereal and sheep cereal-legume systems could be included. Livestock systems are still present in upland and mountainous regions and in arid zones, but sheep numbers are decreasing, resulting in an increase of inflammable biomass and of forest areas affected by fires.
Arable systems, which are mainly confined to semiarid areas, are low yielding and use fallowing to maintain soil fertility, frequently in association with grazing. Permanent crop systems, such as olives, fruits and vines are an important component of Mediterranean lands, but inter-cropping with cereals and livestock grazing is practised in poorer areas.
Sheep-cereal systems are examples of mixed agro-pastoral systems, occupying an intermediate position between livestock and arable systems. Winter cereals represent the best alternative in terms of yields compared with the potential biomass produced by dryland pastures and rangelands. As an example, in semi-arid NW-Murcia (SE-Spain), where about 50% of the land is under cereal cultivation, the mean productivity of the biannual barley-fallow systems (2.7 t DM ha^{-1} $year^{-1}$) is very high compared to that of native rangelands (1.8 t DM ha^{-1} $year^{-1}$ in scrublands and steppes) and dry land pastures (1.2 t DM ha^{-1} $year^{-1}$) (Ríos *et al.*, 1992).
Higher labour cost and declining prices have contributed to the reduced viability of farming in marginal areas where forestation, marginalisation or complete abandonment has occurred in some places. Thus, a loss of agricultural habitats associated with the drier, traditionally less intensive farming systems has been detected in southern Europe countries.

3.2 Intensive-high input systems

Intensive systems like continuous cropping, or animal feedlots, in general are economically more efficient, and can feed more people per unit area in terms of calories and protein, than extensive systems. In intensive cropping systems, the role of animals is taken over by resources from fossil reserves; tractors using diesel oil instead of animals, fertilizers instead of dung, and herbicides instead of grazing. In the case of feedlots, the role of grazing is taken over by cereals, with livestock now consuming more than a third of the entire world's grain as feed concentrates. Every kilo of meat produced uses 5-21 kg of animal feed, which has to be grown somewhere. Grain cereals are also used to produce ethanol by fermentation, a process that leaves a 50% residual (DDGS), rich in protein, which is used as animal feed.

3.3 Intermediate systems

A semi-extensive system which is becoming generally adopted in Spain and other semiarid Mediterranean countries is that of maintaining dry ewes on grazing resources from cereal crops and rangelands, but fattening lambs and supplementing animals with barley grain and other concentrate feeds during periods of high nutritional requirements. The energy requirement of a sheep in a shaded feedlot may be 70% lower than that of a sheep grazing on stubble (Landau *et al.*, 2000). There are also semi-intensive agro-pastoral system around irrigated areas and fertile valleys, where intensive agriculture generates large amounts of by-products, which together with concentrates, make up the

largest part of the animals feed, and nearby urban populations absorb the animal products (Correal and Sotomayor, 1998).

4. Proposals to improve the sheep-cereal systems

The Mediterranean region is a complex mosaic of diversified landscapes. Much of the region is semi-arid and soils become saline, dry and unproductive in response to a combination of natural hazards (droughts, floods, forest fires) and human-controlled activities, notably over-tilling and overgrazing. Hence, proposals must be diverse and related to particular regions.
'Integration' by which farmers produce cereal and livestock to the mutual benefit of each enterprise is a must; however, in most cases owners of livestock do not have land, and cereal farmers do not have animals.
Long term security of land tenure and cooperative management of large territories will provide opportunities to improve livestock feed calendars with measures such as: controlling stocking rates on fallows and stubbles; practise deferred grazing in autumn to get more green feed in winter from weedy fallows; increase water supplies and fence part of cropland to make better use of feed resources; replace part of the fallow with forage legumes, etc.

4.1 Review cereal breeding in relation to sheep utilization of stubble products

Land-race based cultivars with improved straw quality for feeding purposes have been released by ICARDA in Middle East and North African countries. In dry areas, drought stress is associated with a marked reduction of stem height and grain production in barley, but the nutritive value of the straw increases; stubbles also contains more protein in years of lower rainfall. In Syria, barley straw with shorter stems had more leaves (55 *vs* 36%) and appeared more extensively degraded in vitro (80.6 *vs* 68.3%) in research by Thomson and Ceccarelli (1991) which showed a relationship between leaf to stem ratio and straw degradability. Ohlde *et al.* (1992) also found leaves were more degradable than stem internodes.
The quality of stubble from early maturing cultivars is lower than from late maturing cultivars. For this reason, selection of tall and early maturing varieties, which can escape drought, is in conflict with the increase in straw quality required for arid areas, where straw represents an important feed resource (Susmel *et al.*, 1994).
Recently, breeders have engaged in 'reverse evolution', aimed at establishing barley as a permanent pasture crop: a) selecting for wild seed to enable self-regeneration of the pasture; b) replacing awns by hoods to increases palatability of barley hay (Hadjichristodoulou, 1997).

4.2 Use of forage cereals and cereals as forage

When cereal yields are low, as in semiarid marginal areas, whole cereal crops such as barley can be used as forage for livestock, either for winter and spring grazing, or cut for hay at the end of the cycle (milky grain stage) for later use in periods of forage scarcity, such as winter. In Aragon, NE-Spain, several authors have evaluated the possibilities of cereals as forages. Joy and Delgado (1989) evaluating barley, oats and rye, measured winter yields between 200-400 kg DM ha^{-1}, which reduced harvested grain and straw 20% and 30% respectively. When cut for hay in spring, forage yields were 2-3 t DM ha^{-1}, rye being more productive in winter, and oats in spring.
Andueza *et al.* (2004) studied *in vivo* the nutritive value for sheep of hays made from barley, oats, rye, and triticale, and reported that daily intakes of oat and triticale hays (67.7 and 64.4 g DM $BW^{-0.75}$) were higher than those of barley and rye (53.8 and 54.5 g DM $BW^{-0.75}$ respectively). Barley had the highest dry matter digestibility (0.69 DMD) and crude protein (8.02 CP), but gave lower intake values than oat and rye, which the authors suggest could be due to differences in palatability related to presence of awns.
Valiente (2003) investigated the use of whole barley crop as a sheep summer diet; animals consumed first the spikes (50% of the initial biomass), secondly the leaves and thirdly the straw. The barley crop maintained a stocking rate of 65 ewes/ha for 30 days, with liveweight gain of 100 g/animal/day, but

46% of the initial production was left as residual (80% straw and 20% leaves and spikes) when animals were withdrawn from paddocks.

4.3 Organic farming

People living on marginal areas are confronted by several challenges: ecological sustainability (produce whilst preserving basic resources), feed survival (get enough food to feed the population living on it), and economical return (get a commercial benefit). Our modern, mechanized intensive agriculture is not a renewable resource because it consumes fossil energy and requires more work and energy per unit of food. Only a small part of land surface –deep fertile soils- is suitable for intensive agriculture; the rest of the land, which is better suited for range and forest and can be used by domestic ruminants that transform plant production that man cannot utilize (Harlan, 1975).
During recent decades, sheep rearing has gone through an intensification process that has given a negative selection of local breeds, as with 'Segureña' sheep, which lost adaptation to stress conditions and the capacity to transform feed resources of low nutritional value (Belmonte *et al.*, 1991). Thus a new selection process to recover robustness may be required before moving sheep flocks to extensive conditions, as proposed by the new EU-CAP.
Current EU policy on sustainable rural development promotes livestock systems adapted to local resources and environment, and oriented towards production of quality food; however, future predictions indicate that rural populations will continue their current decline and cereal production will evolve towards a competitive open market, as promoted by GATT agreements. With such a scenario, it seems logical that part of winter cereals, particularly barley, should be used for *in situ* consumption in extensive livestock systems.
Organic farming is an alternative to sustain sheep-cereal extensive systems in marginal Mediterranean drylands. In place of fertilizers and pesticides, organic farming relies on local biological resources: fertilizers vs. animal manure or legume cover crops; herbicides vs. animal grazing; confined animals vs. walking animals; medicine vs. plant's medicinal effects. In summary, organic farming could offer consumers foods free of chemicals, environmentally friendly and better tasting. There is more hand labour in organic farming, but livestock are healthier and prices of animal products are usually higher; however, there is still a big gap in the technical-scientific knowledge of Mediterranean agro-ecosystems and its self regulating capacity (Fersino *et al*, 2002) and hence, a lot of research is still needed (IFOAM-EU, 2004) before the economical, ecological and human sustainability goals of organic farming can be fully achieved.

4.4 Introduction of woody forage species

To establish crop hedges and field margins in environmentally sensitive areas, could provide food and habitat for wild fauna and reduce soil erosion (Atkinson *et al.*, 2002). Similarly, introducing woody forage species as natural fences and as protein feed supplements in cereal cropping areas could improve feeding calendars, preserve biodiversity and protect soils.
Fodder shrub plantations (e.g., winter legumes *Medicago, Cytisus,* or summer 'green' C4 species *Atriplex*, etc.) can be used for several purposes: a) to create fodder banks for annual and inter-annual feed scarcity periods, b) as protein or mineral supplements to improve sheep intake of nutritionally deficient feeds (i.e., cereal straws, *Stipa* grasses, etc), c) to control soil erosion in cultivated areas with steep slopes, d) to provide refuge and feed to wild fauna, (Correal, 1993).
Perennial woody legumes, like tree medics (*M. arborea, M. citrina*) are a good option for winter-spring grazing. Cereal-*Atriplex* alley cropping with saltbushes planted in widely-spaced rows following contour lines provides an *in situ* protein supplement to straw/stubble and protects the soil against soil erosion during autumn heavy rains. In Morocco, Narjisse (2005) reported that a barley-*Atriplex* system gave 31% and 97% more grain and straw respectively than the barley-fallow system. In Spain, cereal farmers in Murcia (SE-Spain) planted a few thousand hectares of *Atriplex* (mostly *A. halimus* and *A. nummularia*) as feed banks or supplements for summer and winter periods, but in most cases, poor management reduced the life and success of the plantations, which were well grazed by sheep (in fact, were overgrazed). Sotomayor and Correal (2000) showed that dry sheep fed with a mixed diet of

Atriplex and cereal straw could be maintained during summer with significant increases in weight and body condition.

4.5 Introduction of legumes in cereal fallows

Before the massive mechanization of agriculture, farmers had to cultivate forages of high feeding value as grain and hay legumes, and maintain cereal-legume fallows to produce enough feed for draft animals. Thus, in Seville (Spain), cropped land was rotated in a three year systems in which 1/3rd was cultivated with cereals, 1/3rd was fallow land, and 1/3rd was cropped with legumes (peas, beans or vetch); animals consumed cereal and legume stubbles, weedy fallows, the harvested straw and some of the harvested grain (Kayser, 1992).
With the advent of mechanization, most forage and pasture legumes were lost; however, fallow replacement with legumes for food, feed and pasture has been investigated by ICARDA (Jones, 1992). Grain legumes, such as lentils and chickpeas, had a certain degree of success in areas with good soils receiving more than 300 mm of rainfall, but annual pasture legumes in rotation with cereals were badly accepted by farmers. Approximately 350,000 ha of medic pastures were sown on North Africa and the Middle East during the 1970's and 1980's, mainly using imported seeds, but the results were far from being positive, and few of them are still functioning as the intended ley farming (Riveros *et al.*, 1989). In Morocco, the small farms size forced farmers to use high stocking rates, which reduced seed production and the regeneration of the self-seeding legumes (Jaritz, 1992). In fact, the majority of farmers in North Africa have a multifunctional concept of livestock rearing with the livestock being a source of revenue, nutrition, financial liquidity and providing status in society (Riveros *et al.*, 1989). Hence, they keep stocking rates far in excess of potential plant growth and any significant increase in animal feed is reflected in an increase in the animal population (Jaritz, 1992).
The ley farming system fits well to Australian conditions were properties and flocks are large, there are infrastructures to maintain sheep permanently grazing on the field (fences, watering points, etc), and flocks are stocked at reasonable rates, allowing high seed production and persistence of pasture legumes However, such conditions do not exist in a majority of semiarid Mediterranean countries where attempts were made to introduce annual legumes, with the result that legumes are almost absent from cereal-fallow rotations.

4.6 Annual forage calendars to match resources with sustainable stocking rates

The planning of annual feed calendars for livestock, combining all the possibilities offered by fodder resources such as cereal crops, fodder cereals, grain legumes, pasture legumes, and fodder shrubs can reduce grazing pressure on degraded rangelands and improve the efficiency of animals. Delgado *et al.* (2004) experimented in semiarid Zaragoza (NE-Spain) with a forage system based on the combined use of alfalfa, winter cereals and the forage shrub *Atriplex halimus;* paddocks were fenced, and forage resources rotationally grazed by a flock of local ewes. This continuous forage system maintained 2 ewes ha^{-1}, and produced 1.2 lambs ewe^{-1} year^{-1} with one lambing year^{-1}. Ewes lambed outdoors and lambs were kept permanently with their mothers until reaching a slaughter weight of 22-25 kg. Fálagan (1992) proposed a similar forage calendar using winter cereals, alfalfa and *Atriplex*.
The traditional system in Zaragoza is an alternate cereal-fallow producing an average of 1.8 t ha^{-1} of barley; additionally, a stocking rate of 0.7 ewes ha^{-1} is maintained with cereal by-products and other rangeland forage resources, but the system is in crisis because of scarcity of shepherds and the limited gross margins of farms. With a final product of 2.4 lambs ha^{-1} year^{-1}, the proposed forage system could economically compete with the traditional system and is also socially and environmentally more sustainable because of reduced needs for shepherds and labour, and because livestock are maintained in balance with forage resources and are less dependent on external inputs.
The feeding calendar for a majority of livestock-cereal mixed systems in North African and Middle East countries (Nefzaoui, 1999) is based on the following feed resources: rangelands, cereal stubbles, cereal fallows, standing barley (green or whole dry crop), cereal and legume straws, barley grain, wheat bran, crop residues, olive tree by-products (cake, leaves, twigs), and other supplements (cactus, *Atriplex*, etc.). The contribution of the resources mentioned is changing rapidly with the contribution from native

pasture and rangelands decreasing while the contribution from cereal grains, straw and crop residues is increasing.

5. Promotion of plant and animal diversity

Agricultural policy in Europe is changing from supporting production to encouraging environmental benefits in the context of sustainable rural development. Biodiversity may benefit from integrated farming techniques, such as sheep-cereal systems, but these need to incorporate environmental objectives explicitly, rather than as a fringe benefit. The loss of traditional crop rotations and the polarization of pastoral and arable farming has led to a marked reduction in mixed agriculture, and with it, a dramatic reduction in landscape diversity (Robinson and Sutherland, 2002). The intensification and modernization of cereal cropping has reduced the food supply for wild fauna because of: a) the removal of hedgerows and "rough patches", b) the use of herbicides that eliminate weeds, c) suppression of fallow lands and d) earlier ploughing of stubbles (Newton, 2004).
Weeds are major constraints to crop production, yet they have a role within agro-ecosystems in supporting biodiversity, especially phytophagous insects and birds (Marshall *et al.*, 2003). Fields left fallow after harvest (i.e. stubble fields) support high wintering densities of many species of granivorous birds. In central England, seed abundance and area of bare earth were significantly greater on barley stubbles than on wheat stubbles (Moorcroft *et al.*, 2002). In S Portugal, studies on the diet of wild rabbits (*Oryctolagus cuniculus*) stress the relevance of cereals crops to increase the carrying capacity of 'montados' for rabbits (Martins *et al.*, 2002). In Spain, Verdú and Galante (2002) found positive relationships between density of rabbits, surface grazed by sheep and goats, and the dung beetle endemism index.

5.1 Arable weeds

Relations between arable field crops (cereals, legumes, etc.) and arable weeds are a very old process handled by men. Many weeds may be consumed as wild food and weeds are a source of medicinal products and potential sources of nutraceuticals (Rivera *et al*, 2005) with some weeds providing animal self-medication (Engel, 2002).
Many countries of central Europe and the UK (Sprenger *et al.* 2002; Sutcliffe and Kay, 2000) have a red list of endangered plant, where arable weeds represent about 20% of the wild flora targeted for conservation. According to Waldhardt, *et al.* (2001), in Central Europe´s marginal cultivated landscapes, the seed bank of arable-land weeds is depleted after cultivation is abandoned and largely exhausted after only ca 20 years; on the other side, several aggressive weed species have increased markedly over the past 30 years, mostly because of the increased nitrogen input from intensive techniques.

5.2 Steppe birds

The conversion of forest lands to pastures and cereal crops produced a transformation of the territory and the appearance of spaces similar to secondary steppes and pseudo-steppes (Tucker and Dixon, 1997). About 60% of endangered birds in Europe live on these steppe habitats, and the areas where cereal-sheep mixed systems are present are the most important habitat for the preservation of steppe birds (Suárez *et al.* 2005). In Europe, the largest steppe area is in the Iberian Peninsula (about 17 mill. ha). Of all steppe birds, the great bustard (*Otis tarda*) and the little bustard (*Tetrax tetrax*) are the two species most threatened. Both species are classed as 'endangered' under current IUCN conservation criteria, with 50% of the world bustard population found in the Iberian Peninsula. The measurements suggested to protect steppe bustards are: to maintain fallows and their rich flora; preserve or create borders and living hedges; eliminate herbicides and pesticides, fertilize with organic manure; use native seeds; and maintain traditional cropping cycles (Alonso *et al.*, 2003).

5.3 Cereal land races and old cultivars

In Spain, Gadea (1954) made a cereal inventory through all the country, finding over 200 landraces of several wheat species. The provinces with greater diversity were Asturias, Murcia, Albacete, Cuenca and Eastern Andalusia, provinces where sheep-cereal mixed systems did exist; on the contrary, other Spanish provinces with better conditions for cereal production (e.g. Castilla-León), had lower levels of agro-diversity.
A recent ethnobotanical study in the province of Albacete catalogued 28 local races of wheat, but five less than in 1954 (Fajardo *et al.* 2000). Conservation of old cereal cultivars could be of great value for future breeding of cereals as forage for livestock.

5.4 Local animal breeds: sheep and goats

In the mountain areas of Italy, France Spain and Portugal almost half (47%) of the breed races present in Mediterranean countries are localized with the Alps-Pyrenean axis being like a hot spot for ovine diversity (Mason, 1967; MAPA, 1985). A particular example is the *Merino* ewe (origin in Spain and Portugal), whose diversity has been multiplied through all European countries, South America, Australia and New Zealand. Other important racial groups are the *Awassi* (with fat tail), from the Middle East, and the *Barbarine*, from North Africa. More than 200 ovine races and a smaller number of goat races are distributed in the Mediterranean area, occupying a large diversity of ecological niches. At least 80% of these races are bound to agriculture by-products for its feeding. Unfortunately, the mounting extinction rates among domestic breeds are diminishing the genetic diversity on which adaptability to marginal conditions and future breed improvement might depend (Luikart *et al*, 2001).

6. Conclusions

The sheep-cereal farming is an original Mediterranean system which probably appeared in the Middle Age, during a critical economical situation, as a diversification response to reduce risk and optimize food and feed production.
Sheep-cereal systems survive better on marginal dry land, where cereal yields are low and animal production is economically more interesting; cereals are consumed *in situ* as animal feed in its different forms.
The winter cereal-stubble-fallow system maintains a cereal-steppe landscape where an important part of Mediterranean flora and fauna, especially steppe birds, depends on the habitat and feed resources generated by stubbles and fallows.
Mixed sheep-cereal systems are restricted by their low profitability and the poor integration between agriculture and livestock activities, which limit their economic, ecological and social efficiency.
The practise of sheep-cereal organic farming in marginal areas could not only help the preservation of local cereal races and local sheep and goat breeds, which are better adapted and more productive under difficult conditions than selected races and breeds, but also be justified by the originality and quality of their final products.
The preservation of extensive production systems adapted to the environment, and the quality products, biodiversity and landscape associated with them, are reasons that justify their maintenance in Mediterranean marginal areas. However the search for economic and ecological solutions for Rural Development in these territories, is most crucial to avoid human desertification, a possible scenario that would make unviable their preservation.
Seasonal fluctuation of animal nutritional requirements and forage and pasture resources must be matched in an optimal way. However, even if fodder gaps exist, there are possibilities to improve the system by approaches such as creating fodder banks or hedges with forage shrubs, which can also support biodiversity, or introducing infrastructures like fences, water points and animal shelters in part of the farmland, to maintain animals grazing permanently during long periods, and thus, reduce labour cost and shepherd's demand.

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Session 1

Overcoming seasonal constraints to forage production