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Pastoral systems dominated by cereal/fallow combination in North Africa and West Asia

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SUMMARY - Following a brief description of the traditional pastoral society and the complementarity and/or conflicts between farmers and pastors in North Africa and West Asia region, authors discussed the recent evolution of pastoral system dominated by fallow. They describe the current systems based mainly on rangeland, sedentary small holders mixed farming, and the more recent sedentary intensive system. Most of these systems are located in low rainfall areas of the WANA region and are facing dramatic feed shortage and drought management risks. Feed calendar witnesses of the importance of barley grain as a supplement feed for small ruminants and the relative failure of crop/livestock integration in most of the countries. Rangeland contribution to small ruminant feed requirements is decreasing and barley cultivation is invading the best rangelands, and steppe zones. Therefore, desertification, loss of soil and natural resources is of first concern for the region. Stubble plays a key in filling the summer feeding gap. Crop residues from cereals and olive tree are playing a more and more important role in almost all the countries. The current systems may be improved through the implementation of some technologies such as (i) the promotion of alternative feed resources; (ii) the fallow replacement with adapted (native) legumes; (iii) the promotion of on-farm shrubs planting and their integration with cereal crops production (alley-cropping). Some examples of complementarity between conventional feeds and shrubs are discussed and illustrate the real potential of such integration.

Key words: Pastoral systems, livestock, cereals, fallow, shrubs, integration, arid zones.

RESUME - *"Systèmes pastoraux caractérisés par la combinaison céréales/jachère en Afrique du Nord et Asie Occidentale". Après une description succincte du système pastoral traditionnel et de complémentarité et/ou des conflits entre éleveurs et agriculteurs dans les pays de l'Afrique du Nord et de l'Asie de l'Ouest, l'évolution récente de ses systèmes et ses implications sont abordés. Les systèmes actuels, essentiellement sédentaires, sont ensuite discutés. L'accent est mis sur les zones à pluviométrie limitée qui endurent un manque croissant en ressources alimentaires aggravé par des sécheresses périodiques. La culture de l'orge prend des dimensions importantes dans ces zones où les tentatives d'intégration de l'élevage aux cultures ont échoué. Les apports alimentaires jadis assurés essentiellement par la végétation naturelle des parcours diminuent sans cesse et la complémentation, essentiellement à base d'orge, devient omniprésente. De plus, les meilleures terres de parcours se voient envahies par la culture de l'orge et l'arboriculture en sec aboutissant à des phénomène de dégradation et de désertification. Les chaumes jouent un rôle important dans la mesure où elles comblent le déficit alimentaire estival. Les résidus de récolte issus des céréales et de l'olivier jouent un rôle de plus en plus important dans pratiquement tous les pays de la région. Les systèmes actuels peuvent être améliorés par l'adoption d'un certains nombre de technologies appropriées, parmi lesquelles : (i) la meilleure utilisation des ressources alimentaires alternatives; (ii) le remplacement de la jachère par des légumineuses adaptées; (iii) l'installation d'arbustes au niveau des exploitations et leur intégration dans le calendrier fourrager en favorisant la pratique des cultures en interlignes. Quelques exemples montrant la complémentarité entre les ressources alimentaires conventionnelles et les arbustes fourragers sont discutés pour illustrer l'impact réel d'une telle intégration.*

***Mots-clés** : Systèmes pastoraux, élevage, céréales, jachères, arbustes fourragers, intégration, zones arides.*

The traditional system

The traditional pastoral society

The traditional pastoral system was essentially nomadic or transhumant, with seasonal movement of flocks in search of water and grazing. A sustainable balance was maintained between animal numbers and feed availability. This traditional system was based on a pastoral society which was strongly supportive and egalitarian. The relevant institutions are the tribe and lineage group or extended family.

Local leadership is vested in the tribal sheikh. In this traditional pastoral society there was a great deal of kinship and community solidarity and mutual support, especially in difficult times (Upton, 1995).

This situation remained for a long time, since antiquity until the middle of the XXth century. After 1950, modern technologies and new economic rules have changed dramatically this framework. While pastors are gradually "pushed out", the place of livestock within the cereal production systems is moving: from the zero-livestock system to the modern highly specialized animal husbandry, with all the various intermediate situations.

Farmers *vs* pastors: from complementary to conflict

Traditionally, the relationships between farmers and pastors are regulated by ecology which defines the border limits of each group. But in cultivated lands, the established relationships are more complicated: between farmers growing cereals and transhumants, on the one hand, and on the other hand within the farms where animals are needed as a power, for human consumption, and for soil fertilizing (Keyser, 1992).

Very often it was suggested that cereal production and livestock are incompatible in the Mediterranean basin (Keyser, 1992): pastors were supposed to be the enemies of farmers which were mainly cereal producers. But, actually the situation is more complicated, and it might be stated that crop and livestock are associated under harsh conditions and sometimes with conflicts. This association is not only limited to the face to face herder-peasant since the peasant himself is often a livestock owner, and animals do play a key role in the system.

Indeed, farmers and pastors compete for the same space (Keyser, 1992):

(i) Under favourable climatic conditions, agreement is quickly met between farmers and transhumants (livestock provide some organic fertilizer for poor soils, and provide some cash by renting fallow lands or achaba).

(ii) Under unfavourable climatic conditions (drought): conflicts happen rapidly. Feed resources become scarce, and starving animals in their transhumance routes and in the neighbourhood of cultivated areas cause damage to crops and compete for the meagre available grass with the farmers' livestock. Thus, there is a permanent strip of conflicting area between livestock farmers and pastors. This strip is moving according to the climatic conditions and consequently to the available feed resources.

Evolution of the system

Governments have tried, with varying degrees of success, to settle nomadic pastoralists for national security reasons, to allow for the provision of social services, and to facilitate the collection of taxes. Traditional systems of communal tenure of the rangelands have been abolished and replaced by open access. No individual has an incentive to limit livestock numbers, while some marginal areas have been settled and cultivated. This results in more animals on less land, leading to degradation of rangelands. Feed was inadequate and flocks moved out of the range, utilizing crop residues in cultivated areas for long periods (Upton, 1995).

The agropastoral system is characterized by a decreasing reliance on the rangeland and more inputs provided from cultivated areas. Most producers now have a settled base, but seasonal migrations of flocks may still occur. Flocks are smaller than under a nomadic pastoral system.

Rapid population growth and increasing incomes have led to a rapid growth of the demand for food, and for livestock products in particular. Production has failed to keep pace, so governments have offered subsidised grain and other artificially cheap imports. These policies encouraged the supplementation of grazing with cheap barley. This in turn has encouraged the rapid increase in the number of animals.

Livestock productivity has increased somewhat over the past ten years, but at the expense of an increased use of concentrate feeds and increased costs of production. Feed costs now represent more than half of the value of livestock output at current market prices.

Over the last decades, economic reforms and structural adjustment regimes have been introduced in many countries. Effective currency devaluation has occurred and producer price supports have been reduced. Small ruminant producers are suffering a price squeeze, with the price of purchased feeds rising in relation to the prices of livestock products.

The current systems

The main systems

Rangeland-based system

At least two criteria may allow to differentiate the current agropastoral systems from traditional nomadic pastoralism: (i) most small ruminant producers now have a permanent settled base, and (ii) livestock feeding is much more dependent on cultivated crops for their feed. Crop and livestock production have become more closely integrated.

Sedentary smallholder mixed farming

Under sedentary mixed farming, sheep and goats are kept in small flocks as a supplement to crop production. The main arable crops grown are cereals, mainly barley and legumes. Alternate cropping, with a fallow every other year, is often practised but the area cultivated varies from year to year depending on the rainfall.

Mixed farmer's flocks are fed on straw, crop residues, fallow land grazing, and natural pasture grazing. In summer animals graze on cereal stubble and during autumn and winter they are fed on cereal straw. Animal diets in such sedentary systems are supplemented with barley grain and bran.

Sedentary intensive production

Intensive production, which involves fattening lambs and kids mainly on concentrate diets with a minimum quantity of roughage, is found on a limited scale in some countries.

The joint production of crops and livestock not only improves the family diet but also provides a more reliable and regular income that can be achieved by traditional pastoralism. Diversification into crops and livestock allows a given family labour force to produce a greater variety of foods, increase household income, and reduce risk.

Feed resources and feed calendars

Feed resources of the current systems are: (i) rangeland and fallow grazing; (ii) standing barley (green or whole dry crop); (iii) cereal stubble; (iv) crop residues; (v) cereal and legume straws; and (vi) barley grain, wheat bran, olive cake, olive tree leaves and twigs, cactus, and other supplements.

The feed calendar shown in Table 1 is common in many countries in the region.

The contribution of rangelands to the annual feed requirements of livestock is diminishing continuously. Overgrazing and the deterioration of the range are the major factors which forced pastors to change their migration and feeding patterns. In some countries, animals are heavily supplemented with barley grain and other concentrate feeds. They move in late winter or early spring to rangelands and in many countries the whole barley is grazed between the range grazing and the stubble grazing periods, if it appears unlikely to be worth harvesting the grain.

Table 1. Common feed calendar for small ruminants in the WANA region

Period	Physiological stage	Area	Type of feed	Supplement
May - July	Mating - early pregnancy	Agricultural land	Cereal stubble	Bran, barley, cactus
August - September	Pregnancy	Agricultural land	Cereal stubble, straw	Bran, barley, cactus, shrubs (atriplex)
October - January	Late pregnancy - early lactation	Rangeland, agricultural land	Fallow, hay, natural grazing	Barley, wheat bran, olive tree by-products
February - April	Weaning, fattening	Rangeland, agricultural land	Natural grazing, fallow, standing barley, straw	Olive tree leaves and twigs, barley, bran

Supplementary feeding is mainly in the form of barley grain and is widely practised in the region. It serves several purposes: to supplement the range, to cover higher animal requirements (early pregnancy, early lactation), to build up feed reserves in bad years, etc.

Failure of crop/livestock integration

Two possible levels of relationships between crop and livestock: (i) at the macro/regional level; and (ii) at the farm level.

The integration at the macro level was a failure for the following reasons:

(i) Integration of livestock through the increase of the rainfed forage crop production: this solution has not really succeeded, since the cultivated forage crop areas have remained rather constant during the last 15 years and their contribution to animal feeding is limited to about 10% (Fig. 1).

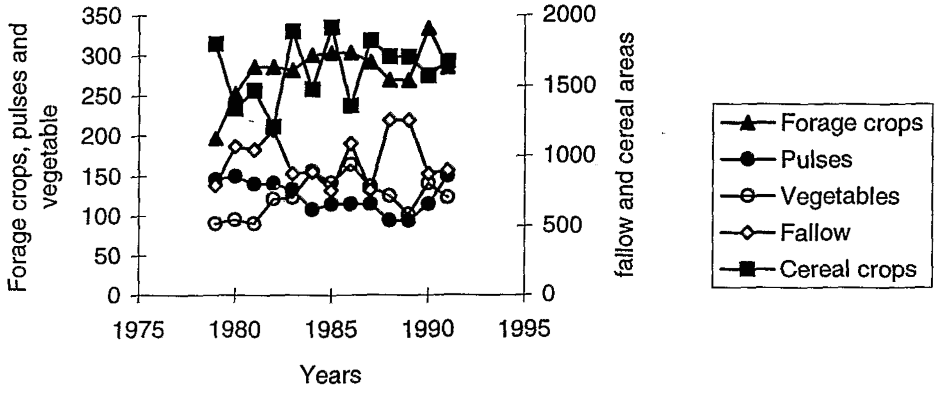

Fig 1. Areas (x 1000 ha) variation of fallow, cereal crops, forage crops, pulses and vegetables in Tunisia (Nefzaoui, 1995).

(ii) Increase of forage crops in irrigated areas: this alternative failed also and is practised mainly at the state farms and in small farms for summer forage crop (sorghum, maize). The "public irrigated perimeter" were established in order to increase fodder production. But rapidly, and for economical reasons, farmers opted for vegetable and/or arboriculture production.

(iii) On the other hand and at the national level, statistics seem to indicate that the contribution of pasture and rangelands in the feed calendar is decreasing dramatically (less than 30% during the 1990s) while the contribution of cereal grains, straw and crop residues in general is increasing.

At the farm level within the production system where cereals are predominant; even if both belong to the same person, the model is quite complex because the production objectives are different. Here also, success stories of livestock/crop integration are limited. The reasons of this failure are, at least for North Africa: (i) large size cereal producers are not livestock owners; (ii) forage crop producers are not always livestock owners (hay production for sale); and (iii) most of the livestock is within small farms with limited forage crop resources.

According to the arguments developed above, the existing interactions are mainly based on the necessity of better use of feed resources, and specially barley cropping (green forage, grain, straw, stubble, alley cropping in association with atriplex, acacia or even cactus).

More and more barley is needed to meet animal requirement

According to Jones (1992), sheep and goat flocks traditionally graze hillsides, steppe pasture, and stubble fields. Nowadays, this simplified portrayal is still there but with much lesser importance. Indeed, the enhancement of the population welfare (income) has increased the demand for animal products and thus the development of more and more intensive livestock production units (peri-urban feedlots) and the generalized technique of supplementation. This type of production systems are big consumers of cereals and cereal by-products (grains, straw, stubble). Consequently and in order to cover animal needs, increasing amounts of feed (maize, barley, soya bean meal, ...) are imported and have a great pressure on the country balance of exchange. In order to limit this effect, great efforts are made to produce these feeds internally. The question is how and at what cost?

The perceived danger of increasing feed production internally are (Jones, 1992):

(i) This production will be at the expense of food crops, especially wheat.

(ii) The greater profitability of livestock production sector will encourage the cultivation of more and more marginal land, destroying the resources base of soil, and natural vegetation (steppe and marginal lands ploughing).

Wheat and barley are the predominant winter cereals of rainfed arable systems in Tunisia and North Africa. The relationship with rainfall is particularly important. Broadly speaking, wheat is more productive in wetter areas, and less productive in drier areas. Distinction between "wheat-based" systems in wetter areas and "barley-based" systems in drier areas appears valid. Animals are found in both systems, but generally their contribution to farm income increases as rainfall decreases. Barley-based systems are therefore predominantly animal-production systems, with the barley - as green pasture, stubble and stored grain and straw - a major source of feed. The dependence on barley is increasing, as fallow land is reduced, cultivation encroaches on grazing lands and the remaining grazing becomes over-exploited.

More barley for sheep and less for humans: barley cultivation is increasing

Barley cultivation has increased significantly (x 3) during the last 30 years (Fig. 2). This increase is not only explained by the area increase (40%), but also by the better yields obtained (average yields were 5.6 q ha^{-1} for the period 1971/77 and 11 q ha^{-1} for the period 1991/93). Sarniguet *et al.* (1994) attributed this increase to:

(i) The subsidies (fertilizers, machinery, etc.) which contribute to the increase of cereal yield, particularly barley. Since 1975, barley production has increased 3 times and yields 2 times.

(ii) The relative easiness of barley production, harvesting, transportation and storage techniques, in comparison to forage crops (hay production, silage, etc.).

(iii) The relative decrease of barley prices as compared to wheat, did not hamper barley extension.

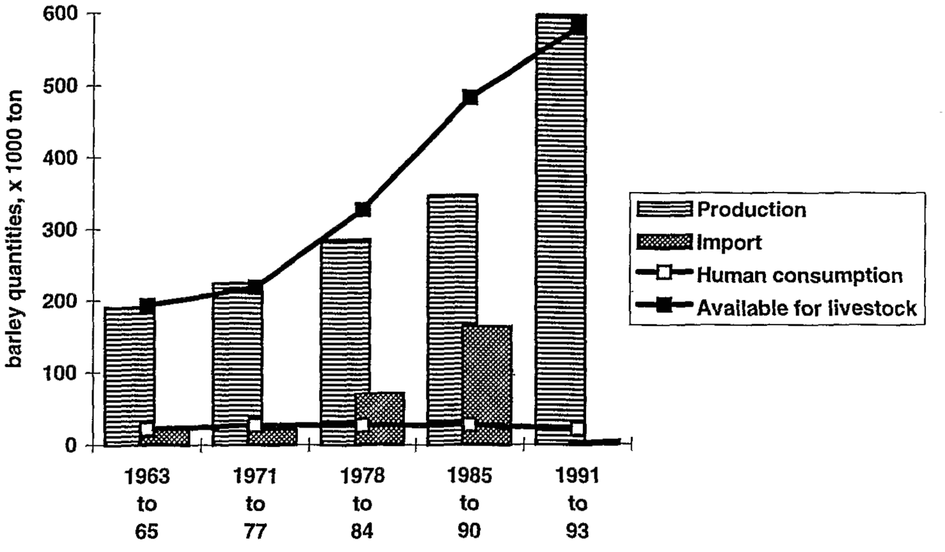

Fig 2. Variation of amounts (x 1000 ton) of barley produced, imported, and used for human consumption and available for livestock feeding in Tunisia.

Most of the barley locally produced and/or imported is used for livestock feeding (concentrates manufacturing, auto-consumed). The amount of barley used for human feeding is in constant decrease (4.3 kg/inhabitant in 1980, 2.6 kg/inhabitant in 1990). It is worth mentioning that the auto-consumption of wheat has been decreasing: 36.2% in 1975, 14.4% in 1980, and 9.6% in 1990. This decrease is due to culinary habit changes.

Barley is produced mainly by small farms: 50% of the total barley area is located in small size farms and 30% in medium size farms.

Crop residues from cereals are vital for sheep production

In most arid and semi arid areas where cereal (barley) and sheep are in a mixed farming system, fodder by-products from cereals (stubble, fallow, and straw) represent the largest resource in quantitative terms (around 20% of the total available feed units), but also in terms of quality and seasonal availability they are the best (Fig. 3). Because of this any future reduction of cereal surface in the marginal areas (steppe for example) will immediately diminish the feed bank of livestock. This alternative can not be supported by livestock owners.

If we consider a typical case study of a smallholder, we may notice that he can produce on a poor soil some 600 to 800 kg of barley per ha from which only 30 to 40 kg will be used for human consumption. The remaining, 560 to 760 feed units from the grain and 120 to 180 feed units from the straw will be used to feed the flock. This amount may cover 25% of 15 to 25 sheep or goat requirements.

Possible improvement of the current systems

Restoration of rangeland productivity is expected to follow from a return to communal or group tenure and grazing rights, with long-term security of tenure for the tribe or cooperative group. Local participation in research and decision-making should be encouraged, to identify appropriate innovations and increase the likelihood of their adoption (Upton, 1995).

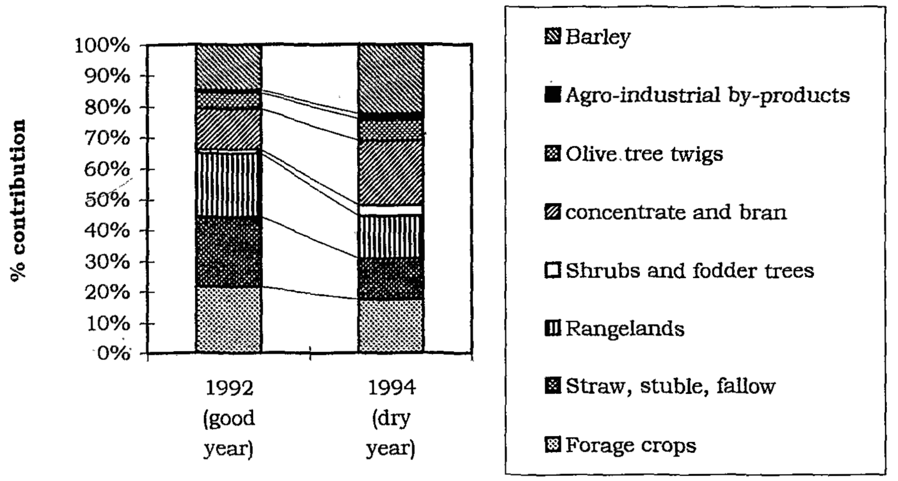

Fig 3. Percent contribution of feed resources to cover livestock requirements in Tunisia in a good year (1992) and dry year (1994) (Nefzaoui, 1995).

Improved management of the rangeland will involve: (i) reduction of stocking rates; (ii) controlled and deferred grazing; (iii) periodic resting; (iv) extended water supplies; (v) reseeding; and (vi) shrub planting.

Productivity can be improved by increasing feed supplies from alternative sources, including: (i) legumes or other forage crops grown in place of fallow; (ii) fodder banks of naturally grown legumes given phosphate fertilizer; (iii) treatment and suitable supplementation of straw; and (iv) other crop residues and agroindustrial by-products.

A planned government strategy for drought relief will reduce the risk to small ruminant producers and encourage increased production.

Promote alternative feed resources

Olive tree by-products

Olive cake and olive tree leaves and twigs from pruning play a key role in some countries of the WANA, particularly in Tunisia. They are available in large quantities, mainly in arid and semi arid areas, during winter and fill an important feed gap. Two examples are reported in Tables 2 and 3 and show the potential of this traditional/alternative feed resource.

Example 1: Under harsh conditions Barbarine ewes may be fed on diets including 35% of olive cake and ensure normal performances (Table 2). Under harsh conditions, diets may be based only on olive cake (70%) supplemented with molasses and urea. Using such diets, ewes survive but their liveweight decreases and lambs' weight at birth decreases also. This type of "survival-diet" may be suggested for extreme dry years.

Example 2: Replacement of the traditional oat-vetch hay by olive tree leaves and twigs in diets fed to yearlings (Table 3) gave similar performances. This alternative is recommended to low rainfall areas of WANA, where forage crops are not sufficiently available and for the pruning season (January to March) or later (summer, autumn) after air-drying of the leaves.

Table 2. Use of olive cake to feed barbarine ewes under harsh conditions in Tunisia (Nefzaoui, 1988)*

Diets	Olive cake (% in the diet)		
	0	35	70
Diet ingredients, %**:			
Olive cake	0	35	70
Bran	70	35	0
Molasses	26	26	26
Mineral mixture + urea	4	4	4
Performances:			
Initial liveweight, kg	52.3	52.2	52.5
Final liveweight, kg	57.3	57.3	42.8
Lamb weight at birth, kg	3.5	3.3	2.6
Total intake, g DM kg^{-1} $LW^{0.75}$	76	105	85

* Ewes were of barbarine breed conducted from mating to lambing
** All mash feeds were distributed *ad libitum* with 300 g of straw per day.

Table 3. Performances of yearlings (Barbarine breed) fed on olive tree leaves and twigs (Ben Rouina, 1986)

Diets	*Control* oat-vetch hay + concentrate	Experimental leaves & twigs + concentrate
Intake, g day^{-1}:		
Fibrous feed	761-829	786-859
Concentrate	680	680
Initial liveweight, kg	25	25
Final liveweight, kg	40.7	42.4
Growth rate, g day^{-1}	171	188

Feed blocks

Some local agro-industrial by-products, though available in large quantities (olive cake, wheat bran, etc.) are not efficiently used by farmers in livestock feeding. Efficient utilization of these by-products through the use of feed blocks may be considered as an opportunity for these farmers to fill the gap between limited feed supply and increasing animal requirements. Therefore, teaching farmers to make feed blocks and how to use them seems to be a suitable alternative to face difficulties in nourishing animals in harsh conditions.

The objectives of the use of this technology are: (i) to improve the nutritive value of poor quality diets using inexpensive and locally available supplements; (ii) to ensure a balanced and synchronous supply of nutrients to the animal (energy, protein, minerals and vitamins); and (iii) to develop a practical and economical technique for supplementing animals in harsh conditions (Ben Salem and Nefzaoui, 1997). To reach such objectives, the following criteria should be considered in feed block making: good consistency, high nutritive value, high palatability, low cost, and easy to handle.

Several on-farm trials were conducted in several countries of the region (Iraq, Jordan, Tunisia, Morocco) with farmers' participation. Feed block technology was successfully adopted in most cases by users. A case study from Tunisia is presented in Table 4.

Table 4. Feed blocks may replace farmer concentrate as in sheep feeding (Ben Salem and Nefzaoui, 1997)

Animal	Dietary treatment *	
	Farmer concentrate	Feed block (urea 7%)
Growth rate, g day^{-1} yearlings	115 ± 60	222 ± 82

* groups each of 10 yearlings (6-month-old) were assigned to the following diets: (a) Farmer model: straw + cactus + concentrate (1/3 barley + 1/3 olive cake + 1/3 wheat bran); (b) Experimental model: straw + cactus + feed blocks (7% urea)

Cereal crop residues

A huge amount of research was done on the use of straws in small ruminant feeding and on methods to improve their nutritive value, using sodium hydroxide in the beginning and later anhydrous ammonia and urea treatment. Two examples of integration are presented in Tables 5 and 6.

(i) In the first example, diets based on ammonia-treated straw were compared to oat-vetch hay given to heifers. In both cases animal performances were high and similar. Moreover, straw-based diets (unchopped) allow for a reduction of about 30% of the feeding cost (Table 5).

Table 5. Feeding heifers with ammonia treated straw-based diets (Rokbani and Nefzaoui, 1993)

Diets*	3% ammonia treated straw		Oat-vetch hay
	unchopped	chopped	
Intake, kg DM day^{-1}:			
Concentrate	2.2	2.2	2.2
Straw	3.9	3.6	4.9
Initial liveweight, kg	173.6	174.7	187.0
Final liveweight, kg	312.1	286.9	324.2
Growth rate, g day^{-1}	657	532	650

* The CP contents of concentrate, hay and treated straw were 19.7, 10.3 and 6.9% of the DM, respectively

(ii) The second example indicates that it is possible to reduce urea-treatment cost by using mud instead of plastic sheet to cover straw stacks. This technique might be well adapted to small holders where access to mechanization is rather limited. Additionally, this technique contributes to reduce plastic pollution (Table 6).

Stubble

In mixed systems crop/livestock in North Africa, stubble plays a key role as a feed resource for herbivores in general and small ruminants in particular. Stubble is available in a period of the year (summer) during which the other natural feed resources are limited. In studies performed in Morocco (Guessous, 1992), immediately after harvesting, an average biomass of stubble of 4 to 6 ton ha^{-1} was recorded, and 100 to 120 kg of grains. Grains are consumed during the first 4 weeks of grazing. Due to the selective behaviour of sheep, the feed value of the diet from stubble is quite high during the first weeks of grazing then it decreases gradually to become rather equivalent to straw. Therefore, sheep liveweight increases during the first month of grazing then decreases, especially if the stocking rate is high. Therefore, it is necessary to supplement animals with a protein source at the beginning and both energy and protein sources later. Under arid conditions (250 mm rainfall) with supplementary irrigation, Guessous (1992) did maintain 20 sheep for 80 days ha^{-1}, and he concluded that one ha of stubble produces the equivalent of about 700 milk feed units. This figure reinforces the key role of stubble and we might be questioned about the possibility of ploughing the stubble at an early stage.

Table 6. Mud as an alternative to plastic sheet for covering urea treated straw. A good example of rehabilitation of indigenous knowledge (Ben Salem *et al*., 1996)

	US	ATS	UTSp	UTSm
Crude protein, g kg^{-1} DM	31	78	76	78
Straw DM intake, g day^{-1}	720	910	816	829
Growth rate, g day^{-1}	56.6	95.6	92.1	92.6

US: untreated straw, ATS: ammonia (3% NH_3) treated straw, UTSp: urea (5.6%) treated straw covered with plastic, UTSm: urea (5.6%) treated straw covered with mud

The other possibility of better using the stubble can be explored when cereals are planted between wide alleys of atriplex and spineless cactus. This landscape is quite frequent in the semi-arid areas in Tunisia. It may be one sustainable way of establishing shrub plantations. The possibility of using atriplex as a protein supplement will be discussed in a later topic.

Improving fallow land by reseeding of appropriate legumes

Fallow replacement with legumes

Some annual feed legumes are promising (vicia, lathyrus, pisum) (Abd El Moneim *et al.*, 1988). Local species of medicago will probably play a key role in dry areas in the future, if seed production increases in order to provide farmers with low cost seeds.

There are good reasons for encouraging farmers to break the habit of growing cereal crops year after year. Just a few years ago, and following the same logic as the Australians, the use of medics in a cereal-based system was promoted. Early work on ley farming involved attempts to introduce species and varieties of medic and other annual legumes from Australia and USA. These attempts failed for several reasons, and one of them is related to the environments which were different from those of the plants' origin (Christiansen and Manners, 1995). Therefore, ICARDA is encouraging seed production of local medic species and varieties by farmers.

This involves the use of locally manufactured appropriate technology (sweeper and thresher). Some interesting results are already visible in Morocco and Tunisia.

Promote on-farm shrub planting-integration with cereal production and possible alley-cropping

Correal (1993) recommended a strategy for fodder shrub plantations, especially in arid and semi arid Mediterranean areas:

(i) Fodder shrub plantations could be used to reduce grazing pressure on degraded areas where plant cover is very poor. If resting periods are enough long, vegetation may recover, increasing its coverture, species diversity and biomass.

(ii) When cereals occupy a large proportion of the land, atriplex plantations could be used as a protein-rich supplement of cereal stubble grazed during summer. If cultivated soils have erosion problems, saltbushes or cactus could be planted in wide spacing rows along contour lines to help soil conservation.

(iii) When available fodders are of poor quality (e.g. *Stipa tenacissima*, *Artemisia sp.*, *Rosmarinus officinalis, Thymus*, sp., etc.), shrub plantations could be used as a feed supplement to increase their intake.

We will discuss some examples showing that in arid and semi arid zones, shrubs and specially cactus play a significant role in providing valuable nutrients to small ruminants. In each example, conventional feeds (concentrates, hay, straw) are used in a limited amount because they are scarce and expensive.

Example 1: Diets based on spineless cactus (Opuntia ficus indica var inermis) and atriplex (Atriplex nummularia) (Table 7)

Table 7. Feeding value of spineless cactus and atriplex based diets (Nefzaoui, 1996)

Diets	D1	D2	D3
Intake, g day^{-1}:			
Cactus	197	353	550
Atriplex	554	391	236
Straw	160	159	167
Diet, g DM d^{-1}*	941(70)	930(72)	983(73)
DOM intake, %**	165	170	182
DCP intake, %**	230	187	165

* the values ( ) correspond to intakes expressed in g of DM kg^{-1} LW$^{0.75}$
** values are expressed in % of sheep maintenance requirements

These diets allow to cover about 1.7 times the energy and digestible crude protein (DCP) requirements of sheep. Diet 1 meets 1.6 and 2.3 times energy and DCP requirements, respectively. It brings enough nitrogen and may be supplemented with an energy source like barley grain. Diet 2 is relatively well balanced in both energy and nitrogen, while diet 3 has an excess of energy and needs to be supplemented with a nitrogen source (non protein nitrogen, like urea).

Cactus is a good source of energy and atriplex a good source of nitrogen. Combining these two non conventional feeds results in an energy and nitrogen balanced diet which meets the requirements of sheep. The level of cactus in the diet may reach 55% on DM basis, without digestive disturbances. A small amount of fibrous feed, such as straw or hay, has to be fed to the animal prior to cactus feeding.

Example 2: Nitrogen supplementation of cactus-based diets fed to Barbarine yearlings (Table 8)

Results showed that cactus based diets may be supplemented efficiently by *Atriplex nummularia*. Urea and *Atriplex halimus* lead to low growth rates in comparison to soybean meal or *A. Nummularia* supplemented diets.

Such diets using low cereal inputs (28% of the diet) and forage (17% of the diet) are recommended to cope with feed deficiency in low rainfall areas prevailing in North Africa and West Asia.

Table 8. Nitrogen supplementation of cactus based diets fed to Barbarine yearlings (Nefzaoui *et al.*, 1996)

Diets	D1	D2	D3	D4
Intake, g DM day^{-1}:				
Spineless cactus	241	252	241	228
Atriplex halimus	0	224.2	0	0
Atriplex nummularia	0	0	225.8	0
Soybean meal	0	0	0	58
Barley	309	244	244	244
Hay	149	143	147	151
Urea	8	0	0	0
Total intake	707	863	858	680
Average daily gains (g day^{-1})	55	58	74	70

Example 3. Spineless cactus and Acacia (Table 9)

Table 9. Feeding value of spineless cactus and acacia (*Acacia cyanophylla*) based diets (Nefzaoui *et al.*, 1993)

Diets	R00	R21	R22	R23
Feed intake, g DM day^{-1}				
cactus	0	167	246	267
acacia	241	373	211	177
DOM intake, %*	148	151	130	115
DCP intake, %*	72	68	35	10

Values are expressed in % of sheep maintenance requirements

In this example, *Acacia cyanophylla,* a wildly spread exotic shrub, was used to supplement cactus-based diets because of its richness in crude protein (about 13% of DM). However, its intake is low (250 g DM day^{-1}) because of its high content in condensed tannins (Ben Salem *et al.*, 1997). These tannins are also responsible for the low level of its digestible crude proteins. Maintenance energy requirements are met with such diets, but we still need to bring an appropriate nitrogen supplementation.

Example 4: Spineless cactus (Opuntia ficus indica, var. inermis) as a supplement for treated straw (Table 10)

Data indicate that it is possible to cover maintenance energy requirements for sheep using diets based on cactus given ad-libitum with 300 g of straw daily. With higher level of straw (600 g day^{1}) it is possible to meet 1.7 to 1.9 energy requirements. Nitrogen maintenance requirements can be met using treated straws. Cacti may be used as a major component of diets containing cereal straws. Non ammonia nitrogen provided by treated straw is well utilized.

In view of the above examples, we recommend the following:

(i) Promote shrub plantations on private farms instead of communal rangelands. In other words, shrubs must be considered as a part of the production system and as a permanent fodder resource instead of a "strategic" or "reserve-type" fodder to be used only during drought. This option will facilitate the shrubs management in a sustainable way.

Table 10. Straw supplementation with spineless cactus (Nefzaoui *et al.*, 1993)

Level of straw*	300 g d^{-1}			600g d^{-1}		
	US	ATS	UTS	US	ATS	UTS
DM Intake, g day^{-1}:						
Cactus	445	447	425	432	462	439
Straw	254	242	249	494	466	486
Diets *in vivo* digestibility, %:						
OM	67.9	64.0	63.3	66.5	69.8	72.6
CP	41.1	48.0	43.3	45.9	61.0	77.1
CF	37.5	30.5	29.2	46.5	49.2	52.7
N retained, g day^{-1}	-0.2	-0.2	--0.60	0.8	2.8	3.9

* US: untreated straw; ATS: ammonia treated straw; UTS: urea treated straw

(ii) Avoid planting a single shrub specie. This way survival risks are minimized and feed availability is promoted during all seasons. Having more than one specie will ensure better equilibrated diets. Cactus can be used all year around, and acacia is mainly used during autumn and winter time, while atriplex can be used during winter and summer seasons.

(iii) Plantations should be established in alley cropping where barley (main cereal sowed in arid zones) is planted between lines of shrubs. This will help to have better barley yields and better use of cereal crops. In fact barley stubble may be grazed directly and supplemented with atriplex or cactus.

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